UNITED NATIONS
INDUSTRIAL DEVELOPMENT ORGANIZATION

INTERNATIONAL CENTER
ON SMALL HYDROPOWER

World Small Hydropower Development Report 2022

Southern Europe

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Suggested citation:

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

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

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

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

Table of Content

Acknowledgements

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

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

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Southern Europe

Countries: Albania, Bosnia and Herzegovina, Croatia, Greece, Italy, Montenegro, North Macedonia, Portugal, Serbia, Slovenia, Spain

INTRODUCTION TO THE REGION

The electricity sectors of countries in Southern Europe are highly integrated due to the participation of all countries in the region in the Energy Community. The Energy Community seeks to harmonize the legal and regulatory frameworks governing the electricity sectors of member nations of the European Union (EU) and non-member nations, including Albania, Bosnia and Herzegovina, North Macedonia, Montenegro and Serbia, participating under the status of Contracting Parties. Additionally, all countries in Southern Europe are connected to the European Network of Transmission System Operators for Electricity (ENTSO-E), which ensures synchronous operation of their national electricity grids. Electricity access in the region is universal.

At the same time, countries in Southern Europe have adopted different strategies in developing their electricity sectors, particularly with regard to reliance on renewable energy sources (RES). Italy and Spain have the largest and most diversified electricity sectors in Southern Europe, with Italy leading the region in solar power capacity. Spain leads the region in wind power, which forms the mainstay of its electricity production and in 2022 outpaced both conventional thermal power and nuclear power in the share of the country's installed capacity and annual generation. Non-hydropower RES including wind power and solar power collectively form the second-largest source of electricity generation in Greece, after gas-fired thermal power plants, as the country has been in the process of phasing out coal power plants. Conversely, coal is the main source of electricity generation in Serbia, and thermal power from various sources also dominates the electricity sectors of Bosnia, North Macedonia and Italy. In Slovenia, nuclear power accounted for the single-largest share of annual electricity generation in 2020.

Hydropower plays an important role in the electricity sectors of all countries in Southern Europe, but its share of annual generation and installed capacity varies considerably by country. Hydropower is the leading source of electricity generation in Albania, where it accounts for nearly 100 per cent of all generation and installed capacity, as well as in Portugal, Montenegro and Croatia. Italy leads the region in both installed hydropower capacity and generation, but the role of hydropower in the country's energy mix is secondary to thermal power. In other countries of Southern Europe, hydropower plays a supplementary role.

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

Table 1. **Overview of Southern Europe**

Country	*Total population (million people)*	*Electricity access, total (%)*	*Electricity access, rural (%)*	*Total installed capacity (MW)*	*Electricity generation (GWh/year)*	*Hydropower installed capacity (MW)*	*Hydropower generation (GWh/year)*
Albania	3	100	100	2,275	5,208	2,162	5,186
Bosnia & Herzegovina	3	100	100	4,531	15,391	2,249	4,618
Croatia	4	100	100	5,211	12,005	2,127	5,871
Greece	11	100	100	20,400	37,989	3,170*	2,958*
Italy	60	100	100	116,383	271,648	22,695	48,952
Montenegro	1	100	100	1,029	3,744	684	1,697
North Macedonia	3	100	100	2,088	5,658	698	1,183
Portugal	10	100	100	22,421	49,324	7,129	13,811
Serbia	7	100	100	8,285	35,540	3,050	9,701
Slovenia	2	100	100	3,924	15,748	1,347	5,106
Spain	47	100	100	114,196	259,905	20,425	32,244
Total	-	-	-	**300,742**	-	**65,736**	-

Source: *WSHPDR 2022*[1]

Note: *Includes only large hydropower. Data in the table are based on data contained in individual country chapters of the *WSHPDR 2022*; years may vary.

REGIONAL SMALL HYDROPOWER OVERVIEW

Most countries in Southern Europe adhere to the definition of small hydropower (SHP) established by the EU, which includes hydropower plants with an installed capacity of up to 10 MW. However, Greece and Albania define SHP as plants of up to 15 MW. Slovenia uses the up to 10 MW definition for water management purposes, and the up to 1 MW definition for the purpose of regulating and incentivizing RES, with plants of up to 1 MW receiving significantly higher operating support tariffs than plants of up to 10 MW.

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

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

Country	*Local SHP definition*	*Installed capacity (local def.)*	*Potential capacity (local def.)*	*Installed capacity (≤10 MW)*	*Potential capacity (≤10 MW)*
Albania	Up to 15 MW	482.0	N/A	432.0	1,963.0
Bosnia & Herzegovina	Up to 10 MW	172.2	1,005.0	172.2	1,005.0
Croatia	Up to 10 MW	45.7	100.0	45.7	100.0
Greece	Up to 15 MW	247.2	2,000.0	N/A	N/A
Italy	Up to 10 MW	3,648.4	7,073.0	3,648.4	7,073.0
Montenegro	Up to 10 MW	34.7	97.5	34.7	97.5
North Macedonia	Up to 10 MW	111.4	258.0	111.4	258.0
Portugal	Up to 10 MW	415.0	750.0	415.0	750.0
Serbia	Up to 30 MW	N/A	N/A	109.0	109.0
Slovenia	Up to 1 MW	N/A	N/A	164.0	180.0
Spain	Up to 10 MW	2,145.0	2,158.0	2,145.0	2,158.0
Total	-	-	-	**7,277.4**	**13,693.5**

Source: *WSHPDR 2022*[1]

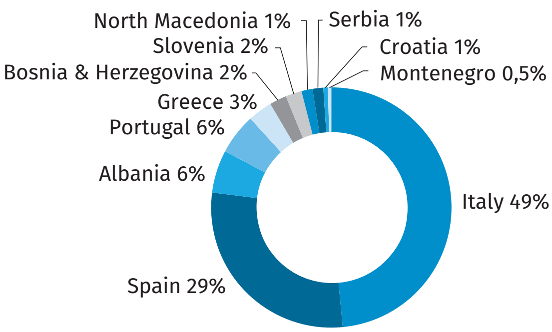
Note: *Based on installed capacity.

The total installed capacity of SHP of up to 10 MW in Southern Europe is 7,277.4 MW, while potential capacity is estimated at 13,693.5 MW. Relative to the *World Small Hydropower Development Report (WSHPDR) 2019*, the installed capacity has increased by nearly 6 per cent as a consequence of ongoing SHP development, while the estimate of SHP potential has decreased by 7 per cent, mainly due to a lack of recent and reliable data on the SHP potential of Greece and Serbia.

Active development of SHP is ongoing across most countries in Southern Europe, with Italy adding several hundred megawatts of new SHP capacity in recent years and Albania and Bosnia and Herzegovina nearly doubling their respective SHP capacity totals. At the same time, public opposition to the development of SHP and hydropower in general is increasing in the region, fuelled by concerns over environmental impact and water scarcity. Additionally, the identified SHP potential of some countries in the region, in particular Spain and Slovenia, is approaching saturation.

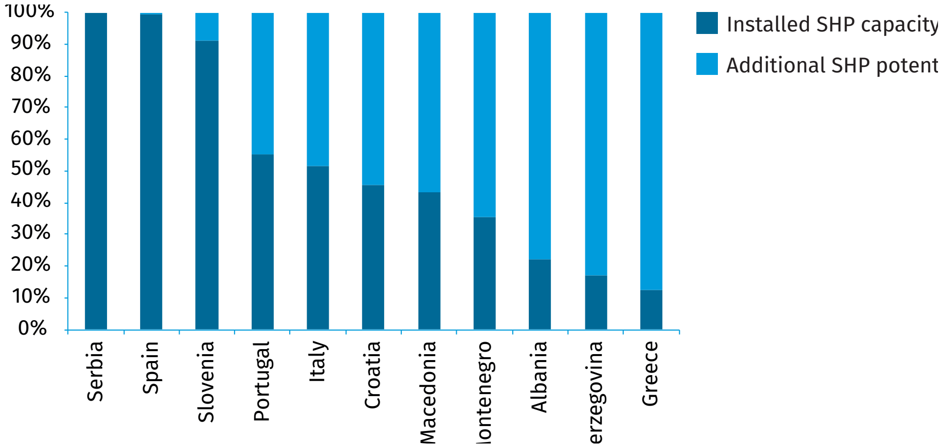
The national share of regional installed SHP capacity by country is displayed in Figure 1, while the share of total national SHP potential utilized by countries in the region is displayed in Figure 2.

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



Source: *WSHPDR 2022*[1]

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



Source: *WSHPDR 2022*[1]

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

Albania has an installed capacity of 432 MW for SHP of up to 10 MW, while potential capacity is estimated at 1,965 MW, indicating that 22 per cent has been developed. The installed capacity for SHP of up to 15 MW is 482 MW, provided by 122 plants. The country has nearly doubled its installed capacity for SHP of up to 10 MW between 2017 and 2019, owing in part to strong support for the sector in the form of feed-in tariffs (FITs) and guaranteed off-take of electricity.

In **Bosnia and Herzegovina**, the installed capacity of SHP of up to 10 MW is 172.2 MW, while potential capacity is estimated at 1,005 MW, indicating that 17 per cent has been developed. The country is actively pursuing SHP development, nearly doubling its installed capacity in recent years. As of 2021, there were 115 SHP plants in operation and an additional 341 SHP projects in various stages of completion. However, generation of electricity from SHP decreased dramatically between 2019 and 2020 due to changing hydrological conditions.

The installed capacity of SHP of up to 10 MW in **Croatia** is 45.7 MW provided by 39 plants, while the feasible potential capacity is estimated at 100 MW, indicating that nearly 46 per cent has been developed. There were at least 29 additional SHP projects in the country as of 2019 in various stages of approval.

Greece has an installed capacity of 247.2 MW for SHP of up to 15 MW, while potential capacity is estimated at 2,000 MW, indicating that approximately 12 per cent has been developed. There are approximately 120 SHP plants operating in the country. Despite rising SHP capacity, generation from SHP has been steadily decreasing over the last several years due to prevailing dry climatic conditions. The country plans to increase its total SHP capacity to 350 MW by 2030, and 70 MW of new SHP projects were awaiting implementation as of 2020.

The installed capacity of SHP of up to 10 MW in **Italy** is 3,648.4 MW, provided by 3,271 plants of up to 1 MW and an additional 922 plants with installed capacities of 1–10 MW. Potential capacity is estimated at 7,073 MW, indicating that approximately 52 per cent has been developed. The SHP sector in the country has been growing at a rapid pace in recent years. New SHP projects have increasingly focused on utilizing existing water supply networks such as aqueducts, with 24 such projects authorized for construction in 2020 alone. Growth in the SHP sector of Italy is driven by comprehensive support schemes including FITs, auctions and other incentives.

Montenegro has an installed capacity of 34.7 MW for SHP of up to 10 MW, while potential capacity is estimated at 97.5 MW, indicating that approximately 36 per cent has been developed. Although SHP development in the country had stagnated for several decades, the sector has revitalized starting in 2013, and 16 new SHP plants were commissioned by 2019. Fifty-five new SHP projects are in various stages of development.

The installed capacity of SHP of up to 10 MW in **North Macedonia** is 111.4 MW, while potential capacity is estimated at 258 MW, indicating that 43 per cent has been developed. There are 101 SHP plants operating in the country. The recent pace of construction has been high, with several new SHP plants commissioned per year between 2017 and 2020.

Portugal has an installed capacity of 415 MW for SHP of up to 10 MW, while potential capacity is estimated at 750 MW, indicating that 55 per cent has been developed. Previous plans had aimed to achieve a total SHP capacity of 750 MW from 250 plants by 2020, but as of 2021 these plans had not been realized. The pace of construction of new SHP plants in the country has slowed significantly since 2017. There are no concrete plans for any additional SHP projects, with ongoing construction in the hydropower sector focusing on large plants.

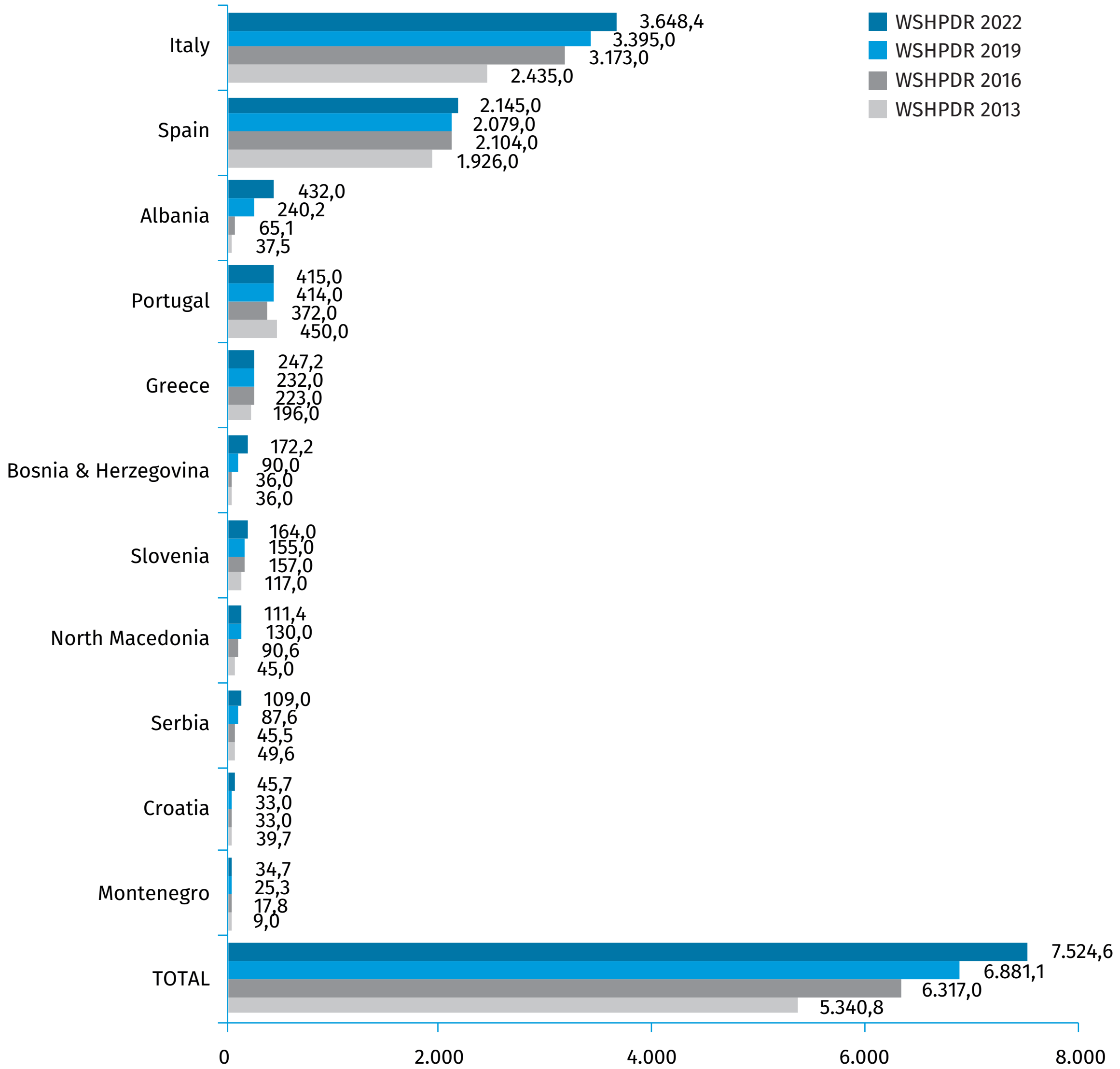
There are 138 SHP plants of up to 10 MW operating in **Serbia**, with a total installed capacity of 109 MW. There are no reliable recent estimates of the country's potential SHP capacity, although previous estimates suggested a potential of several hundred megawatts. The latest estimate of potential was carried out in the 1980s and is no longer considered representative in light of the changing hydrological conditions in the country. Nevertheless, Serbia is actively developing its SHP sector, with many new plants commissioned in 2020–2021, and efforts to produce an updated database of potential SHP sites are also underway.

The installed capacity of SHP of up to 10 MW in **Slovenia** is 164 MW, while potential capacity is estimated at 180 MW, indicating that approximate 81 per cent has been developed. A moderate expansion of the country's SHP sector is planned, with total installed capacity expected to reach 177 MW by 2040. However, strategic development plans have emphasized the refurbishment and modernization of existing SHP plants rather than new construction.

Spain has 1,098 operating SHP plants of up to 10 MW, with a total installed capacity of 2,145 MW. Potential capacity for SHP of up to 10 MW is estimated at 2,158 MW, suggesting that nearly all potential has been developed. Active development of the SHP sector in the country has been continuous since the 1980s, but it remains unclear what additional SHP projects can be realized in light of the increasingly limited remaining undeveloped potential.

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

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



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

Note: For SHP of up to 10 MW except in the case of Greece, where the local definition is used for the purpose of comparison with the previous editions of the *WSHPDR*.

Climate Change and Small Hydropower

The Mediterranean region is already experiencing a much drier climate, relative to historical observations. A decrease in generation from SHP plants has been observed in Greece since 2018. Studies suggest that by 2070, hydropower generation in Italy will decrease by 22 per cent, and a decrease of 5–43 per cent in specific river basins is expected in Spain.

BARRIERS AND ENABLERS FOR SMALL HYDROPOWER DEVELOPMENT

Albania is currently planning to diversify its energy mix away from an almost exclusive reliance on hydropower and develop additional solar power and wind power capacities. Furthermore, there is significant social resistance to new hydropower projects, which has already led to the cancellation of plans for hydropower development in parts of the country. Nevertheless, the country has considerable untapped SHP potential, which remains to be realized.

A key barrier to SHP development in **Bosnia and Herzegovina** is the negative perception of SHP on the part of the population due to poor construction and oversight of plants leading to environmental damage, as well as due to a lack of consultation with local communities on SHP projects. Recent legislation aims to significantly restrict or prohibit SHP construction in the country. The main enabler of any future SHP development is the country's large undeveloped SHP potential.

Barriers to SHP development in **Croatia** include a lack of funding due to high upfront costs, strict regulations, a complex structure of licensing agencies and opposition from the country's tourism sector to the use of watercourses for SHP construction. At the same time, Croatia is committed to the further development of RES, and SHP potential in the country has been carefully mapped by previous studies.

Development of SHP in **Greece** is hampered by the decreasing hydropower output of existing plants, lengthy licensing procedures, an absence of a national water management plan, which has led to increased competition among water users, and the lack of interest in SHP development on the part of investors due to low profit margins. The main enabling factor for SHP development in Greece is the country's remaining undeveloped SHP potential.

Barriers to further SHP development in **Italy** include public opposition to SHP projects in some parts of the country, recent reductions in FIT support and the lengthy periods required for authorization of SHP projects. However, Italy is a regional leader in the SHP sector and a global centre of SHP research, and SHP developers in Italy can rely on significant local technical, scientific and manufacturing capacity, in addition to a well-developed framework of incentives. The remaining SHP potential in the country is significant and offers many opportunities for new projects if the momentum of development is maintained.

Although the SHP sector in **Montenegro** has revitalized over the last decade, public opposition to new SHP construction has resulted in the Government cancelling some SHP contracts. Costs and complexity of ensuring grid connections and a lack of detailed data on potential sites have posed additional obstacles to new development. Enablers for further growth in the SHP sector of Montenegro include demand for increased security of electricity supply, a competitive electricity market and the possible role of SHP projects as mechanisms of job creation, particularly in the less developed parts of the country, particularly if these projects were to be carried out by local companies.

SHP development in **North Macedonia** faces several challenges including a lack of accurate hydrological data on potential sites, cost and difficulty of grid connections, and lack of local manufacturing capacity driving high development costs. At the same time, the SHP sector benefits from FITs and access to loans from local banks, availability of local technical expertise, substantial undeveloped SHP potential and a generally favourable political and social climate for SHP development.

One of the main barriers to SHP development in **Serbia** is the lack of up-to-date information on potential sites or even a reliable overall estimate of the country's SHP potential. Additionally, lack of proper oversight of construction and operation of SHP plants in the country has led to negative environmental impact and generated public opposition to SHP construction. In this context, the most prospective sites for future SHP development in Serbia are likely existing non-powered dams as well as pressure break elements on existing pressurized water systems.

In **Slovenia,** a lack of collaboration between various stakeholders connected to SHP development, lack of human and technical capacities, and mistrust towards SHP development from the general public due to previous violations of environmental requirements by existing plants have hampered growth of the SHP. Current environmental regulations in the country favour the development of large hydropower. Nevertheless, SHP enjoys support in the form of FITs and other incentives, and ample potential for new projects exists both in terms of new stream development as well as in the modernization of existing plants.

The main barrier to SHP development in **Spain** is the almost-fully developed identified SHP potential. Competition with other water users and complicated licensing procedures have also hampered development of SHP in the country, with the additional issue of existing SHP plants running the risk of losing water use licences after a certain period and being abandoned. There are no clear enablers to further development of SHP in Spain other than the liberalized structure of the country's electricity market, which favours private electricity producers.

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Albania

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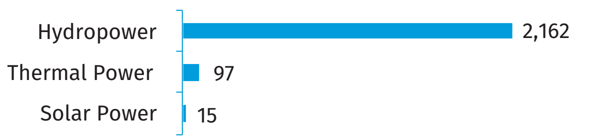
KEY FACTS

Population	2,854,191 (2019)[1]
Area	28,748 km^2[2]
Topography	The topography of Albania is mostly mountainous, with small plains along the coast and river valleys. Mount Korab, situated in the east, at the border with North Macedonia, is the highest peak at 2,751 metres above sea level.[2]
Climate	Albania lies in a transition zone between the Mediterranean and the moderate continental climates. On the coastal plain, winters are cold, cloudy and wet, while summers are hot, clear and dry. In the mountainous interior part of the country, the summers are characterized by rainfall and winters are colder. The average annual temperature is 15 °C, while the minimum average temperature is 1.6 °C and the maximum average temperature is 20.9 °C.[2]
Climate Change	The impact of climate change in Albania is expected to encompass an increase in temperatures and a decrease in precipitation, particularly, during the summer. This could lead to a reduction in water quality and quantity, negatively impacting hydropower generation.[3]
Rain Pattern	The 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 the rainfall occurs from November to March.[3]
Hydrology	Albania is considered rich in water resources and its hydropower potential plays an important role in the development of the country. There are more than 150 smaller rivers and torrents forming eight main big rivers. These rivers have a south-east to north-west flow, predominantly oriented towards the Adriatic coast. The most important rivers are the Drin (340 m^3/s), Vjosa (210 m^3/s), Seman (101 m^3/s), Mat (74 m^3/s) and Shkumbin (60 m^3/s). The total average flow of all the rivers in the country is approximately 1,245 m^3/s. Despite having small flows, the considerable inclination of the Albanian rivers, due the country's mountainous terrain, makes them important for hydropower development.[4]

ELECTRICITY SECTOR OVERVIEW

In 2019, the total installed capacity of Albania stood at 2,275 MW, with 2,162 MW coming from hydropower, 98 MW from thermal power and 15 MW from solar power (Figure 1).[5] In 2019, domestic electricity generation in Albania was almost exclusively from hydropower, with a net generation of 5,208 GWh. Of the total, hydropower accounted for 5,186 GWh (99.6 per cent) and solar power for 22 GWh (0.04 per cent) (Figure 2).[6]

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



Source: ERE[5]

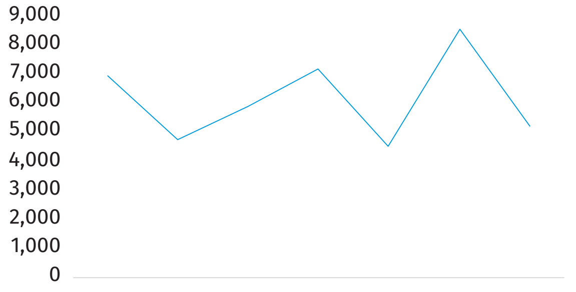
There are three different categories of hydropower plants in Albania. The first category is composed of the three largest hydropower plants, namely, Fierza, Koman and Vau i dejes, with a combined capacity of 1,350 MW. These plants are owned by the Albanian Power Corporation S.A. (KESH), the main state-owned power producer in the country. The second category are large hydropower plants operating on a liberalized market with a total capacity of 252 MW. The third category are the rest of the hydropower plants, which are generally smaller, with a total installed capacity of 560 MW.[5] Albania only has one thermal power plant, the Vlora TPP, owned by KESH, with an installed capacity of 98 MW. However, the plant has never been in operation due to several operational problems, including an issue with its cooling system. Regarding solar power, in 2019 there were eight plants with a total installed capacity of 15 MW.[5]

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

Source: Instat[6]

Since the electricity sector of Albania is largely dominated by hydropower, electricity generation is significantly dependent on the hydrological conditions and has been fluctuating throughout the years (Figure 3). Thus, in 2019 electricity generation decreased by 39 per cent compared to 2018.[5]

Figure 3. **Total Domestic Electricity Generation in Albania in 2013–2019 (GWh)**

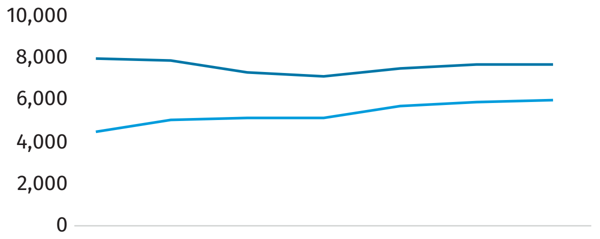


Source: ERE[5]

Albania currently has several planned projects aimed at increasing the installed electricity capacity. Thus, there are several small hydropower (SHP) plants for which construction works are planned to start or which are already in the construction phase. For solar photovoltaics (PV), two large auctions have been conducted. As of the moment of writing of this chapter, one was in the signature phase for a total capacity of 140 MW (Karavasta auction) and the other one was still in the auction phase for a total capacity of 100 MW (Spitalles auction).[7,8] In addition, there are plans to hold auctions for wind generation as well as to revive the Vlora thermal power plant by connecting it to the Trans Adriatic Pipeline (TAP).

In 2019, the net electricity consumption was 5,961 GWh, with total consumption at 7,612 GWh (Figure 4).[5] The level of electricity losses reached almost 22 per cent, representing a significant reduction compared to the previous years, but remained high when compared with the neighbouring countries.[5]

Figure 4. **Electricity Consumption in Albania in 2013–2019 (GWh)**



Source: ERE[5]

The Albanian electricity sector regulator Enti Rregullator i Energjisë (ERE) sets the electricity tariffs for consumers. The tariff for households is approximately 0.11 USD/kWh, while for industrial clients it is at 0.15 USD/kWh.[9,10]

The transmission system is composed of 400 kV, 220 kV, 150 kV and 110 kV lines with the associated substations that serve transmission and international connectivity to Montenegro, Greece and Kosovo. The operator, Operatori i Sistemit të Transmetimit (OST), is entirely state-owned. The level of interconnection in Albania is high compared to the peak load, meaning that Albania can export and import easily to the neighbouring countries.

The distribution company, Operatori i Shpërndarjes së Energjisë Elektrike (OSHEE), is also entirely state-owned. In 2020, OSHEE was unbundled into three companies: Operatori i Sistemit të Shpërndarjes (OSSH), which is responsible for the operation and maintenance of the distribution grid; Furnizuesi i Shërbimit Universal (FSHU), which is the supplier for the clients in the regulated market; and Furnizuesi i Tregut të Lirë (FTL), which is the supplier for the clients in the unregulated market.[11]

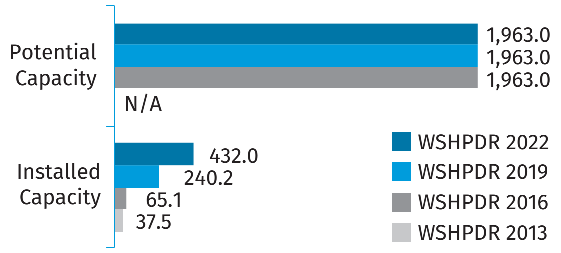
The structure of the electricity market is established through Decision 519 of 13 July 2016 on the approval of the electric power market model.[12] The electricity market in Albania is composed of a regulated and an unregulated market. The vast majority of electricity consumption in the country takes place through the regulated market, for example, through the universal service supplier FSHU, which is part of the OSHEE group. A regulated contract with the public company KESH ensures the bulk of the electricity needs for FSHU at an advantageous price. So far, only high-voltage clients and a few clients at the medium-voltage level have been able to purchase power on the unregulated market. The unregulated market predominantly serves cross-border traders and the utilities to cover the grid losses. The tariffs are set by ERE.

As of the moment of writing of the chapter, there were plans to open ALPEX, a power exchange responsible for the day-ahead and intraday exchanges.[13] In addition, OST is currently setting up a balancing market where balancing products would be purchased following market-based principles.

SMALL HYDROPOWER SECTOR OVERVIEW

In Albania, the definition of SHP is up to 15 MW. In 2019, there were 122 SHP plants with a total capacity of 482 MW (Table 1). Of these, 43 SHP plants with a combined capacity of 217 MW were connected to the transmission grid (110 kV) and 79 plants with a combined capacity of 265 MW were connected to the distribution grid. The installed capacity of SHP plants up to 10 MW totalled 432 MW, with a generation of 489.5 GWh in 2019.[5] Compared to the *World Small Hydropower Development Report (WSHPDR) 2019*, this represents an 80 per cent increase in installed capacity (Figure 5). This significant increase is a result of the efficient support of the sector, including the existence of a guaranteed buyer offering a good minimal price, which has boosted the construction of new plants in the country. The potential capacity of up to 10 MW is estimated to be 1,963 MW, which suggests that a large share of the potential (78 per cent) has not yet been utilized.[14]

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



Source: ERE,[5] *WSHPDR 2016*,[14] *WSHPDR 2013*,[15] *WSHPDR 2019*[16]

Note: Data are for SHP up to 10 MW.

Table 1. **List of Selected Operational SHP Plants in Albania**

Name	*Installed capacity (MW)*	*Operator*
Llapaj	13.6	"Gjo.Spa.POWER" company
Bele 2	11.0	"Alb-Energy" shpk
Lumzi	11.0	MC Inerte Lumzi
Sllabinje	10.4	"Power Elektrik Slabinje" shpk
Dardhe	5.8	"Wenerg" shpk
Topojan 2	5.8	"Euron Energy" shpk
Bele 1	5.0	"Euron Energy" shpk
Orgjost I Ri	4.8	"Energal" shpk
Rrupe	3.6	"Energy partners Al" shpk
Slabinje 2	3.4	"Power Elektrik Slabinje" shpk
Topojan 1	2.9	"Alb-Energy" shpk
Cerunje-2	2.8	"Energy partners Al" shpk
Bishnica 2	2.5	"HEC Bishnica 1,2"shpk
Truen	2.5	"TRUEN" shpk
Cerunje-1	2.3	"Energy partners Al" shpk
Trebisht	1.8	"SA.GLE.Kompani" company
Fterra	1.1	"Hidro Borshi" company
Ternove	0.9	"DITEKO" shpk
Mollai	0.6	"Energii Khaci" company
Kozel	0.5	"E.T.H.H." company

Source: ERE[7]

Currently, SHP plants benefit from preferential treatment as they receive a feed-in tariff (FIT). The off-taker, FTL, which is part of the distribution company OSHEE, is obliged by law to buy all generated electricity at a tariff equivalent to the day-ahead market price in Hungary plus a premium. In 2021, the tariff was set at 60 EUR/MWh (71.7 USD/MWh).[17] The FIT support scheme is valid for a period of 15 years. In addition, SHP plants are not held responsible for imbalances until the end of 2022 or as long as the balancing market is functional.[18]

In previous years, the Energy Ministry of Albania signed a large number of contracts with hydropower developers. However, given that the country is currently seeking to diversify its electricity generation sources away from hydropower, there is no plan to sign further contracts for SHP development.

RENEWABLE ENERGY POLICY

Law 7/2017 on the promotion of the use of energy from renewable sources is the most important piece of legislation on renewable energy in Albania.[18] Under this law, small installations up to 2 MW (3 MW for wind power) are entitled to claim a FIT. Hydropower developers with a plant acceptance certificate received before the end of 2020 can also benefit from the FIT support scheme. The support scheme for installations above 2 MW without a plant acceptance certificate is to be organized through a market-based approach, for example, through auctions for additional renewable energy capacity. The winning bidder would benefit from a sliding feed-in-premium known as a contract for differences. Under this scheme, the developer receives the difference between a prefixed price and the market price for a period of 15 years.

Currently, the target for renewable energy consumption is set at 38 per cent for 2020 and 42 per cent for 2030. A new National Energy and Climate Plan (NECP) is to be published by the end of 2021, which will establish new CO_2 emissions targets as well as new targets for renewable energy generation and consumption. The new NECP is unlikely to have a major impact on SHP, nor is it expected to promote the development of new SHP plants.

The energy regulatory authority ERE, established by the Power Sector Law (Law No. 9072), is responsible for issuing licences for the generation, transmission and distribution of electricity. As per its Rules of Practice and Procedure (Decision No. 21 dated 18 March 2009), ERE guarantees equal treatment in issuing licences and resolving disputes between parties. And under the Rules and Procedures on Certification of Electricity from Renewable Energy Sources, ERE has outlined the procedures for generators to apply for green certificates and approval of project implementation.[16]

FINANCIAL MECHANISMS FOR SMALL HYDROPOWER PROJECTS

Given that there is no intention to further develop new SHP in the country besides the contracts already signed, there are currently no other financial mechanisms available for SHP projects. Nonetheless, SHP can benefit from a FIT according to law 7/2017 on the promotion of the use of energy from renewable sources.

EFFECTS OF CLIMATE CRISIS ON SMALL HYDROPOWER DEVELOPMENT

Hydropower generation in Albania is expected to be greatly impacted by climate change.[19] In particular, reduced precipitation, especially in the summer season, may decrease the generation output of hydropower. In addition, changes in the seasonality of river flows, such as more rapid snowmelt due to higher winter temperatures, could reduce the operating time, resulting in decreased generation.

The Government is looking to diversify the country's over-reliance on hydropower to enhance energy security. Since climate change is exacerbating this risk, the diversification of the generation assets becomes even more important.

BARRIERS AND ENABLERS FOR SMALL HYDROPOWER DEVELOPMENT

The main barriers for further development of SHP in Albania are as follows:

- Current effort to diversify from the almost exclusive reliance on hydropower by encouraging the increase of other sources of renewable energy, such as wind power and solar PV. Such diversification could reduce the impulse for new SHP development.
- Social resistance to new hydropower developments, notably for the Vjosa River.[20] In 2019, the Prime Minister announced the Government's decision to cancel the construction of all hydropower plants on the Vjosa River.[21,22] This generalized resistance might negatively impact the further development of SHP in Albania. Among the factors contributing to this resistance are: infringement on property rights of citizens living in the vicinity of the projects, effects on water quality, potential degradation of the ecosystem, loss of species diversity and genetic diversity, among others.

While in the light of the above limiting factors further SHP development in the country appears unlikely, there, nonetheless, remains a significant untapped potential, which can be considered as the key enabling factor.

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Bosnia and Herzegovina

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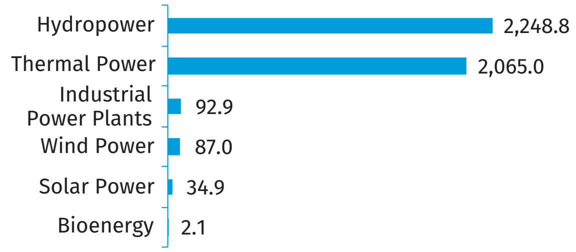
KEY FACTS

Population	3,280,815 (2020)[1]
Area	51,197 km^2 [2]
Topography	Bosnia and Herzegovina (BiH) shares a 932-kilometre border with Croatia to the north and south-west, a 357-kilometre border with Serbia to the east and a 249-kilometre border with Montenegro to the south-east. It borders the Adriatic Sea along its 20-kilometre coastline. The country's territory consists of valleys and mountains, which measure up to 2,386 metres in height, and its lowest altitude is 0 metres. The country is mainly hilly to mountainous, with an average altitude of 500 metres. Of the total land area, 5 per cent is lowlands, 24 per cent is hills, 42 per cent is mountains and 29 per cent is a karst region.[3]
Climate	The country consists of several different climate zones: 1) alpine climate in the mountain regions, 2) continental climate in the northern Pannonia lowlands along the Sava River and foothills, and 3) Mediterranean climate in the coastal and lowland regions of the Herzegovina region in the south and south-east. Due to the temperature characteristics, the territory of BiH is divided into three temperature zones: warm, moderate and cold. The warm zone corresponds to the Adriatic coast and lowland Herzegovina with mean winter temperatures of 5 °C and summer temperatures reaching 40 °C. In the moderate hilly areas, temperatures range from 0 °C in winter and 35 °C in summer. The mountainous, cold regions reach below 0 °C.[4]
Climate Change	The climate change has a significant impact in the country. Frequent flooding, severe and intense rain and drought are only some of the symptoms that impact the tourism and energy sector (particularly, hydropower) in BiH, as well as agriculture, human health, biodiversity and water resources.[4]
Rain Pattern	Annual precipitation ranges from 800 mm in the north along the Sava River to 2,000 mm in the central and south-eastern mountainous regions. Maximum rainfall occurs mostly at the end of autumn or beginning of winter, mostly in November or December.[4]
Hydrology	The waters of the country are made of the Adriatic Sea basin and the Danube River basin. The Sava River subbasin is the second largest subbasin of the Danube River basin, with approximately 40 per cent lying in BiH, whereas the rest of the watershed is shared by Croatia, Serbia and Slovenia.[5]

ELECTRICITY SECTOR OVERVIEW

The total installed capacity of Bosnia and Herzegovina (BiH) in 2020 amounted to 4,530.6 MW (Figure 1).[6] Renewable energy has been used for power generation in the country since the 1950s. While hydropower has dominated among renewable energy sources, since 2010 the relevant BiH institutions started to actively promote the use of other renewable energy technologies as well, with a focus on solar photovoltaics (PV), wind power and biomass. In 2019, the first two wind farms connected to the transmission system, Mesihovina and Jelovača, injected into the network 254 GWh. In 2020, an additional wind farm was connected to the transmission system, Podvelezje, with a total installed capacity of 48 MW.[7]

Figure 1. **Installed Electricity Capacity by Source in Bosnia and Herzegovina in 2020 (MW)**

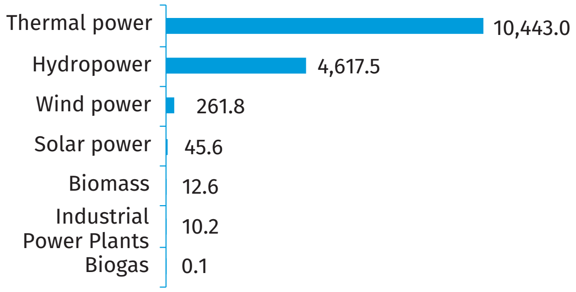


Source: SERC[6]

In 2020, electricity generation reached 15,391 GWh (Figure 2), which was 4 per cent less than in 2019 and 14 per cent less than 2018.[6] In 2020, small-scale renewable energy generation recorded a 26 per cent decrease from 2019 amounting to 399 GWh, much of which was due to a drop in small hydropower (SHP) generation.[6]

In 2020, BiH registered an almost 36 per cent share of renewable energy sources in its energy mix, which was behind its 2018 target of 38 per cent.[7] A new target for 2030 was set within the National Energy and Climate Plan (NECP) by the Ministry of Foreign Trade and Economic Relations (MOFTER) and entity Energy Ministries.

Figure 2. **Annual Electricity Generation by Source in Bosnia and Herzegovina in 2020 (GWh)**



Source: SERC[6]

BiH consists of two administrative entities, Federation of Bosnia and Herzegovina (FBiH) and Republika Srpska (RS). Additionally, the Brčko District, a self-governing administrative unit, remains under international supervision. Under the Constitution of BiH, the energy sector is managed by each administrative entity. In FBiH, the main institutions are the Federal Ministry of Energy, Mining and Industry (FMERI) and the Federation Electricity Regulatory Commission (FERK). The electricity sector is governed by the Law on Electricity and Law on Renewable Energy Sources, both adopted in 2013. The key institutions in RS include the MOFTER, State Energy Regulatory Authority (SERC), Transmission Company (Elektroprenos BiH) and Independent System Operator BiH (ISO BiH). Electricity generation, distribution system operation and supply of electricity are governed by administrative entity legislation respectively in FBiH and RS, as well as by the Brčko District. The local Government of the Brčko District is responsible for the implementation of the Electricity Law of the District, adopted initially in 2004 and amended in 2013.

The country has a 100 per cent electrification rate. The electricity sector in BiH began the process of liberalization in 2015, but to date no electricity wholesale market has been established and consequently no competitive retail market exists.[7]

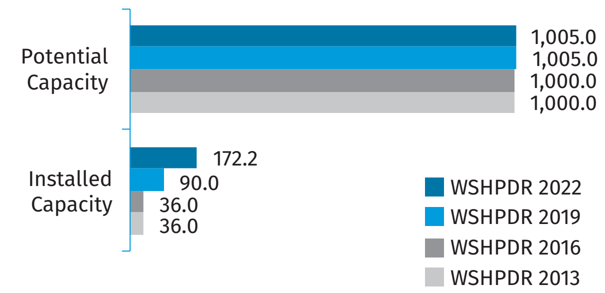
The principal means for regulating the electricity sector is through a licensing regime. Electricity-related licences in BiH are issued by the State Electricity Regulatory Commission (DERK), FERK in FBiH or the Regulatory Commission for Energy in RS (RERS), depending on the jurisdiction. DERK is responsible for regulating tariffs for the services of Elektroprenos BiH, operation of ISO BiH, ancillary services, non-qualified customers belonging to the category of households in the Brčko District and electricity distribution services in the Brčko District as well as for determining the electricity costs of the default supplier in the Brčko District. FERK and RERS are responsible for regulating tariffs for the supply of electricity to non-eligible (tariff) customers and tariffs for distribution system users.[8]

In FBiH and RS, fixed electricity tariffs are calculated by adding technology-specific premiums to a reference price. In FBiH, technology-specific conversion factors are multiplied by the reference price of 0.081 BAM/kWh (0.049 USD/kWh). In RS, absolute determined premiums are added to the reference price of 0.0541 BAM/kWh (0.033 USD/kWh). RS also offers a premium for electricity produced from renewable energy sources, regardless of whether the energy generated is either sold directly to the market or is used for own consumption. Tariffs are granted for 15 years in RS and for 12 years in FBiH.[9]

SMALL HYDROPOWER SECTOR OVERVIEW

In BiH, SHP plants are considered as those up to 10 MW in capacity and are often built on small rivers, streams and canals. In 2020, installed capacity of SHP plants amounted to 172.2 MW (Table 1).[6] This is a significant increase since the *World Small Hydropower Development Report* (*WSHPDR*) *2019* when only 90 MW of installed capacity was recorded, with the difference being due to access to more accurate data and continued growth of the sector (Figure 3). No new studies on SHP potential have been recorded since the *WSHPDR 2019*. Generation from SHP in 2020 (341 GWh) was significantly lower than that in 2019 (498 GWh) due to poor hydrological conditions.[6]

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



Source: Waters of Bosnia and Herzegovina,[10] Gvero,[11] *WSHPDR 2013*,[12] *WSHPDR 2016*,[13] *WSHPDR 2019*[14]

Table 1. **List of Selected Operational Small Hydropower Plants in Bosnia and Herzegovina**

Name	*Location*	*Capacity (MW)*	*Plant type*	*Operator*	*Launch year*
Bočac 2	Bočac	10.00	–	ZP Hidroelektrane na Vrbasu -Bočac 2 a.d.	2018
Podivič	Istocno Sarajevo, Trnovo	0.10	–	Buk d.o.o.	2018
Do	Berkovići	2.00	–	Strajko d.o.o.	2016
Ustiprača	Ustiprača	6.80	–	Hidroinvest d.o.o.	2015
Mesići-Nova	Rogatica	2.00	Reservoir	ERS-MP a.d., ZP Elektrodistribucija a.d.	2015
Žiraja	Bijelo Bučije	0.41	–	Mega elektrik a.d.	2013

Name	*Location*	*Capacity (MW)*	*Plant type*	*Operator*	*Launch year*
Novakovići	Kneževo	5.77	–	EHE društvo za proizvodnju, razvoj i trgovinu d.o.o	2012
SHE Sućeska R-S-2	Strgačina	1.10	–	ERS male hidroelektrane d.o.o. (Energy Zotter Bau)	2012
Kaljani	Prača	1.45	–	Energonova d.d.	2011
Bistrica B-5ª	Dobro Polje	3.87	–	Bobar taubinger elektrik d.o.o. (Anton Kittel Muhle Gmbh)	2010
Sućeska R-S-1	Strgačina	1.80	–	ERS male hidroelektrane d.o.o. (Energy Zotter Bau)	2009
Divič	Kruševo Brdo	2.28	–	Eling male hidroelektrane d.o.o.	2005
Bogatići Nova	Trnovo	10.00	Reservoir	JP Elektroprivreda BiH d.d. (28%), Elektroprivreda RS (72%)	1947
Bogatići Nova	Trnovo	9.40	–	JP Elektroprivreda BiH d.d. (28%), Elektroprivreda RS (72%)	1947
Trebinje II	–	8.00	Run-of-river	ZP Hidroelektrane na Trebišnjici a.d. Trebinje	–

Source: Waters of Bosnia and Herzegovina[11]

As of 2021, there were 115 SHP plants in operation and 341 under various stages of planning and construction (Table 2).[11] For example, the Neretvica SHP plant project consists of 15 plants with an overall capacity of 24.5 MW and a total project cost of EUR 50 million (USD 59 million. The first phase of the project includes four SHP plants with a total of 9.4 MW of installed capacity.[15]

Table 2. **List of Selected Planned Small Hydropower Projects in Bosnia and Herzegovina**

Name	*Location*	*Capacity (MW)*	*Developer*	*Stage of development*
Doboj	Republika Srpska	9.80	Technor Hydro 2 AS, Norveška	Concession agreement terminated
Kruševo	Bioštica, Olovo	9.75	JP Elektroprivreda BiH d.d.	Planned
Volujak	Gračanica	4.50	MM Energi d.o.o.	Environmental permits issued
Bistrica B-4	Foča	2.90	Bobar elektronik d.o.o. Brod na Drini	Concession agreement terminated
Lakat	–	1.70	Čalik enterji(Turska)	Preliminary design

Source: Waters of Bosnia and Herzegovina[11]

Although there has been a rapid rise of SHP in the country, there has also been a pushback from environmental groups against further SHP development in the Balkans. This is due to the larger concern that 817 hydropower plants, representing 49 per cent of all hydropower plants in the Balkan region, lie in protected areas.[16] Because of recent policy developments, it is unlikely that developers will be seeking to develop in the near future.

RENEWABLE ENERGY POLICY

Recently, relevant institutions in BiH, such as Ministry of Foreign Trade and Economic Relations of BiH, Ministry of Energy, Mining and Industry of FBiH, Ministry of Industry, Energy and Mining of RRS and Government of the Brčko District, started to engage in active renewable promotion. The National Renewable Action Plan (NREAP) of BiH, which was developed based on the FBiH and RS Renewable Energy Action Plans, set a target of a 40 per cent share of renewable energy sources in final energy consumption and a 10 per cent share in transport by 2020. The Framework Energy Strategy of BiH Until 2035 is aimed at prioritizing the key energy strategies for the years to come. Under this framework, the country aims to increase the share of renewable energy to 40 per cent with a focus on increasing deployment in the electricity sector.[17]

BiH is a Contracting Party to the Energy Community Treaty, which imposes clear obligations and deadlines to adopt, reform and implement changes related to the energy sector. These include market development and competitive landscape as well as environmental protection.

The legal and regulatory authority framework in BiH electricity sector is complex. At the state level, there are three main laws governing the electricity sector all adopted in 2004: Law on Transmission, Regulator and Electricity System Operator; Law on Establishment of Transmission Company; and Law on Establishment of the Independent System Operator.

The main support scheme for the production of electricity from renewable energy sources in BiH is a FIT. RS promotes the power production from renewable energy sources mainly through a FIT and feed-in premium. Policy makers in BiH have pushed for a reform of the support system to curb its rising cost, questioning the use of FIT in particular. Many in the Government consider FIT to be an effective but not a cost-efficient instrument for renewable energy support and that the use of the FIT is inconsistent with the goal of renewable energy market integration. Instead, large-scale renewable energy plants should be encouraged to sell their electricity to the wholesale market, with any support being additional to market revenues. The underlying rationale for this policy is to enhance the operational efficiency of renewable energy plants via an improved match of demand and supply.

In FBiH, tariffs are regulated by the Renewable Energy Sources Law of FBiH and special decrees and rulebooks. The plant operators need to obtain the status of a privileged power producer to acquire the right to a price support for the generated electricity under the legal requirements. After having concluded a power purchase agreement with the plant operator, the operator for renewable energy sources and coefficient cogeneration (RES Operator) is legally obliged to buy the total amount of electric energy from privileged producers at an incentive price. The amount of the feed-in tariff (FIT) is determined in the annex of the Decision on the determination of the guaranteed prices for electricity from renewable energy sources and efficient cogeneration and depends on the type of technology and the capacity of the power plant.[18]

In RS, tariffs are regulated by the Energy Law of RS, Electricity Law of RS and above all the Renewable Energy Sources Law of RS; there are also special decrees and rulebooks. Firstly, the plant operator needs to obtain a renewable energy source certificate and a decision on the right to support by applying to the Energy Regulator (Art. 12 of Electricity Law). The Support Scheme Operator (Art. 13 of Renewable Energy Sources Law RS) concludes a power purchase agreement at a guaranteed price. The amount of the FIT is determined in the Decision on the amount of the guaranteed prices and premium prices for electricity produced from renewable sources and efficient cogeneration and depends on the type of technology and the capacity of the power plant. The FIT is financed by an incentive fee that the final consumer is obliged to pay on the amount of consumed electricity (Art. 30 of Renewable Energy Sources Law RS).[19]

In both administrative entities, renewable energy developers enjoy other incentives, such as priority in dispatch. Both entities prioritize grid connection for renewable energy source operators. FBiH and RS both also offer other incentives for foreign investors, such as customs-free imported materials in FBiH and corporate tax exemption in RS.

In FBiH, the connection of power plants from renewable energy sources to the grid is mainly regulated by the general legislation on energy (Art. 28, § 1 of Renewable Energy Sources Law FBiH). In RS, the connection of power plants from renewable energy sources to the grid is regulated by the general legislation on energy (Electricity Law of RS, Renewable Energy Sources Law of RS), General Conditions for Delivery and Supply of Electricity, Rule Book on Methodology for Determination of the Fee for Connection to the Distribution Network and Rule Book on Conditions for Connection of the Facilities to the Electric Distribution Network of the RS. In both entities, the grid operators generally provide non-discriminatory access to the grid and renewable energy producers are given priority to connect to the grid.[19]

SMALL HYDROPOWER LEGISLATION AND REGULATIONS

Due to the pressure of environmental activists, the House of Representative of FBiH adopted the Declaration on Protection of Rivers in February 2021 with the aim of completely banning the construction of SHP plants in FBiH.[19] In order for the ban to become effective, FBiH needs to amend the existing legislation. The FBiH House of Representatives gave a three-month deadline to the FBiH Government to analyse and draft the amendments to the current legislation needed for the implementation of the Declaration and ban. On top of this, the Government rejected a proposal in April 2021 that would amend the Law on the Use of Renewable Energy Sources and Efficient Cogeneration to allow 17 SHP plants to continue benefiting from a subsidy scheme until the end of their concession agreements.[20]

Although the construction of SHP plants has not been banned in RS, the entity has enacted a set of measures that seem to have a similar goal. The RS National Assembly instructed the RS Government to draft a proposal of measures for the review of all concession agreements and the status of activities envisaged by the latter to temporarily suspend the initiatives for construction of new SHP plants until the finalization of the aforementioned review, and to reassess and amend the incentives system for electricity produced from SHP plants.

FINANCIAL MECHANISMS FOR SMALL HYDROPOWER PROJECTS

Most SHP projects are financed by commercial bank loans and guarantees are topped up by the companies' own resources. Pledge registries, business registries and land registries in some countries sometimes contain information on loans taken for the construction of hydropower plants. Three greenfield projects identified in BiH have confirmed financing from multilateral development banks: Vranduk with financing from the European Bank for Reconstruction and Development (EBRD) and European Investment Bank (EIB) signed; the Brestovni Potok plant financed by the EBRD through an unidentified financial intermediary; and the Kraljuščica 1 plant near Konjic, also financed by the EBRD through UniCredit as a financial intermediary.[21]

There is also some interest from Chinese banks in BiH, however there are no commitments on paper yet. The project sponsor of the Ulog project on the Upper Neretva, the Energy Financing Team (EFT), has stated in June 2012 that it is in negotiations with the China Development Bank regarding financing.[22] Chinese companies have also expressed interest in the controversial Dabar hydropower plant, part of the Gornji Horizonti complex, which would move water from the Neretva attachment to the Trebišnjica, as well as the Buk Bijela project on the River Drina and the lesser known Trn and Laktaši plants on the River Vrbas near Banja Luka.[21]

EFFECTS OF CLIMATE CRISIS ON SMALL HYDROPOWER DEVELOPMENT

Climate change is expected to exacerbate problems related to low river flows. The expected summer precipitation decreases in inland areas could lead to a fall in the production of hydropower, which could also jeopardize energy security and electricity exports. Droughts have contributed to reductions in the production of hydropower. This reduction can be compensated for through thermal power generation or imports, although neither is economically viable or environmentally friendly. Furthermore, the climate crisis is expected to increase the risk of damage due to more frequent floods as well as lower the quality of potable water.[22]

Planned outputs and activities of the Climate Change Adaptation and Low-Emission Development Strategy, adopted by the council of ministers in October 2013 that are related to hydropower include:

- Improved guidelines for the construction of hydropower plants, considering the potential impact of climate change (technical assistance and capacity building programme to develop guidelines, followed by training and awareness raising);
- Improved and functioning licence control for hydropower plants (revised regulations, monitoring and enforcement programme);
- Hydrological models for various climate scenarios need to be developed to support both risk management strategies and mitigation measures.[23]

BARRIERS AND ENABLERS FOR SMALL HYDROPOWER DEVELOPMENT

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

- Negative environmental impacts on protected areas due to poor construction practices including water pollution, waste disposal, soil erosion impacts and habitat encroachment;
- Lack of adequate economic incentives;
- Lack of adequate consultation with local population;
- Recent adoption of the Declaration on Protection of Rivers with the aim to ban construction of SHP in FBiH;
- Strong negative reputation of SHP in the country due to perceived harmful practices.

The following points summarize the main enablers that have been identified:

- Remaining and vast undeveloped potential in the country.

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Croatia

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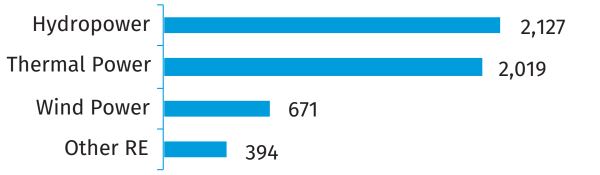
KEY FACTS

Population	4,058,165 (2019) [1]
Area	56,594 km^2 [2]
Topography	The topography of Croatia is divided into three distinct areas: 1) the lowland basin between the Sava and Drava Rivers and along the border with Hungary (the Pannonian Plain) in the east and north-west; 2) the mountainous karst region of the Dinaric Range in the centre and 3) the littoral region along the Adriatic coast, which runs from the Istria County in the north through Dalmatia to the Prevlaka peninsula in the south. Approximately one quarter of the territory of Croatia is arable. The highest peak is Mount Dinara at 1,831 metres, located on the border between Croatia and Bosnia and Herzegovina.[3]
Climate	The climate of Croatia varies across regions. A continental climate predominates on the Pannonian Plain and a Mediterranean one along the Adriatic coast, while variations of those two climates are present in the Central Belt of the Dinaric Mountain barrier. The coastline is marked by frequent strong winds — the colder Bura as well as the warmer Jugo.[4]
Climate Change	The average annual air temperatures in Croatia in 2019 exceeded the multi-annual average (1981–2010) by 0.7 °C (Komiža) to 1.9 °C (Gospić and Zagreb-Grič). At the Zagreb-Grič station, the average annual air temperature in 2019 was 14.2 °C, compared with the 1981–2010 average of 12.3 °C, making the 2019 annual average the warmest observed at the station since the beginning of meteorological observations in 1862.[5] The Regional Climate Model for Croatia indicates a further increase in air temperatures in the coming decades. Thus, for the period 2011–2040, the temperature in Croatia is expected to increase by 0.6 °C in winter and by 1 °C in summer. For the period 2041–2070, the model projects an increase of 2 °C in the continental part of the country, 1.6 °C in the south and 3 °C in the coastal region. Precipitation is also expected to decline in the coming decades but the patterns of change are projected to vary regionally and across seasons. Furthermore, many projections foresee a future climate with winters wetter in the north and drier in the south.[6]
Rain Pattern	The precipitation regime in Croatia reflects the diversity of topographic areas and climactic zones and the influence of the mountain barrier between them. While in the Pannonian Plain average annual precipitation reaches 800–1,300 mm per year, in the coastal region it is only approximately 700–800 mm. In the Gorska Hrvatska region, average annual precipitation ranges from 1,300 mm to 3.500 mm.[7] Areas receiving the least annual precipitation include the small, remote Croatian archipelago of Palagruža in the middle of the Adriatic Sea (304 mm) and eastern Slavonia and Baranja (Osijek, 650 mm).[8,9] An analysis of annual precipitation in 2019 indicates that precipitation values in Croatia across all surveyed stations were within the range of 103–143 per cent of the 1981–2010 average.[5]
Hydrology	The main hydrological divisions of Croatia are the Black Sea catchment basin and the Adriatic catchment basin. The Black Sea basin comprises approximately 62 per cent of the country's territory. It can be further subdivided into the Danube and the Drava basins lying within the Pannonian Plain and the Sava River basin in the Dinaric karst, which also includes its tributaries the Kupa, Bosut and Una Rivers. The Danube is the major navigable river of Croatia. Meanwhile, the Adriatic basin comprises 38 per cent of the territory of the country, and includes the Cetina, Krka, Zrmanja and Rjecina Rivers.[10,11] Major lakes in Croatia include Lake Vransko (30.7 km^2), as well as the artificial reservoirs Lake Dubrava (17.1 km^2) and Lake Varaždin (10.1 km^2) on the Drava River and Lake Peruća (13 km^2) on the Cetina River.[11]

ELECTRICITY SECTOR OVERVIEW

The total installed capacity of power plants in Croatia at the end of 2019 was 5,211 MW, with hydropower providing 2,127 MW (41 per cent), thermal power 2,019 MW (39 per cent), wind power 671 MW (13 per cent) and other renewable energy sources a total of 394 MW (8 per cent) (Figure 1). These figures exclude the installed capacity of the Krško nuclear power plant, located on the territory of Slovenia, of which Croatia owns a 50 per cent share.[12,13] Wind power in Croatia has been undergoing a rapid expansion in the last decade, by April 2021 reaching an installed capacity of 738.25 MW, up from 26.8 MW in 2009.[13,14]

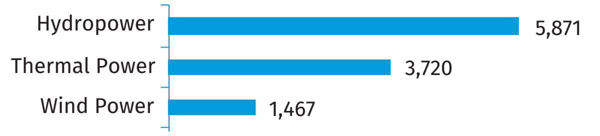
Figure 1. **Installed Electricity Capacity by Source in Croatia in 2019 (MW)**



Source: HERA[12]

Total generation of electricity in 2019 was 12,005 GWh, of which hydropower provided 5,871 GWh (49 per cent), thermal power 3,720 GWh (31 per cent), wind power 1,467 GWh (12 per cent), and other renewable energy sources 947 GWh (8 per cent) (Figure 2).[12]

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



Source: HERA[12]

Access to electricity in Croatia is 100 per cent.[15] Total annual consumption of electricity realized in the transmission network in 2019 was 16,821 GWh, with system peak load at 3,038 MW and a total of 22,198 GWh of electricity transmitted. Total transmission losses were 387.9 GWh (approximately 1.8 per cent of all transmitted electricity). Imports, including electricity produced by the Krško nuclear power plant, totalled 6,163 GWh, amounting to 35.6 per cent of total consumption.[12,13]

The electricity sector of Croatia has been liberalized but remains dominated by the state-owned company Hrvatska Elektroprivreda (HEP), especially in the area of large hydropower and thermal power. The national electricity market of Croatia is fully aligned with the European Union (EU) directives governed by EU regulations. Croatia has adopted the independent transmission operator (ITO) model of market unbundling, with the Croatian Transmission System Operator (HOPS) being separate from the state-owned utility HEP, which owns the transmission network. Authorities of major importance for the energy sector include the Ministry of Environmental Protection and Energy, in charge of developing energy policy; the Croatian Energy Regulatory Agency (HERA), an independent public institution in charge of regulating energy activities; and the Croatian Energy Market Operator (HROTE), which organizes the electricity and gas markets as a public service under the supervision of HERA.[16]

The structure of the electricity market in Croatia is outlined in the Energy Act and the Electricity Market Act. In fact, there are two distinct electricity markets in the country. The initial energy market model was a bilateral one in which electricity trading was carried out based on bilateral contracts between market participants. The Rules of Organizing the Electricity Market of 2015 introduced the concept of balancing groups, enabling portfolio optimization of subjects bundled into a single balance group. The second electricity market is regulated by the Croatian Power Exchange Ltd. (CROPEX), which was created in 2016 and in 2018 was merged with the Slovenian stock market. Any producer, supplier, energy trader or eligible customer is a market participant in the Croatian electricity market. For performing energy-related activities, a licence must be obtained from HERA and an Electricity Market Participation Agreement must be signed with HROTE.[17,18] The Integrated National Energy and Climate Plan of Croatia for the period 2020–2030 with an outlook until 2050, adopted in December 2019, aims to strengthen the country's energy market and to integrate it completely with that of the EU and the international energy markets. Regulatory activities are to be steered towards simplifying market access and allowing equal and non-discriminatory access to the grid infrastructure.[19]

The average electricity price including all taxes, levies and VAT for an annual consumption of 2,500–5,000 kWh for household end users in the second half of 2020 was 0.131 EUR/kWh (0.16 USD/kWh) while the average electricity price for non-household consumers with an annual consumption of 500–2,000 MWh, excluding all recoverable taxes and levies, was approximately 0.102 EUR/kWh (0.12 USD/kWh).[20,21] The prices generally vary with the amount of electricity consumed, making it cheaper for larger consumers such as business and industry. For eligible producers taking part in the incentive system for renewable energy under the Renewable Energy Source and High-Efficiency Cogeneration Act, the weighted average price of electricity paid in 2019 was approximately 2.5 times higher than the annual average electricity price on the day-ahead market on the CROPEX electricity exchange (0.37 HRK/kWh (0.06 USD/kWh)).[12]

SMALL HYDROPOWER SECTOR OVERVIEW

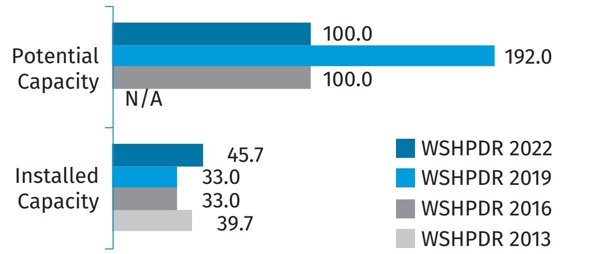
Small hydropower (SHP) plants are defined in Croatia as plants having an installed capacity of less than 10 MW, as per the EU standard.

The total natural hydropower generation potential in the Republic of Croatia is approximately 21.3 TWh, while the technical hydropower generation potential is approximately 12.4 TWh. Currently, around 49 per cent of the technical hydropower potential is utilized, which means that the remaining available technical hydropower potential is approximately 6.2 TWh. Approximately 8 per cent of the total technical hydropower potential is accounted for by the potential of small watercourses (514.92 GWh/year).[22]

The technical potential capacity of SHP plants in Croatia (not considering environmental constraints) is approximately 350 MW, while the most recent data suggest that the realistically achievable potential is 100 MW, according to the conclusions of the "Small hydropower plants in Croatia" symposium held in 2015.[23] The possibility of using a large part of the currently-unused potential will depend on the harmonization of the interests of Croatia and neighbouring countries. Part of the hydropower potential will likely remain unused due to ecological and other constraints.

As of 2019, there were 39 SHP plants operational in Croatia with a total installed capacity of 45.68 MW.[24] Relative to the *World Small Hydropower Development Report (WSHPDR) 2019*, the installed SHP capacity increased by nearly 39 per cent; however, this increase is primarily due to more accurate data on operational SHP plants becoming available (Figure 3, Table 1). Of the operational SHP plants, 14 with a total installed capacity of 5.9 MW were enrolled in the incentive scheme for renewable energy sources and two additional SHP contracts with a total installed capacity of approximately 0.8 MW were pending as of 2020.[12,25] SHP projects previously considered for development include the Dale SHP plant (6.4 MW), TE-TO Zagreb SHP plant (84.3 kW) and four SHP plants on the Sava River near Zagreb (Jarun, Šanci, Petruševec and Ivanja Reka) with a total capacity of 40 MW.[26,27] As of 2019, there were plans in Croatia for at least 29 additional SHP projects with a total planned installed capacity of 27.64 MW, in various stages of approval (Table 2).[24]

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



Source: Croatian Water Institute for Water Management,[24] *WSHPDR 2013,*[28] *WSHPDR 2016,*[29] *WSHPDR 2019*[30]

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

Name	*Location*	*Capacity (MW)*	*Plant type*	*Operator*	*Launch year*
Pamučna industrija Duga Resa	Mrežnica River	1.10	Run-of-river	Duga Resa Cotton Industry	1884
Jaruga	Krka River	5.60	Run-of-river	HEP	1903
Ozalj 1	Kupa River	3.54	Run-of-river	HEP	1908
Roški Slap	Krka River	1.77	Run-of-river	Hidro-Watt LLC	1909
Zeleni Vir	Curak watercourse	2.00	Run-of-river	HEP	1922
Ozalj 2	Kupa River	2.20	Run-of-river	HEP	1952
Zavrelje	Zavrelje source	2.10	Run-of-river	HEP	1953
Fužine	Ličanka River	6.50	Pumped storage	HEP	1957
Varaždin PS	Drava River	0.64	Run-of-river	HEP	1976
Golubić	Butižnica River	7.50	Run-of-river	HEP	1981
Čakovec 1	Drava River	1.10	Run-of-river	HEP	1982
Čakovec 2	Drava River	0.34	Run-of-river	HEP	1983
Krčić	Krčić watercourse	0.36	Run-of-river	HEP	1988
Dubrava 1	Drava River	1.10	Run-of-river	HEP	1989
Dubrava 2 and 3	Drava River	0.68	Run-of-river	HEP	1991
Bujan	Kupčina River	0.05	Run-of-river	Josip Bujan	1995
Lepenica	Lepenica accumulation	1.20	Reversible	HEP	1996
Mataković 1 and 2	Mrežnica River	0.02	Run-of-river	Obrt Mataković, metal machining	2007
Pleternica	Orljava River	0.23	Run-of-river	Pleternica SHP LLC	2012
Pranjčevići	Cetina River	1.31	Run-of-river	HEP	2017

Source: Croatian Water Institute for Water Management[24]

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

Name	*Location*	*Capacity (MW)*	*Plant type*	*Developer*
Gomirsko Vrbovsko	Dobra River	0.22	–	Nova energija LLC
Korana 1	Korana River	0.35	Run-of-river	Ekološki sistemi LLC
Odeta 1	Korana River	1.25	Run-of-river	Odeta LLC
Odeta 2	Mrežnica River	0.42	Run-of-river	Odeta LLC
Požega	Orljava River	0.12	Run-of-river	Pleternica SHP LLC

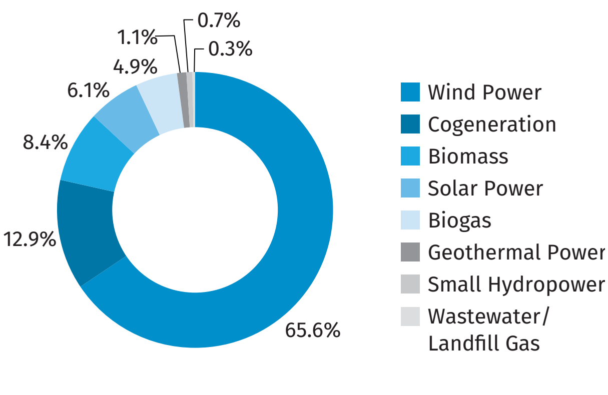
Source: Croatian Water Institute for Water Management[24]

RENEWABLE ENERGY POLICY

The Integrated National Energy and Climate Plan of Croatia for the period 2020–2030 with an outlook until 2050 was adopted in December 2019 under the mandate of the Energy Act.[19] Of the targets addressed in this Plan, decarbonization is the most significant. The two key components of the decarbonization target are a reduction in greenhouse gas emissions (at least 43 per cent for the European Emissions Trading System (ETS) sector and at least 7 per cent for the non-ETS sector) and an increased share of renewable energy sources in final energy consumption (63.8 per cent of electricity consumption, 36.4 per cent of gross final energy consumption and 13.2 per cent in the transport sector) by 2030. According to the Plan, renewable energy is expected to account for 79 per cent of all produced energy by 2050. All non-renewable energy sources, including thermal power and public and industrial cogeneration, are expected to decrease their production, with their combined share decreasing from 37.1 per cent in 2010 to 27.8 per cent in 2030 and to 21 per cent in 2050.[19]

As the share of renewable sources in the country's energy mix and the financial viability of renewable energy projects increase, the Plan aims to gradually decrease incentives paid to renewable energy producers, with the end goal of reaching a point where incentives will no longer be necessary. At the same time, continued support for the development of renewable energy sources will be provided by unburdening such projects from certain taxes and levies, removing administrative obstacles, simplifying permit issuance procedures and setting guidelines, recommendations and best practices for projects in urban areas. The national Government as well as local and regional authorities will be expected to contribute to the project's development by preparing necessary studies and documentation.[31]

Figure 4. **Share of Renewable Energy Sources in the Incentive System of Croatia in 2019 (%)**



Source: HERA[12]

The current tariff system incentivizing renewable energy sources, which reduced support for wind and solar power plants, was introduced in 2014. Under the tariff system for production of electricity from renewable energy sources and cogeneration, renewable energy producers who have obtained the status of a privileged producer and subsequently won a public tender carried out by HROTE receive a premium on the base tariff for a period of 14 years.[32] The share of each renewable source among power plants currently enrolled in the incentive system is displayed in Figure 4, with tariffs showed in Table 3.

Table 3. **Premium Tariff for Renewable Energy in Croatia**

Energy type	*Capacity (MW)*	*Incentive price (USD/kWh)*
Hydropower	<0.3	0.17
	0.3–2	0.15
	2–5	0.14
Wind power	>5	RC
Biomass	<0.3	0.21
	0.3–2	0.20
	2–5	0.19
	>5	RC
Geothermal		0.19
Biogas	<0.3	0.22
	0.3–2	0.20
	2–5	0.19
	>5	RC

Source: HROTE[32]

Note: RC stands for reference price; for each accounting period, plants that have the incentive price of RC will be paid the amount of currently valid RC.

On 1 January 2016, a new Law on Renewable Energy Sources and High-Efficiency Cogeneration came into force and introduced a premium tariff support scheme for these technologies. The Law aims for the efficient use of energy and reduction of the impact of fossil fuels on the environment. It represents the first comprehensive codification of provisions concerning the planning and promotion of renewable energy sources in the country.[33] The Law elaborates in detail the method and conditions for the implementation of new incentive models consisting of market premiums and buy-offs at a guaranteed price, setting maximum reference values and maximum guaranteed buy-off prices, contracting procedures and setting incentive quotas.

SMALL HYDROPOWER LEGISLATION AND REGULATIONS

The legal framework regulating activities for investing in SHP in Croatia includes the following acts:

- Act on the Regulation of Energy Activities (Official Gazette Nos. 120/12 and 68/18);
- Energy Act (Official Gazette Nos. 120/12, 14/14, 102/15 and 68/18);
- Electricity Market Act (Official Gazette Nos. 22/13, 102/15 and 68/18);
- Law on Renewable Energy Sources and High-Efficiency

Cogeneration (Official Gazette Nos. 100/15 and 111/18);
- General Administrative Procedure Act (Official Gazette No. 47/09); and
- Other ordinances (rules) and decisions correlated to the above-mentioned acts.[34]

Permits required for construction and operation of SHP plants in Croatia include:
- An environmental permit in the case of SHP plants above 5 MW, predicated on a decision by the Ministry of Environmental Protection, Physical Planning and Construction on the need for an environmental impact assessment;
- A building permit allowing the construction of the facility;
- An energy permit, which also applies to all facilities that exploit natural resources, with the exception of solar power plants integrated into rooftops and walls of buildings.[34]

COST OF SMALL HYDROPOWER DEVELOPMENT

Based on the cost of hydropower plants commissioned in recent years, the specific investment cost of SHP development in Croatia can be estimated to range between EUR 2.2 million and EUR 3.5 million (USD 2.67–4.24 million) per installed MW.

In 2014, the Pleternica SHP plant was commissioned, with an installed capacity of 220 kW. The specific investment costs of the project stood at approximately EUR 3.5 million (USD 4.24 million) per installed MW.[35] The Velika Šuma SHP plant near the town of Umag was put into trial operation in 2016, the first in Croatia to be built on a water supply system. The installed capacity of the plant is 90 kW and the investment costs were approximately EUR 307,000 (USD 372,000), giving a specific cost of approximately EUR 3.4 million (USD 4.12 million) per installed MW.[36]

FINANCIAL MECHANISMS FOR SMALL HYDROPOWER PROJECTS

Besides the premium tariffs discussed above, financial support for renewable energy projects in Croatia includes, at the national level, the environmental protection loan scheme issued by the Croatian Bank for Reconstruction and Development (HBOR) and conducted through commercial banks, as well as financial incentives in the form of interest-free loans or subsidies offered by the Environmental Protection and Energy Efficiency Fund (EPEEF). On the international level, financial support for renewable energy development in Croatia is offered by the European Bank for Reconstruction and Development (EBRD) and the European Regional Development Fund (ERDF).[34]

EFFECTS OF CLIMATE CRISIS ON SMALL HYDROPOWER DEVELOPMENT

In addition to the projected shifts in average annual temperature, climate change is expected to impact the hydrological environment in Croatia in several ways. While recent observations have recorded a marked increase in average annual precipitation across Croatia, other indicative scenarios project a decrease in precipitation over the long term. In particular, the United Nations Development Programme (UNDP) climate projections for Croatia for the period 2070–2100 predict that relative to the base period (1961–1990), winter precipitation will increase by 16.5 mm, while summer precipitation could decrease by as much as 75.6 mm.[5,37] While the overall hydrological impact on a geographically diverse country such as Croatia is difficult to predict, some estimates expect a decrease in runoff in western Croatia of 10–20 per cent by the middle of the 21st century.[34]

BARRIERS AND ENABLERS FOR SMALL HYDROPOWER DEVELOPMENT

There are several barriers to the development of SHP in Croatia, including:
- Bureaucratic obstacles in the form of strict EU regulations and the complex structure of state and local agencies within Croatia responsible for issuing permits for development and operation of SHP plants;
- Pressure from the economically important tourism sector in Croatia to preserve the environmental and aesthetic integrity of rivers;
- Lack of funding due to high upfront costs and long payback periods;
- Difficulties SHP producers face in balancing responsibilities.

Enablers of SHP development in Croatia include:
- Proven commitment on the part of the Government to promote renewable energy in general;
- The knowledge base provided by previous studies that have carefully mapped the SHP potential in the country.

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Greece

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KEY FACTS

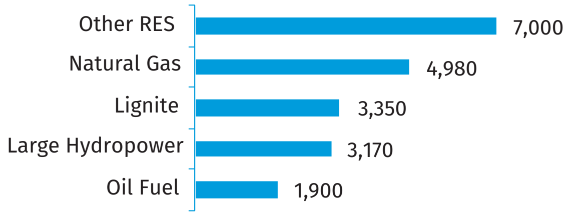
Population	10,715,549 (2020)[1]
Area	131,957 km^2 [2]
Topography	Greece is a peninsular country, with an archipelago (Aegean) containing over 2,500 islands.[3] The coastline of Greece, including the islands, measures almost 15,000 kilometres. Greece is one of the most mountainous countries in Europe, with 80 per cent of its area covered with mountains. The Pindus Mountain Range stretches across the centre of the country from the north-west to the south-east, with a maximum elevation of almost 2,650 metres. Central and western Greece features 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.[4,5]
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 season, 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, with average minimum temperatures between 5 °C and 10 °C in coastal areas and between 0 °C and 5 °C in mainland areas. In the northern part of the country, the winter is much cooler, with temperatures occasionally falling down to -20 °C. In the months of July and August, the average maximum temperatures range between 29 °C and 35 °C.[2,4,5]
Climate Change	Climate change is already being felt in Greece, with extreme heat waves during the summer of 2021 causing maximum daily temperatures to reach 46.3 °C and massive wildfires in different parts of the country.[6] Projected changes to mean summer temperatures include increases of 1.5–2.5 °C over the 2021–2050 period, and of as much as 5 °C by 2100, relative to the baseline period 1961–1990. The length of dry spells is also projected to increase by as many as 40 additional consecutive dry days in the central parts of the country by 2071–2100.[2]
Rain Pattern	Rainfall in Greece, even during the winter, does not last for many days and winter storms usually end in 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.[4,5] The lowest annual precipitation is observed on the Cyclades islands.
Hydrology	The most important rivers in Greece are the Evros, Nestos, Strimon, Axios, Aliakmon, Penios, Arachthos, Acheloos, Sperchios and Alfios. The Acheloos River has a considerable water flow of approximately 300 m^3/s during December, while the flow rate of the Axios is almost 230 m^3/s in March. Finally, the flow rate of the Evros varies between 200 and 220 m^3/s from January to March. The total domestic water resources are estimated at 85 TWh/year, while the annual specific theoretical hydrodynamic potential of Greece amounts to 0.73 GWh/km^2. The technically and economically exploitable hydropower potential is estimated at 21 TWh/year.[4,7]

ELECTRICITY SECTOR OVERVIEW

The national Electricity Generation System (EGS) is divided into two main sectors: the interconnected system of the mainland, referred to as the Hellenic Electricity Transmission System (HETS), and the autonomous power plants of the Aegean Archipelago islands (also known as the Non-Interconnected Islands or NIIs).[8] With the recent completion of the first phases of the Cyclades Interconnection project by the Independent Power Transmission Operator (IPTO) of Greece, the electrical systems of Paros (including Naxos, Antiparos, Ios, Sikinos, Folegandros), Syros and Mykonos islands are now interconnected with HETS. The majority of the remaining Aegean islands (including Crete, the rest of the Cyclades, the Dodecanese and the islands of the north-eastern Aegean) are expected to be interconnected with HETS between 2021 and 2030, starting with the interconnection of Crete, which is expected to be completed by the end of 2023.[9,10]

As of December 2019, the total installed capacity of Greece was approximately 20,400 MW, comprising the installed capacity of HETS (18,200 MW) and the installed capacity of the NIIs, including Crete and Rhodes (2,200 MW). Renewable energy sources (RES), including wind power, solar photovoltaics (PV), large and small hydropower, biomass and cogeneration, provided 10,170 MW (50 per cent) of the total installed capacity, with large hydropower alone providing 3,170 MW (16 per cent) and other RES providing 7,000 MW (34 per cent). Natural gas-fired power plants operated by the Public Power Corporation (PPC) and by private companies provided 4,980 MW (24 per cent); lignite provided 3,350 MW (16 per cent), following the shutdown of the Ptolemais lignite power plant; and oil fuel-fired power plants, operated exclusively on the NIIs, provided 1,900 MW (9 per cent) (Figure 1).[11,12] By August 2021, the installed capacity of RES in Greece reached 7,609.2 MW, including 4,059.9 MW of wind power, 3,196.6 MW of solar power, 247.2 MW of SHP and 105.5 MW of biomass and biogas.[13]

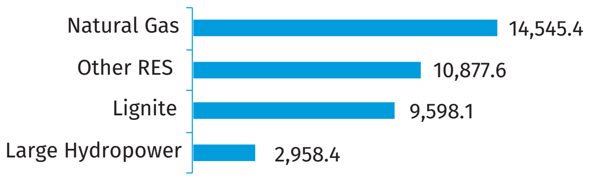
Figure 1. **Installed Electricity Capacity by Source in Greece in 2019 (MW)**



Source: Energypedia,[11] HEDNO[12]

Annual electricity generation in 2019 reached 37,989.4 GWh, excluding the interconnections' energy balance. Natural gas provided 14,545.4 GWh (38 per cent) of this total, RES (excluding large hydropower) 10,887.6 GWh (29 per cent), lignite 9,598.1 GWh (25 per cent) and large hydropower 2,958.4 GWh (8 per cent) (Figure 2).[14]

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



Source: IPTO[14]

Access to electricity in Greece is 100 per cent.[15] Annual electricity demand in Greece equalled 42,896.9 GWh in 2019.[16] The evolution of electricity demand over the last few decades has been non-linear. The significant increase in Gross Domestic Product (GDP) during 2000–2008 was accompanied by a corresponding increase in electricity consumption, which peaked at 57 TWh in 2008. Subsequently, the economic crisis in Greece led to a significant decline in consumer activity, with electricity demand in 2014 dropping to the level of 2000. Since then, electricity consumption has remained almost constant at 2014 levels. Given the continuing economic uncertainty, the demand for electricity is not expected to recover in the near future. However, due to consumption outpacing domestic generation, imports form a significant share of the electricity supply, reaching 18 per cent of consumption in 2020.[17] Imports from the Balkan counties have increased in recent years, due to the relatively low cost.

In recent years, a series of legislative reforms has been attempted in order to liberalize the state monopoly in the electricity sector, but the undertaken efforts have not led to major changes so far. A more significant development has been the effort to reduce CO_2 emissions in the energy sector and promote generation from RES. In line with the European Union (EU) RES targets, Greece is expected to cover 60 per cent of its gross domestic electricity consumption from RES by 2030. At the end of 2020, the RES-sourced share of consumption did not exceed 35 per cent.[14] Due to this fact and the commitments to the European Commission on reduction of CO_2 emissions, as well as the increasing environmental awareness in Greece as a whole, the current political leadership of the Ministry of the Environment and Energy (MoEE) has increased support for the transition to a more renewable electricity generation mix. This has included implementing energy transition development plans in the areas with lignite-fired power plants (mainly western Macedonia and the Peloponnese regions). Following the Decarbonization Master Plan announced by the Government of Greece, the lignite-fired power plants in Ptolemais and Amyntaio were decommissioned during 2020, while three additional lignite plants in Kardia and Megalopoli were to complete the decommissioning process by the end of 2021, leading to an aggregate removal of 810 MW of installed capacity from the Greek electricity system.[18]

Meanwhile, the RES sector has been experiencing extensive development, including the rapid addition of 2,500 MW from solar PV power plants during 2011–2013 spurred by high feed-in tariffs (FITs) for solar power, the support provided to the construction of large wind farms, particularly on the islands of the Greek Archipelago, in addition to the planned undersea interconnection of the islands with the mainland. Moreover, new investments in the RES sector have been announced, including a 2 GW cluster of solar power parks, which have attracted the interest of many European key players on the market.[11,18]

In 2019, the cost of electricity generation was based on the respective System Marginal Price (SMP) and the price of electricity to consumers was implicitly controlled by the Government. The marginal production cost for the interconnected system varied between 50 EUR/MWh (59 USD/MWh) and 90 EUR/MWh (106 USD/MWh), with an average value of 60 EUR/MWh (70 USD/MWh). Due to the impact of the COVID-19 pandemic on the electricity sector in the country, in the first months of 2020 the average wholesale monthly SMP had decreased by more than 20 EUR/MWh (24 USD/MWh) compared to the analogous period in 2019.[19]

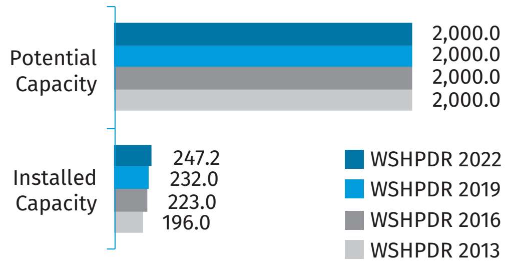
In the case of electricity production from SHP, the electricity price ranges between 85 EUR/MWh and 100 EUR/MWh (100-

118 USD/MWh), adjusted every year through a Ministerial Decree. The average electricity price of SHP in 2020 was 86 EUR/MWh (101 USD/MWh).[20]

SMALL HYDROPOWER SECTOR OVERVIEW

SHP is defined in Greece as hydropower plants of up to 15 MW of installed capacity. The installed capacity of SHP in Greece stood at 247.2 MW as of August 2021, corresponding to slightly over 1 per cent of the current national power mix.[13] Approximately 120 SHP plants operate in Greece under official licences, with installed capacities ranging from 60 kW to 10.8 MW.[21,22,23] The economically feasible SHP potential is estimated at 2,000 MW, indicating that only approximately 12 per cent of this potential has been developed. The overall annual technically feasible hydropower generation potential in Greece is estimated at 20 TWh.[24] Relative to the *World Small Hydropower Development Report (WSHPDR) 2019*, the installed capacity of SHP in Greece had increased by approximately 7 per cent, while the potential estimated SHP capacity has remained the same (Figure 3).[4]

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



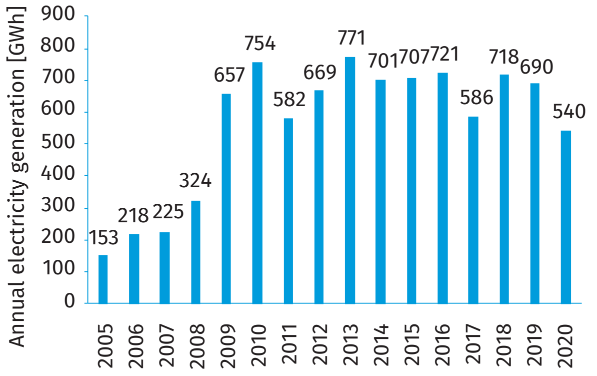
Source: *WSHPDR 2019*,[4] DAPEEP,[13] *WSHPDR 2013*,[25] *WSHPDR 2016*[26]

Note: Data for SHP up to 15 MW.

In 2009, the installed SHP capacity was approximately 182 MW, indicating a gradual increase of approximately 7 MW per year and corresponding to a construction of 5–10 new SHP plants annually. The same year, only 95 MW out of the total installed SHP capacity corresponded to projects with a capacity of more than 5 MW, while 37 MW were composed of mini- and micro-hydropower projects with an installed capacity of less than 1 MW.[21,22,23]

Annual electricity production from SHP increased from 153 GWh in 2005 to 754 GWh in 2010 and has experienced moderate fluctuation in subsequent years. In 2020, generation from SHP decreased to 540 GWh due to the prevalent dry weather conditions. The evolution of annual generation from SHP plants between 2005 and 2020 is displayed in Figure 4.[24] The estimated average load factor of SHP projects varied between 25 per cent in 2020 and 35 per cent in 2019, almost twice the corresponding value of large hydropower plants in the same period.

Figure 4. **Annual Small Hydropower Generation in Greece between 2005 and 2020 (GWh)**



Source: Sakellari et al.[24]

A large portion of the water resources in Greece is concentrated in the western and northern parts of the mainland, along with the majority of existing hydropower plants including SHP plants. Large numbers of SHP plants in Greece are located in Central Macedonia (exploiting the abundance of rivers in the region) and Epirus (owing to its rugged terrain), as well as in Western Greece. As of December 2020, 54.0 MW of SHP were installed in Central Macedonia, 46.9 MW in Epirus, 47.6 MW in Western Greece, 32.9 MW in Sterea (Central Greece), 27.9 MW in Thessaly, 24.8 MW in Western Macedonia, 6.2 MW in the Peloponnese and approximately 4.7 MW in East Macedonia-Thrace, Attica and Crete.[21,22,23]

The national SHP installed capacity target for 2030 is 350 MW. As of 2020, new SHP projects awaiting implementation in Greece totalled 70 MW. The total SHP installed capacity was expected to increase by approximately 10 MW by the end of 2021.[27,28] A partial list of existing SHP plants in Greece is displayed in Table 1, while lists of selected ongoing SHP projects and potential SHP sites are displayed in Tables 2 and 3, respectively.

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

Location	*Municipality*	*Capacity (MW)*
Ardeutiki Dioryga of River Aliakmonas (Makrochori)	Veroia	10.80
Exodos Siraggas Leontariou	Sofades	10.00
River Louros	Arta	8.70
Exodos Siraggas Mornou	Delfoi	8.50
SHP Paliouri	Zitsa	7.40
SHP Klimatias	Zitsa	7.40
Kleideres of Rema Platanias	Argithea	6.85
Eleoussa	Chalkidona	6.60
Bridge Floka Alfeios	Ancient Olympia	6.59
River Acheloos - Army Region	Agrinio	6.20
River Glafkos - Zoupata Souliou	Patra	5.50

Location	*Municipality*	*Capacity (MW)*
Roufrachti - Kerkini	Irakleia	5.00
River Smiksiotikos	Grevena	4.95
River Inachos	Makrakomi	4.50
River Aliakmonas - Abbey of Ilarionas	Kozani	4.20
River Kalamas	Filiata	4.20
Rema Malakassiotiko	Meteora	4.18
Asprorema	Almopia	4.10
Gkoura (Smiksi - Plagia - Agia Triada)	Central Tzoumerka	3.90
River Glafkos - Roufraktis	Patra	3.70

Source: Greek Association of Small Hydropower Plants,[20,27] DAPEEP[28]

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

Location	*Municipality*	*Capacity (MW)*
River Louros - Preveza	Arta	8.70
Makrochori II	Apostolos Pavlos	4.84
Smokovo II	Tamasio	3.20
Vermio	Veroia	1.80

Source: Greek Association of Small Hydropower Plants,[27] DAPEEP[28]

Note: Data as of 2021

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

Location	*Municipality*	*Potential capacity (MW)*	*Status*
Ladonas	Gortynia	10.00	Feasibility study completed
Kalamas	Souli and Filiata	5.80	Feasibility study completed
Ilarionas	N/A	4.00	Feasibility study completed
Chelidonou	Acharnes - Thrakomakedones	1.23	N/A
Psyttaleia	Piraeus	0.35	N/A

Source: Greek Association of Small Hydropower Plants,[27] DAPEEP[28]

Note: Data as of 2021

RENEWABLE ENERGY POLICY

The Government of Greece supports the expansion of RES in the domestic energy balance, in line with the EU policy on decarbonization. However, the targets established as part of this policy have been ambitious and often poorly planned, including the rapid expansion of large-scale wind power and solar power (an additional capacity of 640 MW and 930 MW, respectively, by the end of 2021). Owning to issues stemming from the current poor infrastructure of electricity networks and the negative social reactions to the establishment of large wind farms, some of the aforementioned targets may be jeopardized.[26]

Stemming from the fact that by the end of 2017 the installed capacity of solar power had reached almost 2,650 MW, exceeding the capacity targets previously set for 2020, the Government of Greece decided to limit the uncontrolled dynamics of the domestic RES market by both reducing dramatically the electricity purchase price (which in 2012 was 0.5 EUR/kWh (0.6 USD/kWh)) and impose a retroactive tax of 30 per cent on revenues from solar PV plants for the years 2012 and 2013.[29] In this context, the enthusiasm of the Government for the further development of water resources for hydropower use also decreased, as large hydropower faced persistent negative reactions from local communities and SHP was not considered capable of significantly altering the foundations of the national energy mix.[26]

In 2016, the Parliament of Greece approved a new law (Law 4414/2016) on the RES sector. The new law allows feed-in premium (FIP) schemes, competitive tenders and virtual net metering. While virtual net metering was allowed for any type of RES, access to it was limited to certain institutions such as city and regional councils, educational institutions, farmers and farming associations.[30] The previously active FIT scheme closed on 31 December 2015 and was replaced by the aforementioned law. The Government additionally granted priority to RES with regards to the use of the grid.

Law 4425/2016, regulating the MoEE alongside other Ministries, was amended by Law 4512/2018 with provisions establishing the following four markets: the wholesale market of forward electricity products (renamed the “energy financial market”), the Day-Ahead market, the Intraday market and the Balancing Market. Another key provision of the amended law was the establishment of the Hellenic Energy Exchange (“HEnEx”). Under this framework, the wholesale electricity market model (referred to as the “target model”) was introduced, aiming to gradually harmonize different national electricity markets so that a unified EU electricity market can be realized. The final stage of the integration of RES units into the target model in Greece was expected to begin at the end of 2021. Under the provisions of Law 4512/2018, the IPTO will be responsible for managing the markets and balancing the system in real time, preparing the ground for new energy trading procedures and having a significant impact on the methods used to calculate final electricity costs.[31]

COST OF SMALL HYDROPOWER DEVELOPMENT

Although SHP projects in Greece are not associated with significant environmental problems or negative social reaction as is often the case with large hydropower plants, there is also no significant state support for SHP development.[32] The initial development cost of an SHP plant ranges from 0.8 million EUR/MW to 1.5 million EUR/MW (0.94–1.76 million USD/MW) with the typical price corresponding to 1 million

EUR/MW (1.17 million USD/MW).[33,34] In its turn, the relevant annual operation and maintenance (O&M) cost is estimated at approximately 1–2 per cent of the corresponding turnkey cost for SHP plants with an installed capacity under 10 MW.

During the previous decade, state subsidies for SHP projects accounted for up to 40 per cent of the initial capital for new SHP projects.[33] Nowadays, although there are still state incentives for the implementation of new SHP projects, prices for the purchase of electricity produced from SHP are low. However, SHP projects are still considered a financially efficient investment option, as attested to by the current high investment interest.

EFFECTS OF CLIMATE CHANGE ON SMALL HYDROPOWER DEVELOPMENT

During dry years the generation of electricity from SHP in Greece has fluctuated considerably and has been on a decreasing trend since 2018 despite the growth of total installed SHP capacity. However, the future impact of climate change on Greece is uncertain. Although the length of the dry season is expected to increase over the course of the next century by as many as 40 additional days, the volume of surface runoff is also projected to increase by 16–30 per cent.[2] Greater instability in the water supply to hydropower plants can thus be expected. Additionally, hydropower development is already facing significant negative attention from local communities and environmental groups and is likely to fall under increased scrutiny if access to water resources becomes less secure, especially in cases of competing priorities in water resources allocation such as the Acheloos water transfer project.[2]

BARRIERS AND ENABLERS FOR SMALL HYDROPOWER DEVELOPMENT

Some of the major factors decelerating expansion of SHP in the electricity market of Greece include the following:

- Lengthy administrative procedures for obtaining the licensing required for SHP construction, usually taking up to three years;
- The absence of an integrated national water management plan, which allows stakeholders competing for water resources with hydropower to use informal means and political influence to secure their access to these resources at the expense of SHP;
- Lack of interest in investment in SHP from large developers due to low profit margin; development is thus driven primarily by small companies which face challenges including limited budgets, expertise and knowledge of the SHP sector.

The main enabling factor for SHP development in Greece is the substantial undeveloped SHP potential, especially in certain regions of the country. Policy developments that could support the realization of this potential include the adoption of a careful and fair national water management plan that would balance the interests of all stakeholders in the water use sector, as well as integrated strategic plans for the development of SHP cascades on a single water course, which would allow for economies of scale to increase the economic efficiency of the construction of each individual site and attract the interest of large investors and developers.

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Italy

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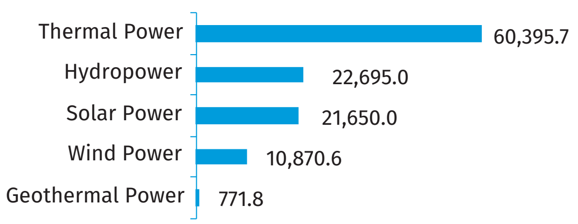
KEY FACTS

Population	60,244,639 (2019)[1]
Area	302,068km^2 [2]
Topography	The territory of Italy is mostly mountainous. The Alps form the northern boundary of the country and the Apennine Mountains stretch north to south along the length of the Italian Peninsula. The largest plain is the Po Valley (71,000 km^2) and the highest peak is Mont Blanc (4,810 metres above sea level).[3]
Climate	Northern Italy experiences cold winters and hot and humid summers. Winters in central Italy are milder, while very hot summers and very mild winters predominate in the south and on the islands. Average temperatures are from 3 °C (north) to 14 °C (south) in January and from 28 °C (north) to 30 °C (south) in July.[3]
Climate Change	An increase in temperature of up to 2 °C over the period 2021–2050, relative to the period 1981–2010, is expected due to climate change. In the worst-case scenario, the temperature increase may reach 5 °C. Summer precipitation will decrease in the central and southern regions, whereas intense precipitation events are projected to increase. Across all scenarios, the number of hot days and periods without rain will increase.[4]
Rain Pattern	Mean annual rainfall in Italy is approximately 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.[3]
Hydrology	There are approximately 1,200 rivers in Italy, but they are generally shorter than in other European countries 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.[3]

ELECTRICITY SECTOR OVERVIEW

Total net installed electricity capacity in Italy amounted to 116,383.1 MW as of 2020, with thermal power accounting for 60,395.7 MW (52 per cent of the total), hydropower for 22,695.0 MW (20 per cent), solar power for 21,650.0 MW (19 per cent), wind power for 10,870.6 MW (9 per cent) and geothermal power for 771.8 MW (1 per cent) (Figure 1).[5]

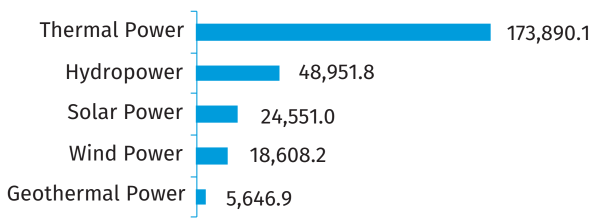
Figure 1. **Installed Electricity Capacity by Source in Italy in 2020 (MW)**



Source: Terna[5]

Net electricity generation in 2020 equalled 271,648.0 GWh, including 173,890.1 GWh (64 per cent of the total) from thermal power, 48,951.8 GWh (18 per cent) from hydropower, 24,551.0 GWh (9 per cent) from solar power, 18,608.2 GWh (7 per cent) from wind power and 5,646.9 GWh (2 per cent) from geothermal power (Figure 2).[6] Small hydropower (SHP) (0–10 MW) accounted for approximately 26 per cent of gross hydropower generation in 2020. Over the last decade, hydropower generation has fluctuated considerably, from a high of 58,545.4 GWh in 2014 to a low of 36,198.7 in 2017.[7]

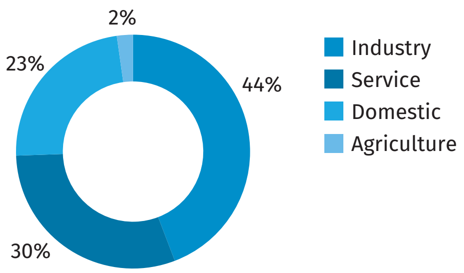
Figure 2. **Annual Electricity Generation by Source in Italy in 2020 (GWh)**



Source: Terna[6]

Minimum and maximum grid load observed in 2020 reached 17,896 MW and 55,166 MW, respectively.[8] The maximum annual grid load in recent years has moved from the winter period to summer, due to the increasing use of air conditioning in the summer. Electricity consumption in 2020 amounted to 283,814.5 GWh, exceeding generation. Imports of electricity the same year totalled 39,789.9 GWh. Domestic consumption was dominated by the industrial sector at 125,417.3 GWh (44 per cent of the total), followed by the service sector at 85,875.0 GWh (30 per cent), the domestic sector at 66,211.6 GWh (23 per cent) and the agriculture sector at 6,310.5 GWh (2 per cent) (Figure 3).[6] Access to electricity in Italy is 100 per cent.[9] However, the existing transmission and distribution networks suffer from congestion at several points. With transmission and distribution losses in 2020 amounting to approximately 3 per cent of gross generation, investments are needed to improve the aging energy infrastructure in order to increase the efficiency and resilience of the networks and to secure power supply for users.[6]

Figure 3. **Share of Electricity Consumption by Sector in Italy in 2020 (%)**



Source: Terna[6]

As a result of liberalization of the energy market, the production, transmission and distribution of electricity In Italy are managed by different companies. These sectors are regulated by the Authority of Electricity and Gas (AEEG, Law 481/1995) and competition is encouraged. Terna S.p.A. is the Transmission System Operator (TSO) and owns 99.7 per cent of the National High-Voltage Transmission Grid, which spans 72,844 kilometres. Since 2014, 11 other companies have been involved in low-voltage grid management at the regional scale. The number of companies generating electricity stood at 16,109 in 2020, an increase of over 3 per cent relative to the 15,579 generation companies operating in 2019. Finally, 12 large companies are active in the distribution subsector. In particular, E-distribuzione S.p.A. accounted for both the largest share of electricity provided to domestic and industrial users (85 per cent) and the share of users provided with electricity (85 per cent).[10]

The regulated wholesale electricity market in Italy was introduced in 2004. The electricity market, commonly called the Italian Power Exchange (IPEX), enables producers, consumers and wholesale customers to enter into hourly electricity purchase and sale of 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, the intraday auction market (MI) based on seven sessions and a platform for ancillary services (MSD) in collaboration with the TSO. In 2019, retail electricity prices in Italy for domestic users were on average 233 EUR/MWh (270.6 USD/MWh) and 96 EUR/MWh (111.5 USD/MWh) for industrial users.[11,12]

The long-term plans of Italy for the development of the energy sector are focused on the reduction of reliance on fossil fuels for electricity production and improving the security of the energy supply, which in the case of Italy is highly sensitive to the global political instability (for example, the Libyan civil war resulted in a 32 per cent reduction of oil imports by Italy from Libya). Consequently, the diversification of energy sources and the promotion of renewable energy sources (RES) are key national objectives.

SMALL HYDROPOWER SECTOR OVERVIEW

Italy is one of the three major producers of hydropower in Southern Europe. The development of hydropower in Italy in the 20th century was dominated by the construction of conventional plants that rely on large dams (reservoir-type hydropower), which induce changes in the landscape and significant alteration of river flow. However, conventional reservoir-type hydropower plants are close to saturation in the country. The remaining unexploited hydropower potential is thus mainly represented by SHP and by the modernization of the existing plants, including reservoir-type plants, in order to satisfy the targets of the Integrated National Energy and Climate Plan.[13] The SHP sector has become increasingly important during the last decade thanks to government policies that have fostered the installation of new SHP plants and have resulted in an expansion of SHP development exceeding expectations.

SHP plants in Italy are classified according to their minimum and maximum capacity:

- Micro-hydropower: P < 0.1 MW;
- Mini-hydropower: 0.1 MW ≤ P < 1 MW;
- SHP: 1 MW ≤ P < 10 MW.

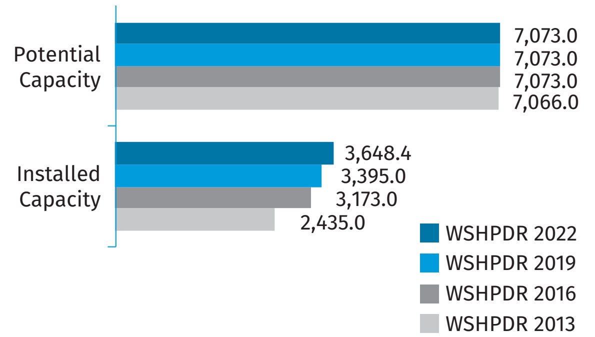
The gross hydropower generation potential in Italy, calculated on the basis of hydrological and topographical factors, is estimated at approximately 200 TWh/year, of which 38 TWh/year is accounted for by SHP. Net hydropower potential, based on technical and economic feasibility of hydropower development as well as the potential of existing plants, is estimated at approximately 50 TWh/year, which is also the annual hydropower generation target set by the National Energy Strategy of Italy (2017) for 2030. This goal will be realized primarily by supporting the renovation of large hydropower plants (some of which were built 100 years ago) as well as the construction of SHP plants.[14] Estimates of the technical SHP generation potential range between 12.5 TWh and 20 TWh, while potential SHP capacity, including currently operational plants, is estimated at 7,073 MW.[3,15]

As of 2020, there were 3,271 micro- and mini-hydropower (up to 1 MW) plants in operation in Italy with a cumulative installed capacity of 902.1 MW, in addition to 922 SHP (1–10 MW) plants with a cumulative installed capacity of 2,746.3 MW. The total installed capacity of all SHP plants up to 10 MW in 2020 was thus 3,648.4 MW, indicating an increase of approximately 2 per cent over the previous year's total of

3,575.1 MW.[5] SHP plants (up to 10 MW) produced a total of 12,195 GWh in 2020.[7]

Relative to the *World Small Hydropower Development Report (WSHPDR) 2019*, the installed capacity of SHP in Italy has increased by over 7 per cent, owing to the rapid development of SHP in the country in recent years. Thus, since 2018, 576 new micro-, mini- and small hydropower plants were constructed, representing a nearly 16 per cent increase. The estimate of potential capacity of SHP in Italy has remained unchanged due to lack of current and accurate survey data (Figure 4).[3] A list of 20 recently constructed SHP plants is displayed in Table 1.

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



Source: Terna,[5] *WSHPDR 2019*,[3] *WSHPDR* 2016,[15] WSHPDR *2013*[16]

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

Plant Name	*Location*	*Capacity (MW)*	*Head*	*Plant type*	*Operator*	*Launch year*
Badia	Mella River	0.280	3.6	N/A	INIZIATIVE MELLA S.R.L.	2021
OP Monte Argento	Nera River	0.100	7.0	N/A	ERG HYDRO S.P.A.	2021
Bassana	Mella River	0.280	2.1	N/A	INIZIATIVE MELLA S.R.L.	2020
Calcagna	Mella River	0.170	1.4	N/A	INIZIATIVE MELLA S.R.L.	2020
Urago DMV	Oglio River	0.330	3.2	N/A	IN.BRE. S.P.A.	2020
Palosco DMV	Oglio River	0.290	5.7	N/A	IN.BRE. S.P.A.	2020
Exilles	Galambra Creek	2.490	508.0	N/A	SIMI S.R.L.	2019
Turano DMV	Turano River	0.100	49.6	N/A	ERG HYDRO S.P.A.	2019
Santa Maria Magale	Nera River	0.300	4.3	N/A	ERG HYDRO S.P.A.	2019
Moncalieri	Piemonte	4.500	N/A	Run-of-river	IREN ENERGIA S.P.A.	2015
Casnigo	Lombardia	5.265	N/A	Run-of-river	ENERCOS SPA	2012
Marebbe - Enneberg	Trentino Alto Adige	0.736	N/A	Run-of-river	OFF.ELETT. S.VIGILIO DI MAREBBE SPA	2012
Valdagno	Veneto	0.160	N/A	Run-of-river	IMPIANTI AGNO SRL	2011
Recoaro Terme	Veneto	0.132	N/A	Run-of-river	IMPIANTI AGNO SRL	2011
Posina	Veneto	0.070	N/A	Run-of-river	IMPIANTI ASTICO S.R.L.	2011
Valle Aurina - Ahrntal	Trentino Alto Adige	7.968	N/A	Run-of-river	AURINO ENERGIA SRL	2011
Vignola	Emilia Romagna	1.050	N/A	Run-of-river	CENTRO-ELETTRICA SPA	2011
Brennero - Brenner	Trentino Alto Adige	0.400	N/A	Run-of-river	COOPERATIVA CENTRALE ELETTRICA FLERES SOC. COOP. A R.L.	2011
Bellano	Lombardia	4.580	N/A	Run-of-river	HYDRO ENERGY POWER S.R.L.	2011
Monno	Lombardia	3.520	N/A	Run-of-river	AZIENDA ELETTRICA OGLIOLO SRL	2011

Source: Frosio Next[18]

Gestore dei servizi energetici S.p.A (GSE) is the organization responsible for regulating the RES sector in Italy. Among other functions, it issues authorizations for construction of new plants based on RES, including SHP plants. In 2019, 239 SHP plants were authorized, for a total installed capacity of 103.6 MW, an average capacity of 430 kW per plant (Table 2).[19]

Table 2. **Small Hydropower Plant Authorization Procedures in Italy in 2019**

GSE procedure	*Total installed capacity (MW)*	*Number of plants*	*Average plant capacity (MW)*
1	21.5	5	4.30
2	10.0	77	0.13
3	3.1	6	0.52
4	2.5	1	2.50
5	14.7	3	4.90
6	10.0	91	0.11
7	1.6	3	0.53
8	23.1	5	4.62
9	16.2	46	0.35
10	0.9	2	0.45
Total	**103.6**	**239**	

Source: GSE[19]

One of the ongoing trends in SHP development in Italy is the installation of hydropower plants on water distribution networks, especially in aqueducts. In 2020, 24 SHP plants to be installed on aqueducts were authorized for construction, with a total installed capacity of 3.26 MW.[20] A list of several plants authorized for construction on aqueducts in 2020 is provided in Table 3.

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

Location	*Capacity (kW)*	*Plant type*	*Developer*	*Authorization year*
Magasa	42.36	Aque-duct	Comune di Magasa	2020
Berzo Demo	49.95	Aque-duct	Comune di berzo Demo	2020
Erice	54.00	Aque-duct	Siciliacque spa	2020
La Thuile	64.70	Aque-duct	Comune di La Thuile	2020
Salbeltrand	79.00	Aque-duct	Comune di Civ-io Lombardia	2020

Source: GSE[20]

Note: As of 2020.

SHP growth in Italy has been driven by comprehensive feed-in tariffs (FITs) introduced in 2008, set at 0.22 EUR/kWh (0.26 USD/kWh) for 15 years, with subsequent modifications.[21] For hydropower plants up to 1 MW, the FIT is an alternative to Green Certificates (GC), while hydropower plants above 1 MW receive both the incentive and the GC.[14,22] The GC, which conventionally certifies the production of 1 MWh of renewable energy, is issued by the GSE at the request of the owner of a plant powered by an RES and is a negotiable share with a value of 1 MWh. These incentives have been effective at promoting the construction of new SHP plants. However, the Government of Italy, which has borne the financial cost of these incentives, has recently started a gradual reduction of FITs for SHP.

The current FITs are set by the Renewable Energy Source (FER) Decree of 2019. While the FIT rates under the new decree are significantly lower compared to the previous rates (a reduction of between 15 per cent and 65 per cent depending on the installed capacity), the duration of the contract is longer by 5–15 years, providing additional security to potential investments. The FIT rates for SHP under the new decree are provided in Table 4.[21]

Although it is still an important source of electricity, substantial additional development of hydropower in Italy is not expected in the coming years. The Government's plan for large hydropower mainly involves the refurbishment of existing plants. Construction of new large plants is constrained by the absence of suitable sites and by the extensive environmental impact expected from such projects, which is difficult to mitigate in a densely-populated country such as Italy. Likewise, SHP development is also not expected to expand despite the significant unexploited potential, with wind and solar power likely to take the lead in RES development in the coming years.

Table 4. **Feed-in Tariffs for Small Hydropower Plants in Italy in 2019**

Category	*Feed-in tariff in EUR/MWh (USD/MWh)*	*Duration (years)*
Run-of-river plants:		
1 < P ≤ 400 kW	115 (118)	20
400 < P ≤ 1,000 kW	110 (133)	25
P > 1,000 kW	80 (97)	30
Reservoir plants:		
1 < P ≤ 1,000 kW	90 (109)	25
P > 1,000 kW	80 (97)	30

Source: GSE[21]

At the same time, Italy has been and remains a global center of research on hydropower, with a particular focus on SHP. Due to the wide-spread diffusion of old mills, research on water wheels has been very active at the Polytechnic University of Turin, and water wheels have proven to be effective and fish-compatible hydropower converters for very low-head sites, typically below 30 kW[23,24]. For high-head sites, the research conducted at the University of Padua is worth mentioning on Pelton turbines, while studies on Cross Flow turbines have taken place at the University of Palermo.[25,26] The hydrological aspects of hydropower operation, eco-hydraulic studies on fish passages and plant sustainability are also under investigation at various institutions.[27,28,29] Efficient and innovative technologies are also being developed by private companies, especially for SHP plants on low-head sites and aqueducts. Examples include the VLH turbine and the Mariucci turbine.[30]

Several research projects ongoing as of 2021 include the RIBES project on river flow regulation and fish behaviour in hydropower contexts and the RELAID project on dams. The University of Perugia is cooperating with industry on sediment dilution studies, while the University of Salerno is testing rainwater-powered pico-Pelton turbines to be used for domestic purposes (Rain Eco Power).[31] Finally, the University of Naples is working on the REDAWN project focused on turbines in water distribution networks.[32]

The expansion of the RES sector as a whole, in line with the European Union (EU) and international targets, may prove beneficial to system integration (between electricity, hydropower and gas systems in particular), which should be implemented on a trial basis, including with a view to researching the most efficient long-term storage methods for renewable energy. The National Energy and Climate Plan (NECP) of Italy estimates that the number of permanent staff in the field of hydropower development is likely to grow from 15,294 in 2017 to 16,380 in 2030.[13]

RENEWABLE ENERGY POLICY

In 2019, Italy submitted a 10-year Integrated NECP under the terms of EU Regulation 2018/1999 on the Governance of the Energy Union and Climate Action. Based on its NECP, Italy intends to accelerate the transition from traditional fuels to RES by promoting the gradual phasing out of coal for electricity generation in favour of an energy mix based on a growing share of RES and, for the remainder, gas-fired thermal power.[13] Making this transition a concrete reality requires the planning and construction of replacement plants and the necessary infrastructure.

Italy is committed to the reductions of greenhouse gas emissions, agreed to at the EU and the international level. For those sectors covered by the EU Emissions Trading System (EU ETS)—primarily the thermoelectric sector and energy-intensive industries—measures adopted in pursuit of emissions reduction include the phasing out of coal by the end of 2025, contingent upon replacement plants and necessary infrastructure being constructed on schedule, a high CO_2 allowance price and a significant acceleration of RES deployment and energy efficiency measures in manufacturing processes.[13] The CO_2 allowance price on the EU ETS reached 65 EUR/ton (75.5 USD/tonne) in October 2021, more than doubling its value since October 2020.[33] The high carbon price provides a competitive advantage to hydropower and other RES in Italy as these technologies are associated with reduced greenhouse gas emissions and are thus exempt from carbon taxation.

Moreover, RES will play an important role in reaching the goal of reducing CO_2 emissions by 40–70 per cent by 2050 compared to the 2010 emissions levels. This target was established at the G7 summit in June 2015 and is expected to lead to the decarbonization of the economy of Italy over the course of the following decades. The target share of energy from RES in the gross final consumption of energy in Italy by 2030 is 30 per cent for the economy as a whole and 22 per cent for the transport sector, with the goal of entirely eliminating fossil fuels in electricity production by 2050.[13]

The FER Decree of 2019 divides power plants that can access incentives into four groups based on the plant type, RES type and category of intervention:

- Group A includes the new construction, full reconstruction, reactivation or enhancement of on-shore wind farms as well as newly-built solar photovoltaic (PV) systems;
- Group A-2 includes newly built solar PV systems whose modules are installed to replace roofs of buildings and rural structures;
- Group B includes new (greenfield) hydropower plants, those undergoing complete reconstruction (excluding plants on aqueducts) and the reactivation or upgrading of plants utilizing gas residues from purification processes;
- Group C includes plants subject to total or partial refurbishment: on-shore wind farms, hydropower plants and plants utilizing gas residues from purification processes.[21]

There are two different ways of accessing the incentives depending on the power of the plant and the group to which it belongs:

- Registration on a priority list: plants with an installed capacity greater than 1 kW (20 kW for solar PV) and less than 1 MW belonging to Groups A, A-2, B and C must be registered on a priority list;
- Participation in auctions: plants with an installed capacity greater than or equal to 1 MW belonging to Groups A, B and C must participate in auctions, through which the quota of available power is assigned in accordance with incentive levels.

An annual capacity threshold for incentives for hydropower of 80 MW has been introduced.[21]

There are two different incentive mechanisms, depending on the power of the plant:

- The All-inclusive Tariff (TO) consisting of a single tariff, corresponding to the tariff due, which also remunerates the electricity collected by the GSE;
- An Incentive (I), calculated as the difference between the tariff due and the hourly energy price, since the energy produced remains available to the operator.

For power plants up to 250 kW, it is possible to choose one of the two modes, with the possibility of switching from one mode to the other no more than twice during the entire incentive period. Plants with a power capacity greater than 250 kW, on the other hand, can only access the Incentive (I) mechanism.[21]

SMALL HYDROPOWER LEGISLATION AND REGULATIONS

SHP plants with a capacity larger than 100 kW are required to undergo a Strategic Environmental Assessment (SEA).[34] The Decree on Fisheries of 1931 sets the main regulatory framework for aquafauna in Italy, but is rarely applied. In line with this law, additional protections regulating the impact of hydropower on aquafauna are set by provincial governments rather than the national Government.[35] For example, the Piedmont Province, where many SHP plants are located, has comprehensive regulations requiring all weirs and barrages to be equipped with fish passes.[36]

COST OF SMALL HYDROPOWER DEVELOPMENT

The cost of construction for SHP plants in Italy typically range from 3,000 EUR/kW to 11,700 EUR/kW (3,463.5– 13,507.5 USD/kW). Cost for small projects (up to 1,000 kW) is typically much higher per kW than for larger projects with an installed capacity of several MW or above, particularly with regard to personnel costs.[37] Construction costs can be reduced by retrofitting and repowering existing structures.[30]

EFFECTS OF CLIMATE CRISIS ON SMALL HYDROPOWER DEVELOPMENT

According to models of future climate change, the hydropower potential in Italy is projected to decrease due to lower precipitation and water availability. Studies predict reductions in generation potential of 22 per cent by 2070 relative to the beginning of the 21st century, as well as a 30 per cent reduction in summer runoff in the Italian Alps between 2016 and 2065 and a consequent reduction of generation by run-of-river plants of approximately 3 per cent over the same time horizon.[38,39] Nevertheless, this decreasing trend is expected to be compensated for by additional generation realized through the refurbishment of existing plants. While Italy is expected to remain a key regional player in providing ancillary services, this role will be mainly fulfilled through reliance on its extensive pumped hydropower capacity.[40]

BARRIERS AND ENABLERS FOR SMALL HYDROPOWER DEVELOPMENT

The main barriers to SHP development in Italy include the following:

- The recent adoption of the new FER Decree of 2019 has significantly decreased FITs for SHP compared to 2016. Payback periods have consequently been extended, which is likely to discourage investors.
- The authorization process in Italy takes 2–3 years on average. Permits (water concessions, construction licenses, etc.) are granted by different departments. Moreover, there is no substantial difference between the water concession for SHP and for 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 authorization process.
- Social mobilization against SHP is increasing in Italy, especially in the northern part of the country (the Alps). Even though the impact of SHP on aquatic ecosystems and local communities is smaller compared to large dams, it is not insignificant when the ratio of generated power to impact is taken into account, as well as the cumulative impact of SHP cascades located along a single watercourse There are examples of new SHP plants that have been stopped or whose construction was delayed because of this opposition.

Enabling factors for SHP development in Italy include:

- A well-developed incentive system, albeit with reduced benefits;
- Untapped small hydropower potential, e.g. at existing barriers, old mills and in aqueducts;
- Extensive local industrial and scientific capacity for innovative SHP projects;
- Despite the recent negative perception of SHP among some parts of the population, many examples of sustainable SHP projects exist in Italy, such as the rehabilitation of historic mills, and the installation of SHP plants on existing structures such as previously non-powered dams, water distribution networks and navigation locks, that significantly reduce any additional impacts. There are likewise examples of SHP projects that have generated benefits and income flows for local communities, such as those in the Valle Maira (Piedmont) region.[30]

Given the recent expansion of SHP plants in Italy and the disturbance on riverine ecosystems, an emphasis must be placed on combining the energy/financial needs of various stakeholders with environmental preservation. The SHP technology is likely to gain a higher social value in the next decades if the environmental and hydrological footprint associated with the hydropower exploitation of surface water takes a higher priority in civil infrastructure planning. Furthermore, the hidden potential in existing infrastructures and facilities should be considered.[41]

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Montenegro

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KEY FACTS

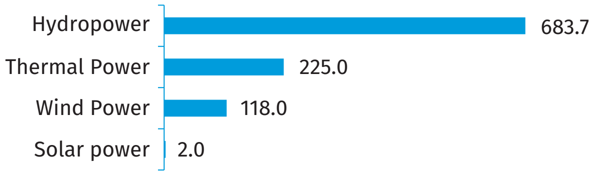
Population	622,028 (2019)[1]
Area	13,810 km^2[2]
Topography	The northern part of Montenegro is dominated by high mountains, descending through the central part with large depressions, ending in a coastal plain varying in width from several hundreds of metres to several kilometres from the coast. The lowest part of the central inland area are the valleys of the Zeta River, comprising the Zeta-Bjelopavlići Plain. The Tara River Gorge is the lowest canyon in Europe, with a depth of 1,300 metres. The mountain ranges in the north include 37 peaks with heights above 2,000 metres. One of the highest peaks is the Bobotov Kuk, reaching 2,523 metres.[2]
Climate	The southern region of Montenegro has a Mediterranean climate, with hot and dry summers and relatively rainy winters. The central and northern regions have the characteristics of a mountainous climate, although the influence of the Mediterranean Sea is also evident. The highest average temperature is in July with 18.9 °C and the lowest is in January with −1.5 °C.[3]
Climate Change	Climate projections indicate that by 2040, the annual temperature will increase by 1.5-2 °C throughout the country. By 2070, the average annual temperature will rise by up to 3 °C, while the projected increase by 2100 is 5.5 °C. The annual average rainfall is expected to decrease, especially during the summer months, coupled with an increase in precipitation in the winter months in some parts of the country. It is expected that by 2070 the average annual rainfall will be reduced by 20 per cent over the entire territory.[3]
Rain Pattern	Annual precipitation across the country is very irregular, ranging from approximately 800 mm in the far north to approximately 5,000 mm in the far south. The mean annual precipitation in the country is 1,138 mm. Rainfall is the highest in November, with an average of 123 mm. It is the lowest in August, with an average of 66.3 mm.[4]
Hydrology	The main rivers within the Adriatic Sea basin are the Morača, Zeta, Cijevna and Bojana; and within the Danube River basin they are: the Piva, Tara, Lim, Ibar and Ćehotina. The largest onshore surface water body is Lake Skadar, which is shared between Montenegro and Albania.[4]

ELECTRICITY SECTOR OVERVIEW

The main energy resources used in Montenegro for producing electricity are hydropower and thermal power from coal, with some wind power capacity as well. According to the latest report from the Energy Regulatory Agency, in Montenegro there was 1,028.7 MW of installed capacity in 2019. Of the total, hydropower plants accounted for 683.7 MW of installed capacity, thermal power for 225.0 MW, wind power for 118.0 MW and solar power for 2 MW (Figure 1).[5,6,7] Since 2013, installed capacity increased by 96.0 MW. The hydropower capacity comes from two large plants, Piva (342 MW) and Perucica (307 MW), as well as 23 small hydropower (SHP) plants (34.7 MW).

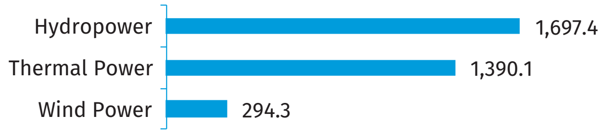
In 2018, the production of electricity amounted to 3,743.90 GWh, which is in the highest level reached within the previous 10-year period. Compared to the average generation achieved over the past decade, electricity generation in 2018 increased by almost 21 per cent. This resulted in a 15 per cent higher generation than planned, with hydropower exceeding the planned generation by almost 22 per cent. In 2018, renewbale generation made up 61 per cent of the toal, including 57 per cent (2,138.14 GWh) from hydropower.[5] In 2019, electricity generation reached 3,381.8 GWh, of which 59 per cent was from renewable energy sources (Figure 2).

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



Source: Energy Regulatory Agency,[5,7] Balkan Green Energy News[6]

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



Source: Energy Regulatory Agency[7]

Montenegro has a 100 per cent electrification rate. As a candidate country for the European Union (EU) accession and a contracting party of the Energy Community Treaty, it has an obligation to follow EU policy for energy and environment. The Energy Law (2016) is fully in line with the Third Energy Package, as well as its bylaws.[8]

The main electricity generator in Montenegro is Elektroprivreda Crne Gore (EPCG). In July 2017, a former strategic partner with the Government, Italian company A2A, initiated a withdrawal procedure by exercising the put option after its contract expired on 1 July 2017. The Government decided to purchase A2A shares, increasing its ownership stake to 88.6 per cent in total. In 2009, Crnogorski elektroprenosni sistem (CGES) was established, becoming the independent transmission system operator, and in 2016 the Crnogorski elektrodistributivni sistem (CEDIS) was established, becoming the independent distribution system operator. This has unbundled the transmission and distribution responsibilities from EPCG.

The electricity network of Montenegro consists of transmission and distribution capacities, which include: high (HV), medium (MV) and low voltage (LV) power lines, as well as transformer stations. 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 was put into operation at the end of December of 2019 (Trans-Balkan Corridor Project).[9] It connects 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 enabled 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 the neighbouring systems of Serbia (two 220 kV lines and one 110 kV line), Bosnia and Herzegovina (one 400 kV line, two 220 kV lines and two 110 kV lines), Albania (one 400 kV line and one 220 kV line) and Kosovo (one 400 kV line).[7]

Due to the complexity and large area occupied by the distribution system, the Montenegro territory is divided into seven regions. 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. According to the data available for 2019, the total length of the distribution network was 19,561.4 km. The distribution system is in its final phase of replacement of the old electricity meters with smart meters, which can provide a real-time data exchange with the data centre. Additionally, the reconstruction of a LV 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 15.6 per cent in 2016 to 13.2 per cent in 2019.[7]

The electricity market of Montenegro was opened based on the decisions of the Energy Regulatory Agency (RAE) and the Energy Law of 2003. Since 2017, the electricity prices for small customers and households are determined by the Energy Law of 2016 (Table 1). All other customers must either buy electricity from the market or choose a supplier. The retail price for distributed consumer categories is calculated based on the active electricity, the engagement of the transmission and 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.

In 2019, the average realized price of electricity, which includes the fee for encouraging renewable energy sources for customers connected to the distribution system, was 0.091 EUR/kWh (0.11 USD/kWh) (excluding VAT). On 1 June 2019, the Government passed a decree on a fee for stimulating the production of electricity from renewable sources and highly efficient cogeneration, which abolished the fee for encouraging renewable energy sources for customers whose consumption is less than 300 kWh.[7]

Table 1. **Regulated Electricity Tariffs in Montenegro as Defined by Energy Law of 2016**

Consumption category	*Price (EUR/kWh (USD/kWh))*
35 kV	0.05 (0.06)
10 kV	0.07 (0.09)
Distribution customers at 0.4 kV whose power is measured	0.10 (0.12)
Distribution customers at 0.4 kV whose power is not measured, two-tariff measurements	0.08 (0.10)
Distribution customers at 0.4 kV whose power is not measured, one-tariff measurements	0.10 (0.12)

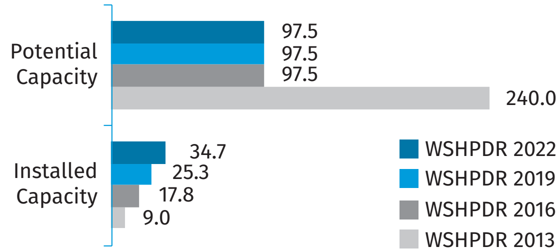
Source: Electricity Regulatory Agency[10]

SMALL HYDROPOWER SECTOR OVERVIEW

In Montenegro, SHP is defined as hydropower plants with installed capacity of less than 10 MW. At the end of 2019 there were 23 SHP plants in operation, from which 7 are 30 or more years old and 16 were built in the last 10 years. As a result, in 2019, the overall installed SHP capacity was 34.74 MW with annual generation of 80.34 GWh.[7] Compared to the

World Small Hydropower Development Report (WSHPDR) 2019, the installed capacity increased by approximately 37 per cent, with the change being due to recently concluded 36 concession contracts for 55 new SHP sites (Figure 3). A total of EUR 13 million was put aside for these contracts in 2018, with a further EUR 30 million allocated for 2019.[15] The potential capacity figure compared to the *WSHPDR 2016* and *WSHPDR 2019* has remained unchanged.

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



Source: Energy Regulatory Agency,[7] *WSHPDR 2013*,[11] *WSHPDR 2016*,[12] *WSHPDR 2019*[13]

The development of the power system in Montenegro in the 20th century, in addition to the construction of large power plants, was marked by the construction of SHP plants. Since 2013, after a break of almost 24 years, a new stage of intensive SHP construction has begun with the introduction of incentive measures for the use of renewable energy sources (Table 2). From then until the end of 2019, 16 SHP plants were put into operation, which increased the total projected utilization of the hydropower potential of smaller watercourses to approximately 0.108 TWh.[14] Fifty-five further SHP projects are under development (Table 3).[15]

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

Name	*Location*	*Capacity (MW)*	*Head (m)*	*Plant type*	*Turbine type*	*Operator*	*Launch year*
Bistrica Majstrovina	Bijelo Polje	3.06	695.5	Run-of-river	2x Francis	DOO Hydro Bistrica Podgorica	2018
Šeremet Potok	Andrijevica	0. 79	105	Run-of-river	1x Pelton	DOO Nord Energy Andrijevica	2018
Piševska rujeka	Andrijevica	1.08	360	Run-of-river	1x Pelton	DOO Igma Energy Andrijevica	2017
Babino polje	Plav	2.21	1743.5	Run-of-river	1x Pelton	DOO Kronor Podgorica	2017
Šekular	Berane	1.68	1198.5	Run-of-river	1x Pelton	DOO Hidroenergija Montenegro Podgorica	2016
Jara	Plav	4.56	2232.7	Run-of-river	2x Pelton	DOO Kronor Podgorica	2016
Bistrica	Berane	5.60	164	Run-of-river	2x Pelton	DOO Hidroenergija Montenegro Podgorica	2015
Rmuš	Berane	0.47	194	Run-of-river	1x Pelton	DOO Hidroenergija Montenegro Podgorica	2015
Spaljevići 1	Berane	0.65	105	Run-of-river	1x Pelton	DOO Hidroenergija Montenegro Podgorica	2015
Orah	Berane	0.95	110	Run-of-river	1x Pelton	DOO Hidroenergija Montenegro Podgorica	2015
Jelovica 2	Berane	0.62	45	Run-of-river	1x Pelton	DOO Hidroenergija Montenegro Podgorica	2015
Vrelo	Bijelo Polje	0.62	943.7	Run-of-river	1x Pelton	DOO Synergy Podgorica	2015
Bradavec	Andrijevica	0.95	250	Run-of-river	3x Pelton	DOO Igma Energy Andrijevica	2015
Jezerštica	Berane	0.84	360	Run-of-river	1x Pelton	DOO Hidroenergija Montenegro Podgorica	2014
Lijeva rijeka	Podgorica	0.11	410.8	Run-of-river	Banki	EPCG AD Nikšić	1955
Šavnik	Šavnik	0.20	26	Run-of-river	Francis	EPCG AD Nikšić	1955
Glava Zete	Danilovgrad	4.48	221.5	Run-of-river	Kaplan	DOO Zeta Energy Danilovgrad	1955
Slap Zete	Danilovgrad	1.71	7	Run-of-river	Kaplan	DOO Zeta Energy Danilovgrad	1952
Rijeka Mušovića	Kolašin	1.95	160	Run-of-river	Pelton	EPCG AD Nikšić	1950
Rijeka Crnojevića	Rijeka Crnojevića	0.65	25	Run-of-river	1x Michell–Ossberger	EPCG AD Nikšić	1948
Podgor	Cetinje	0.48	54	Run-of-river	Michell–Ossberger	EPCG AD Nikšić	1940

Source: Sekulić[15]

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

Name	*Location*	*Capacity (MW)*	*Head (m)*	*Plant type*	*Turbine type*	*Developer*	*Planned launch year*	*Stage of development*
Vrbnica	Plunica	6.50	251	Run-of-river	1x Pelton	MHE Vrbnica DOO	2021	70%
Jelovica 1	Berane	3.15	180	Run-of-river	1x Pelton	Hidroenergija Montenegro DOO	2020	90%
Mojanska 1	Andrijevica	1.78	113	Run-of-river	1x Pelton	Small Hydro Power Plant Kutska DOO	2020	90%
Kutska 1	Andrijevica	1.66	81.5	Run-of-river	1x Cross-flow	Small Hydro Power Plant Kutska DOO	2020	90%
Mojanska 2	Andrijevica	1.10	110	Run-of-river	1x Pelton	Small Hydro Power Plant Kutska DOO	2020	90%

Source: Sekulić[15]

As detailed in the Energy Development Strategy until 2030, EPCG is planning to undertake reconstruction of existing SHP plants with a combined capacity of 11.4 MW. The Strategy includes data from the 2001 Water Master Plan, which estimates the overall theoretical hydropower potential of Montenegro to be between 10.6 TWh and 10.8 TWh and the technical potential between 5.0 TWh and 5.7 TWh.[12] 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.[16] 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 stations and the quality of the equipment. Therefore, it is expected that the estimated hydropower potential on individual water streams will become more reliable.[16]

Under the National Renewable Energy Action Plan (NREAP) objectives, it was intended that by 2020, the installed capacity of SHP plants would amount to a total of 97.5 MW, with an annual generation of 287 GWh (Table 4). This would require a 280 per cent increase compared to the current installed SHP capacity. With the newly approved reconstruction projects expected to increase the installed SHP capacity to 94.8 MW, the country is close to achieving this objective.[17] Given the lack of accurate data on the total SHP potential of the country, the current chapter uses the 97.5 MW target as the minimum estimate of available SHP potential.

Table 4. **National Goals for the Construction of Small Hydropower up to 2020 in Montenegro**

Plant size	*Capacity (MW)*	*Generation (GWh)*
< 1 MW	11.2	35
1–10 MW	86.3	252
Total	**97.5**	**287**

Source: Ministry of Economy[12]

RENEWABLE ENERGY POLICY

The existing generation portfolio relies on hydropower and coal, however, the Strategy for Energy Development in Montenegro up to 2030 foresees intensive usage of wind power, solar power and biomass as well as other renewable energy sources as a priority. Hydropower is planned to remain the dominant source, with wind power contributing significantly as well. Moreover, the 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.[12] The NREAP also defines the targets for different types of renewable energy. Installed capacity from the hydropower plants was planned to total 826 MW by 2020, with an annual generation of 2,050 GWh.[13]

In Montenegro, electricity from renewable sources is supported through a feed-in tariff (FIT). The operators of plants that generate electricity from renewable sources can obtain the status of a privileged producer and thereupon acquire the right to a price support for the generated electricity under the legal requirements. Every year in January, a new incentive fee is adopted, which is applied to the end customers, who bore the costs from renewable energy sources. The amount of the incentive fee to encourage the production of electricity from renewable energy sources and cogeneration in 2018 was 0.0047 EUR/kWh (0.0057 USD/kWh). The Energy Market Operator (COTEE), who is legally obliged to buy electricity from privileged producers, pays the incentive for a period of 12 years after having concluded a formal agreement. The exact amount is determined in the Tariff System Decree and mainly depends on the type of renewable energy technology.[12]

SMALL HYDROPOWER LEGISLATION AND REGULATIONS

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. The FITs for SHP are based on the annual electricity generation and favour the construction of smaller facilities (Table 5). The same flat rate FIT is also implemented for the refurbished SHP plants.[14]

Table 5. **Feed-in Tariffs for Small Hydropower Plants in Montenegro**

Power at plant's exit (P_{PE})	*Incentive price (EUR/kWh (USD/kWh))*
P_{PE} < 1MW	0.10 (0.13)
1 ≤ P_{PE} < 3 MW	0.10 (0.13)–(0.7 * P_{PE})
3 ≤ P_{PE} < 5 MW	0.09 (0.11)–(0.24 * P_{PE})
5 ≤ P_{PE} < 8 MW	0.08 (0.10)–(0.18 * P_{PE})
8 ≤ P_{PE} < 10 MW	0.07 (0.08)

Source: Ministry of Economy[18]

Note: The first column represents the installed capacity reduced by losses from the turbine, generator and transformation. The second column shows the incentive price calculated based on the power at the plant's exit.

EFFECTS OF CLIMATE CRISIS ON SMALL HYDROPOWER DEVELOPMENT

Climate change will modify the seasonality of inflows and the annual volumes of water exploitable for hydropower generation in Montenegro, which will affect the management and revenue of hydropower plants. A decrease in the water balance in all river basins in Montenegro has been observed, and further reduction of rainfall and snowfall will drastically affect the availability of surface waters. By the end of the 21st century, the average annual flow is expected to decrease by 27 per cent. Adaptation measures should focus on the application of an integrated approach to water resources and systems management and on strengthening cross-sectoral planning and activity.

BARRIERS AND ENABLERS FOR SMALL HYDROPOWER DEVELOPMENT

Despite the measures and actions undertaken by the Government to improve the legislative and developmental processes for SHP, many obstacles for developing an attractive environment for investment still remain.

Grassroots activists in Montenegro have campaigned against hydropower, which has led to the Government entering into negotiations on the termination of contracts for the construction of seven SHP plants in four northern municipalities.[19] Furthermore, corruption allegations have been brought forward against the Prime Minister, President as of the moment of writing of this chapter, who signed a concession for the construction of an SHP plant to the company owned by his son.[20]

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

- Public opposition against hydropower, including SHP, due to environmental consequences;
- Government negotiations to terminate SHP contracts in response to public opposition;
- Recent corruption allegations regarding SHP concession contracts;
- No accurate data available on potential water flow and site capacity;
- Complex procedure for obtaining opinions and permits from numerous relevant state institutions;
- Complicated procedure of connecting to the electricity distribution network, as well as an increase in costs in the cases when the connection point is located very far from the power plant.[10,20]

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

- The need for increased security of electricity supply;
- Rise of a competitive energy market in the country;
- Potential for job creation in the less developed parts of the country through SHP projects;
- The need to increase energy efficiency.

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North Macedonia

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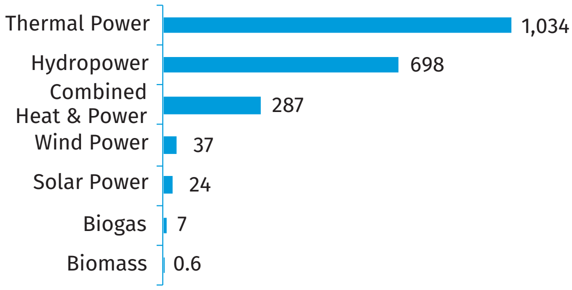
KEY FACTS

Population	2,976,255 (2019)[1]
Area	25,713 km^2[2]
Topography	North Macedonia is a landlocked country, located in the Balkan Peninsula in South-Eastern Europe. It has a mountainous territory covered with deep basins and valleys. The country is bisected by the Vardar River; there are also three large lakes, each divided by a frontier line. The highest point is Mount Korab at 2,753 metres above sea level and the lowest point lies at 50 metres above sea level at the Vardar River.[2]
Climate	The climate of North Macedonia is transitional from Mediterranean to continental. It is characterized by warm and dry summers and autumns (June–October), with July and August being the warmest months with temperatures exceeding 40 °C in some regions. Winters (December–February) are relatively cold with heavy snowfall. The coldest month is January with an average temperature of 0.3 °C. Average annual temperatures range from less than 0 °C in January to 20 °C in July and August.[3]
Climate Change	North Macedonia, as a signatory to the United Nations Framework Convention on Climate Change, has agreed to provide information on its nationally defined contributions to the objectives of the Paris Agreement.[4] The new methodology will integrate climate change into the new spatial plan.[5] It is projected that the average temperature in North Macedonia will increase by 1.0 °C in 2025, 1.9 °C in 2050, 2.9 °C in 2075 and 3.8 °C in 2100, while precipitation is expected to decrease by 3 per cent in 2025, 5 per cent in 2050, 8 per cent in 2075 and 13 per cent in 2100 in comparison with the 1961-1990 period.[6]
Rain pattern	Average annual precipitation varies between 1,700 mm in the western mountainous region and 500 mm in the eastern part of the country. The wettest months are November, December, April and May.[3]
Hydrology	In North Macedonia, there are four river basins (the Vardar, Crn Drim, Strumica and South Morava) and three natural lakes (Ohrid, Prespa and Dojran). There are 21 large reservoirs and 120 smaller reservoirs and artificial lakes. The water level in these surface waterbodies mainly depends on precipitation and snowmelt.[5] The National Hydrometeorological Service performs hydrometric measurements and observations of surface waters using 110 hydrological stations.[7]

ELECTRICITY SECTOR OVERVIEW

Electricity production in North Macedonia mainly originates from lignite and large hydropower. In 2019, the total installed capacity stood at 2,088 MW, including almost 50 per cent from thermal power, over 33 per cent from hydropower, almost 14 per cent from combined heat and power plants, less than 2 per cent from wind power, 1 per cent from solar photovoltaics (PV) and less than 0.5 per cent from biogas and biomass combined (Figure 1). Compared to 2018, the total installed capacity increased by 10.9 MW.[8]

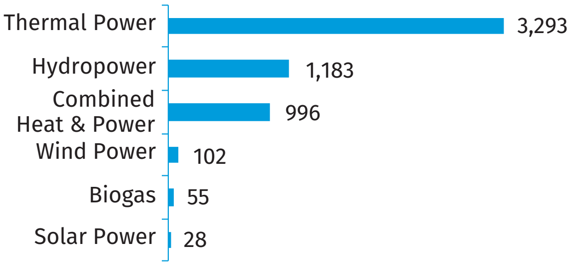
Figure 1. **Installed Electricity Capacity by Source in North Macedonia in 2019 (MW)**



Source: ERC[8]

Electricity generation in 2019 totalled 5,658 GWh. Thermal power plants contributed over 58 per cent, hydropower 21 per cent (including 263 GWh from small-scale plants), combined heat and power plants almost 18 per cent, wind power less than 2 per cent, biogas 1 per cent and solar PV 0.5 per cent (Figure 2).[8] North Macedonia is also dependent on imports for its electricity supply. In 2019, 24 per cent of electricity supply (1,826 GWh) was imported from four neighbouring countries: Serbia, Bulgaria, Greece and Albania. In 2019, 20 traders/suppliers imported electricity in North Macedonia. The Hungarian Electricity Market (HUPX) is considered a reference market for comparing the movements of the wholesale electricity market in North Macedonia. In 2019, the average import price was 54.7 EUR/MWh (64.3 USD/MWh).[8]

Figure 2. **Electricity Generation by Source in North Macedonia in 2019 (GWh)**



Source: ERC[8]

The most important renewable resource in North Macedonia is hydropower, with large hydropower accounting for 28 per cent of total installed capacity and small hydropower (SHP) for 5 per cent. The share of wind power in the country's energy mix will increase in the future, adding to the current capacity of 36.8 MW from Bogdanci, the first wind park in the country. Electricity generation from solar power plants is also increasing. Finally, several biogas plants are also in operation with a total installed capacity of 6.99 MW.[8]

Construction of the following hydropower projects is planned: Galiste (78 MW) by 2035, Globocica II (20 MW) by 2035, Veles (96 MW) by 2030, Gradec (75 MW) by 2030, Cebren (458 MW) by 2029, Vardar Valley SHP 1 plants (45 MW) by 2025, Vardar Valley SHP 2 plants (152 MW) by 2030 and other SHP projects (135–160 MW) by 2021. By 2040, additional capacities of 86 MW of wind power, 13 MW of biomass thermal power and 92.5 MW of SHP (including those under construction or with the status of a temporary preferential producer) will be built under the feed-in tariff system (FIT).[9]

The electrification rate in North Macedonia is close to 100 per cent with some remote areas still lacking access to the grid. The distribution grid is operated by EVN Macedonia, which, according to the Energy Law, is responsible for grid development and upgrading.

As a candidate country for the European Union (EU) membership and a contracting party in the Energy Community, North Macedonia is committed to applying the EU Community Acquis in domestic legislation. Thus, the Energy Law adopted in 2018 transposed the EU Third Energy Package in the electricity and natural gas sector, as well as the Renewable Energy Directive.[10]

In 2019, the electricity market of North Macedonia was fully liberalized. On the electricity market, in accordance with the Energy Law, two new entities appeared, namely the EVN HOME DOO Skopje responsible for providing electricity supply as a universal service, and the MEMO DOOEL Skopje entrusted with the organization and management of the electricity market.[10] Electricity transmission is performed by the state-owned Electricity Transmission System Operator (MEPSO). The electricity transmission system connects the larger production capacities and the country's two electricity distribution systems. The power transmission network operates at the 400 kV and 110 kV voltage levels. Electricity distribution is performed by two separate legal entities, with the distribution network covering the following voltage levels: 110 kV, 35 kV, 20 kV, 10 kV, 6 kV and 0.4 kV.[8]

The support for renewable energy sources will continue to develop in line with the Directive 2009/28/EC, which is transposed with the adoption of the Energy Law and by-laws. The Energy Law contains requirements for a competitive bidding process for FITs, which will enable support for renewable energy producers and market integration of renewable energy sources.[9] The strategy foresees further development of the distribution system network to integrate more renewable energy sources, as well as continuous improvement of the network reliability.

The electricity market reform implemented in 2019 enabled all consumers to freely choose an electricity supplier at prices and tariffs approved by the Energy Regulatory Commission.[8] Average electricity rates are shown in Table 1.

Table 1. **Average Electricity Selling Prices in North Macedonia**

Tariff type	*Average selling price (USD/kWh)*		
	2018	*2019*	*2021*
Consumers – 35 kV	0.044	0.043	0.093
Consumers – 10(20) kV	0.051	0.050	0.093
Other I level	0.059	0.057	0.075
Other II level	0.170	0.170	0.182
Households 1T	0.087	0.087	0.059
Households 2T	0.080	0.080	0.117

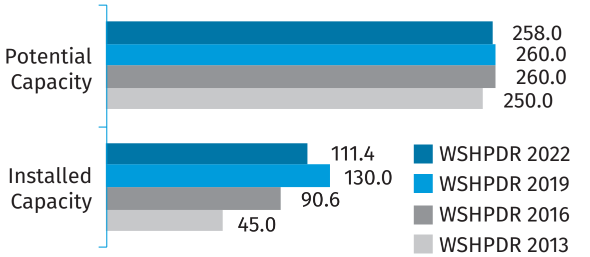
Source: ERC[8,11]

SMALL HYDROPOWER SECTOR OVERVIEW

North Macedonia defines SHP as hydropower plants with an installed capacity of 10 MW or less.

In 2019, the installed capacity of SHP in North Macedonia was 111.43 MW (5.34 per cent of the total installed capacity) from a total of 101 plants generating 263 GWh.[8] Out of the total number of SHP plants, 90 sell the produced electricity at the FIT, while the remaining 11 plants sell the produced electricity on the electricity market. SHP currently accounts for 16 per cent of the total installed hydropower capacity.[8] Compared to the *World Small Hydropower Development Report (WSHPDR) 2019*, the installed capacity decreased by 14 per cent, whereas the potential decreased only slightly, both changes being based on more accurate data (Figure 3).

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



Source: ERC,[8] Republic Committee for Energy,[12] *WSHPDR 2013*,[13] *WSHPDR 2016*,[14] *WSHPDR 2019*[15]

In 2007, a concession for the construction of SHP plants in North Macedonia began, with approximately 120 SHP projects signed until 2021. The concessions for the use of water for electricity generation are based on the DBOT model (Design–Build–Operate–Transfer). In accordance with tender documentation, water concessions are granted for a period of 23 years beginning on the day of signing of a concession agreement. The concessionaire has the right to apply for an extension of the concession period. The projects include the Vardar Valley SHP 1 project consisting of multiple SHP plants with a combined expected capacity of 45.0 MW (start year 2025), the Vardar Valley SHP 2 project with a combined expected capacity of 152.5 MW (start year 2030) as well as other SHP projects started in 2019 for a total SHP capacity (including existing plants) of a maximum of 135–160 MW (Table 2). Additionally, the capacity of the water supply systems could be used for SHP development if justified based on economic and technical aspects.[9]

Table 2. **Most Recently Commissioned Small Hydropower Plants in North Macedonia**

Name	*Location*	*Capacity (MW)*	*Head (m)*	*Turbine type*	*Operator*	*Launch year*
Topolka 315	Caska	2.160	214	Pelton	MHE Topolki Dooel Skopje	2020
Topolka	Caska	2.880	226	Pelton	MHE Topolki Dooel Skopje	2020
Kovacka 23	Makedonski Brod	0.990	123	Francis	Actuel energy group DOO Skopje	2020
Kovacka 22	Makedonski Brod	0.504	98	Francis	Actuel energy group DOO Skopje	2020
Kovacka 21	Makedonski Brod	0.504	100	Francis	Actuel energy group DOO Skopje	2020
Topolka 317	Caska	1.997	126	Francis	MHE Topolki Dooel Skopje	2019
Filternica	Bitola	0.408	52	Francis	JP Strezevo Bitola	2019
Dovledjik	Bitola	0.472	63	Francis	JP Strezevo Bitola	2019
MHEC Odrenska reka 106	Tetovo	0.360	166	Pelton	Super nuova energy DOO Tetovo	2019
MHEC Odrenska reka 105	Tetovo	0.360	135	Pelton	Super nuova energy DOO Tetovo	2019
MHE Lukar 3	Kavadarci	0.250	95	Francis	MHEC Lukar DOOEL Kavadarci	2019
MHE Lukar 2	Kavadarci	0.250	94	Francis	MHEC Lukar DOOEL Kavadarci	2019
MHE Lukar 1	Kavadarci	0.250	95	Francis	MHEC Lukar DOOEL Kavadarci	2019
MHE Gabrovska reka	Tetovo	1.800	390	Pelton	Nord energy group DOO	2019
MHE Padiska 14	Gostivar	0.480	103	Francis	MHE Padiska DOO Skopje	2019
Konska 184	Gevgelija	0.990	113	Francis	Actuel energy group DOO Skopje	2018
MHE Recica i Grmesnica	Ohrid	0.720	123	Francis	Energomont-MZT-DOO Bitola	2018
MHE Vranovska reka 312	Caska	0.792	144	Francis	MHE Topolski DOO Skopje	2018
MHE 267 Semnica`	Bitola	0.800	152	Francis	Energomont-MZT-DOO Bitola	2017
MHE so r.b. 115 na Banjanska r	Cucer - Sandevo	0.293	95	Francis	Hidroenergija s. Batinci Studenicani	2017

Source: Republic Committee for Energy,[12] ERC[16]

The Government of North Macedonia has supported the construction of SHP plants as a renewable energy source through FITs (Table 3).[17]

Table 3. **Feed-in Tariffs for Small Hydropower in North Macedonia**

Monthly quantity of distributed electricity (kWh)	*FIT (EUR/kWh (USD/kWh))*
≤ 85,000	0.120 (0.14)
> 85,000 and ≤ 170,000	0.080 (0.09)
> 170,000 and ≤ 350,000	0.060 (0.07)
> 350,000 and ≤ 700,000	0.050 (0.06)
> 700,000	0.045 (0.05)

Source: Ministry of Economy[17]

SMALL HYDROPOWER PROJECTS AVAILABLE FOR INVESTMENT

A study of SHP potential in North Macedonia was conducted in 1982. Its findings suggest the possibility to construct 406 SHP plants with a total installed capacity of 258 MW, with individual capacities ranging from 50 kW to 5 MW and an average annual electricity generation of 1,094 GWh. This study, in fact, serves as a technical base for granting concessions for SHP construction in North Macedonia.[12] Of the listed sites, approximately 100 are under concession. Table 4 shows a sample of five SHP sites from this study.

Table 4. **List of Selected Small Hydropower Sites Available for Development**

Name	*Location*	*Potential capacity (MW)*	*Head (m)*	*Type of site*
Bela reka	Crna reka	2.340	200	New
Satoka	Crna reka	0.645	115	New
Gradeshka	Crna reka	0.522	93	New
Gradeshka	Crna reka	1.000	144	New
Buturica	Crna reka	1.135	208	New

Source: Republic Committee for Energy[12]

RENEWABLE ENERGY POLICY

Increase of the share of renewable sources in the country's energy mix and improvement of energy efficiency are two of the key strategic goals set by the Government for the energy sector.[8,9,10] The support for renewable energy will continue to develop in line with the Directive 2009/28/EC, which was transposed with the adoption of the Energy Law.[10] The share of renewable sources in total electricity production in 2019 was projected to reach 23.9 per cent, however, the actual share for that year stood at 24.2 per cent.[8]

North Macedonia ratified the Paris Agreement and is also converting its legislative and regulatory framework according to the EU 2030 Climate and Energy Framework. The Intended Nationally Determined Contribution (INDC) of North Macedonia includes reduction of CO_2 emissions from fossil fuel combustion by 30 per cent (or by 36 per cent at a higher level of ambition) by 2030 compared to the business-as-usual scenario. The Law on Environment incorporates articles that stipulate general obligations and responsibilities regarding greenhouse gas inventories and the national plan for climate change action.

Renewable energy is covered in the Energy Law and relevant by-laws, including the Decree on measures to support the production of electrical energy from renewable energy sources, the Rulebook on renewable energy sources and the Rulebook for preferential producers that use a FIT.[10,17,18,19] The Strategy for Energy Development of the Republic of North Macedonia until 2040 envisages two types of financial mechanisms to support renewable energy: FITs and feed-in premiums.[9] According to the Decree on measures to support the production of electrical energy from renewable energy sources, all feed-in premiums are to be granted via a tendering procedure. The highest level of support should be achieved in the period 2020–2025 in all three scenarios. The maximum total renewable energy capacity to receive support is set at 570 MW, including the capacity that existed in 2017. The largest supported capacity is for solar PV at 200 MW, followed by SHP at 160 MW and wind power at 150 MW.[17]

FITs for wind power are 0.089 EUR/kWh (0.10 USD/kWh), for biomass thermal 0.150 EUR/kWh (0.18 USD/kWh) and for biogas 0.180 EUR/kWh (0.21 USD/kWh). A premium is awarded to preferential producers for 20 years in the case of wind power plants and for 15 years in the case of solar PV plants.[17]

SMALL HYDROPOWER LEGISLATION AND REGULATIONS

The development of SHP in North Macedonia is regulated by the Energy Law and relevant by-laws, as well as the Law on Waters, the Law on Concessions and Public Private Partnership and the Law on Construction.[9,17,18,19,20,21,22] In 2020, the Ministry of Economy published the Handbook on the procedures for the development and construction of power plants for electricity production from renewable energy sources — hydropower plants, which aims to provide detailed guidance to investors.[23]

COST OF SMALL HYDROPOWER DEVELOPMENT

Based on the experience of the authors of this chapter and according to a simple calculation of profitability of investment into SHP projects (as a ratio between invested funds and money received from generated electricity), the average payback period in North Macedonia can be estimated at approximately 5–7 years.

In 2019, 90 SHP preferential producers who used the FITs, with a total installed capacity of 80 MW and generation of

170 GWh, were paid EUR 9,063,665 (USD 10,986,793). The average price for produced electricity was approximately EUR 0.813 (USD 0.99) per kWh.[8]

FINANCIAL MECHANISMS FOR SMALL HYDROPOWER PROJECTS

The Government of North Macedonia has signed several direct agreements with the European Bank for Reconstruction and Development (EBRD) to support loan agreements with several concessionaires. This possibility is available to all investors who signed the agreements and are seeking loans from different financial institutions.[10,15]

EFFECTS OF CLIMATE CRISIS ON SMALL HYDROPOWER DEVELOPMENT

The production of electricity from hydropower mostly depends on the hydrological conditions. In 2019, the production from SHP significantly reduced due to the unfavourable hydrological conditions: from 202 GWh in 2018 to 169 GWh in 2019. At the moment, the Government or the Ministry of Economy do not take special measures to address the impact of climate change on SHP.

BARRIERS AND ENABLERS FOR SMALL HYDROPOWER DEVELOPMENT

There are no significant barriers precluding SHP development in North Macedonia, but rather some factors that can pose certain limitations:

- There is a need for more accurate hydrological data for an extended time period, because the previous estimates of the capacity potential have been criticized for overestimating the volume of water at some sites;
- There is also a need for connection to the distribution grid, since most of the potential SHP sites are located in rural areas with either no connection or no stable quality network;
- The grid connection cost is often very high, with the average price for the 10 (20) kV cable line at 25,000–30,000 EUR/km (29,400–35,300 USD/km) and for the 35 kV cable line at 30,000–35,000 EUR/km (35,300–41,200 USD/km). The price refers to the total value including design and construction, with the lower level of the price range referring to lighter terrain, plains and fields and the higher level to mountainous terrains with hard surface and partly rocky terrain;
- Since 2020, the construction of new SHP plants should be carefully assessed to avoid the risk of disproportionate environmental impact compared to electricity generated;
- The equipment (turbines, generators, hydromechanical equipment, transformers, glass fibre-reinforced plastic (GRP) pipes, control system) need to be procured from abroad.

The factors that can be considered as enablers for SHP development include:

- There is a significant SHP potential, including the capacity of the water supply systems and coastal SHP, which could be used for plant development if justified based on economic and technical aspects. According to the analysis and opinion of the authors, there are real opportunities for building approximately 110 SHP plants of different types;
- There is a favourable political, social and energy climate for the development of SHP in North Macedonia;
- Availability of bank loans for financing SHP projects as well as FITs;
- Availability of engineering staff as well as construction and maintenance companies experienced in SHP projects.

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Portugal

Laura Stamm, International Center on Small Hydropower (ICSHP)

KEY FACTS

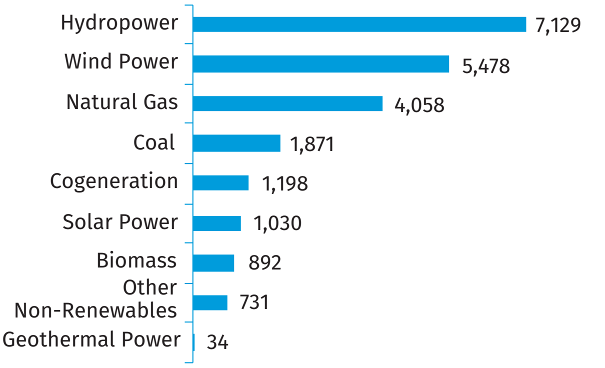
Population	10,297,081 (2020)[1]
Area	92,225.6 km^2 [2]
Topography	The northern and central regions of Portugal have higher elevations with several mountain ranges, whereas the southern region is lower and flatter. In the very north of the country are the Larouco Mountains to the east and the Trás-os-Montes to the west. The Montemuro Mountains, also in the northern region, form south of the Douro River basin and north of the Mondego River basin. In the northern central region is the prominent Estrela Mountain range where the highest altitudes are found and the highest point of the mainland, Serra de Estrela at 1,993 metres, is located. The southern region is largely low-lying plains with marshy coastlines. The Azores Islands in the Atlantic Ocean are of volcanic origin and are the location of the country's highest point, Mount Pico, at 2,351 metres.[2,3]
Climate	The climate has Atlantic, Mediterranean and continental influences. The north, especially north-west has a mild and wet climate with cool winters, warm summers and a lot of rainfall. The interior experiences colder winters and hotter summers, with the exception of very high altitudes that do not reach very high temperatures. The Estrela Mountain region experiences temperatures below 0 °C in winter and snow remains on the peaks throughout most of the year. The southern region has a mild temperate climate with an average range of 10 °C in winter and 24 °C in summer.[2]
Climate Change	The major concerns of climate change in Portugal are rising temperatures and declining annual precipitation. Since the 1970s average temperatures have been increasing at a rate of approximately 0.3 °C per decade and rainfall has been decreasing at a rate of approximately 25 mm per decade. These trends are expected to continue into the next decades and accelerate towards the end of this century. By 2100, temperatures may increase by between 2 °C and 4 °C and rainfall may decrease by an estimated 30 per cent.[3]
Rain Pattern	Precipitation varies between regions and seasons. The north receives the most rainfall, with an average range of 1,000 mm to 2,000 mm per year with some areas receiving more than 2,500 mm per year. Central and southern regions receive an average of 600 mm per year, with some drier pockets inland. Most of the precipitation happens during the winter between November and February, whereas June to August are the driest months.[2,3]
Hydrology	The largest rivers in Portugal begin in Spain and flow through the country to empty into the Atlantic Ocean. These rivers are the Douro in the northern region, The Tagus in the central region and the Guadiana in the south. The largest river exclusively within the country's boundaries is the Mondego which rises in the Estrela Mountains and flows west to the Atlantic. Other important rivers within the country are the Vouga, Sado and Zêzere. Many rivers in the central and southern regions have seasonal variation of flow with extremely low flows during the dry summer season.[2]

ELECTRICITY SECTOR OVERVIEW

In 2020, the total installed capacity in Portugal was 22,421 MW, of which 65 per cent was with renewable sources and 45 per cent with non-renewable sources. Hydropower accounted for 7,129 MW (approximately 32 per cent) of the total installed capacity, wind power for 5,478 MW (24 per cent), natural gas for 4,058 MW (18 per cent), coal for 1,871 MW (8 per cent), cogeneration for 1,198 MW (5 per cent), solar power for 1,030 MW (5 per cent), biomass for 892 MW (4 per cent), other non-renewable sources for 731 MW (3 per cent) and geothermal power for 34 MW (less than 1 per cent) (Figure 1).[4]

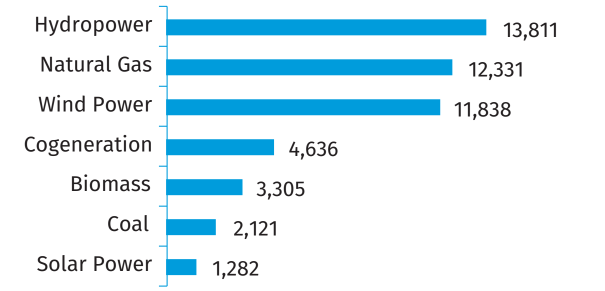
The total electricity generated in continental Portugal in 2020 was 49,324 GWh, of which 62 per cent was from renewable sources and 38 per cent from non-renewable sources. Hydropower generated 13,811 GWh (28 per cent), natural gas 12,331 (25 per cent), wind power 11,838 GWh (24 per cent), cogeneration 4,636 GWh (9 per cent), biomass 3,305 GWh (7 per cent), coal 2,121 GWh (4 per cent) and solar power 1,282 GWh (3 per cent). In the same year, 6,397 GWh of electricity was imported and 4,942 GWh of electricity was exported. Total electricity consumed for the year was 50,779 GWh.[5]

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



Source: DGEG[4]

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



Source: APREN[5]

The electricity sector of Portugal is liberalized, a process that began at the end of the 20th century and was completed around 2014. The market began to open gradually in 1995 and by 2006 all consumers were able to choose their electricity suppliers.[6] Before complete privatization in 2013, Energias de Portugal (EDP) was the main utility company in the country but is now one of many companies, while still holding a considerable market share, especially in regards to distribution.[7] While any company is allowed to generate or distribute electricity, only one company has exclusive rights for all transmission in the country, the Rede Eléctrica Nacional (REN). Since the end of the privatization process of REN that occurred between 2007 and 2014, the State Grid of China has been its largest shareholder with a 25 per cent share.[8]

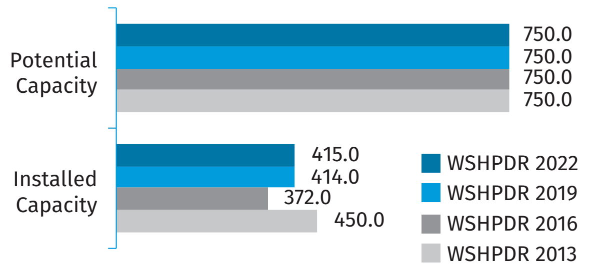
The Iberian Electricity Market (MIBEL) includes both Spain and Portugal. Spot market trading is managed by the Iberian Market Operator of Spain (OMIE) and future market trading is managed by the Iberian Market Operator of Portugal (OMIP).[9] The energy market of Portugal is regulated by the Energy Services 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.[10] The General Directorate of Energy and Geology (DGEG) oversees the energy sector as a whole and plays an integral role in the implementation of energy legislation and policies.

The electrification rate of Portugal is 100 per cent.[11] There are two types of markets that determine electricity tariffs and consumers are able to choose which market they would like to pay on. The free market is unregulated and prices are determined by the electricity suppliers and are part of the customer's contract. The regulated market is based upon supply and demand, fluctuating hourly. Both types share the same network access tariff base approved by ERSE plus a supplement according to the type. There is a social tariff determined by ERSE available for low-income consumers with contracts under 6.9 kW, which is the same discount regardless of the market the costumer pays on.[6] While free market prices depend on individual companies, the average hourly price on the regulated market in January 2022 was EUR 0.202 (USD 0.21) per kWh.[12]

SMALL HYDROPOWER SECTOR OVERVIEW

In Portugal, small hydropower (SHP) is defined as plants with a capacity of 10 MW or less. At the end of 2021, installed SHP capacity was 415 MW, which generated 845 GWh of electricity for the year.[13] Although there are no accurate or complete studies for SHP potential, the country's National Renewable Energy Action Plan (PNAER) 2013–2020 was aiming for a total of 750 MW capacity from 250 plants by 2020, suggesting that, at a minimum, this potential exists.[10] Current capacity constitutes approximately 50 per cent of this target. Compared to the *World Small Hydropower Development Report (WSHPDR) 2019*, installed capacity has increased by 1 MW and potential capacity has remained the same (Figure 3).

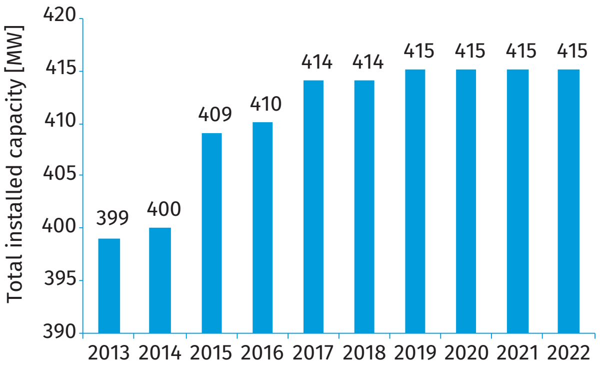
Figure 3. **Small Hydropower Capacities in the WSHPDR 2013/2016/2019/2022 in Portugal (MW)**



Sources: *WSHPDR 2019*,[10] DGEG,[13] *WSHPDR 2016*,[14] *WSHPDR 2013*[15]

SHP constituted approximately 6 per cent of all hydropower installed capacity as well as generation in 2020. As part of the PNAER, Portugal was aiming for an annual average generation of 1,511 GWh from SHP by 2020, corresponding to a total installed capacity of 750 MW from 250 plants.[10] As of 2021, this goal was unmet (Figure 4) and both actual installed capacity and annual generation reached approximately 55 per cent of their respective goals.

Figure 4. **Small Hydropower Capacities in Portugal in 2013–2022**



Source: DGEG[13]

Due to the country's topography and climate, most of the SHP plants are concentrated in the northern region which is characterized by a mountainous terrain and high annual precipitation. However, even in the rainy regions there is great seasonal variability in generation. During the dry summer months, hydropower plants in all regions experience a lower flow and electricity generation than during wetter months such as January and February.[13]

While no upcoming SHP projects in Portugal have been announced, the National Plan for Dams with High Hydropower Potential has been underway since 2007, defining the construction of 10 new large dams, some of which have already been cut. As of 2022, construction of the Tâmega hydropower complex is still undergoing and is expected to be finished by 2024. This project will be the largest hydropower project in Portugal and will comprise three plants with three water reservoirs on the Tâmega River in the northern region. When completed, total installed capacity will be 1,158 MW with 880 MW worth of pumped storage. The objective for this major project is to lessen energy dependence on imports from other countries while also moving towards the decarbonization of the electricity sector.[16]

RENEWABLE ENERGY POLICY

A key challenge for the energy sector of Portugal is to reduce energy dependence on imports, a goal which can only be achieved by developing renewable energy sources. Currently, renewable energy sources constitute a 31 per cent share of the energy sector and a 65 per cent share of the electricity sector.[4]

The PNAER 2013–2020 set targets for renewable energy sources. These targets included to have 31 per cent of final energy consumption be from renewable energy as well as to have 59 per cent of renewable energy sources in the electricity sector. Both of these targets were met on time with 33 per cent of renewable sources in final energy consumption and 65 per cent in the electricity sector in 2020.[17] Targets set in the country's National Energy and Climate Plan (PNEC) for 2030 include 47 per cent of renewable energy in final energy consumption, which was an interim plan towards the Road Map for Carbon Neutrality 2050 (RNC2050) plan. The RNC2050 establishes a pathway towards carbon neutrality by 2050, calling for a 99 per cent reduction in carbon emissions compared to 2005. The plan expects a 100 per cent reliance on renewable energy in the electricity sector to be done by heavy investments in all renewable energy sources, but especially in wind and solar power. The end of using coal for electricity is anticipated to be around 2029 and gas in 2040.[18] To facilitate the transition on the electricity grid, all renewable energy with the exception of hydropower above 30 MW has non-discriminatory priority. A framework for a feed-in-tariff (FIT) existed up until 2012, but this has since been dismantled and new plants are to be remunerated in the wholesale electricity market.[19]

SMALL HYDROPOWER LEGISLATION AND REGULATIONS

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.[10]

BARRIERS AND ENABLERS FOR SMALL HYDROPOWER DEVELOPMENT

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, which can take, on average, between 3 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 financial incentives such as FITs;
- Limitations on energy exports are an obstacle to the increase of renewable energy sources.

Major enablers for SHP include:

- There is still untapped potential availability in the country;
- SHP is socially preferred over large dam construction due to reduced environmental and economic impacts;
- A liberalized market allows any company to enter the industry to generate electricity;
- With the ambitious aspiration to have a fossil fu-

el-free electricity sector in less than 20 years, SHP can be a key tool towards this goal as it has lower start-up costs and faster construction times than large projects;
- The political environment is supportive and committed to increasing the share of renewable energy in the mix.

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Serbia

Slobodan Cvetković and Rastislav Kragić, independent experts

KEY FACTS

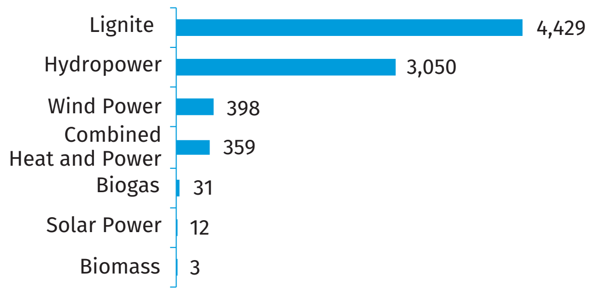
Population	6,945,235 (2019)[1]
Area	88,509 km²[2]
Topography	The northern part of Serbia is characterized by plains lying at elevations of up to 100 metres above sea level. The central part of the country is covered in hills and mountains, belonging to the Dinaric Alps, the Carpathian Mountains and the Rhodope Mountains. Important mountains in Serbia include Kopaonik, Stara Planina, Tara, Zlatibor, Golija, Suva Planina and Zlatar. The highest point in the country is Đeravica (2,656 metres) in the Prokletije Mountains.[2,3]
Climate	The climate of Serbia is predominantly continental, with local diversity due to geographic location, relief, terrain exposition, presence of rivers, vegetation and urbanization. The south-western part of the country includes both the Mediterranean and continental climates. The climate of Serbia is characterized by warm summers and cold winters, with an average annual temperature range of over 22 °C.[2]
Climate Change	The current trend of average annual temperature increase in Serbia is 0.6 °C per 100 years. The estimated rate of decrease of annual surface flows is 30 per cent per 100 years, but varying depending on the region. The smallest changes in surface flows are expected in the south-western part of the country, while the biggest decline is expected in the eastern part.[2]
Rain Pattern	The precipitation regime in Serbia is very heterogeneous on a regional scale. Annual precipitation ranges from approximately 500 mm in the north to over 1,000 mm in the mountain regions, with average precipitation nationwide of approximately 730 mm per year. Precipitation is highest in June and lowest in February and March.[2]
Hydrology	The majority of the territory of the Republic of Serbia (92 per cent) belongs to the Black Sea drainage basin, 5 per cent belongs to the Adriatic drainage basin and the remaining 3 per cent belongs to the Aegean basin. The Danube River flows for 588 kilometres through the territory of Serbia and along the border with Croatia and Romania. Other main rivers in Serbia are tributaries of the Danube, including the Sava (flowing from the west) and Tisa (flowing from the north). The Drina River, on the border with Bosnia and Herzegovina, is the biggest tributary of the Sava River. The longest river flowing exclusively through the territory of Serbia is the Velika Morava River, with a total length of 185 kilometres.[3]

ELECTRICITY SECTOR OVERVIEW

The total installed capacity of Serbia in 2020 was 8,285 MW (excluding the installed capacity of the Autonomous Province of Kosovo and Metohija), of which 4,429 MW (53 per cent) was provided by lignite thermal power plants, 3,050 MW (37 per cent) by hydropower plants, 398 MW (5 per cent) by wind power plants, 359 MW (4 per cent) by combined heat and power (CHP) plants and the remaining 49 MW (less than 1 per cent) by other energy sources, including solar power, biomass and biogas (Figure 1).[4]

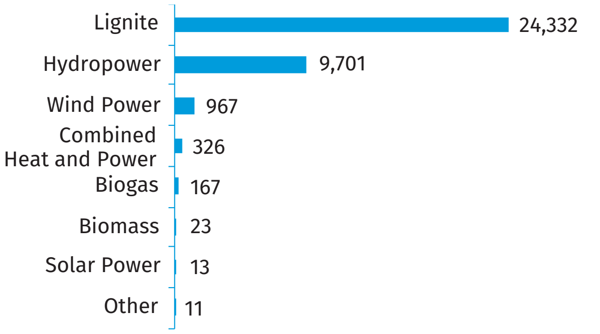
Generation of electricity in Serbia in 2020 reached 35,540 GWh, of which coal-fired thermal power plants produced 24,332 GWh (68 per cent), hydropower plants 9,701 GWh (27 per cent), wind power plants 967 GWh (3 per cent), CHP plants 326 GWh (1 per cent) and biomass, biogas, solar power and other sources provided a combined total of 214 GWh (less than 1 per cent) (Figure 2).[4] In 2020, Serbia imported 5,002 GWh of electricity and exported 5,943 GWh.[5]

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



Source: AERS[4]

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



Source: AERS[4]

Access to electricity in Serbia is 100 per cent in both urban and rural areas.[6] Electricity consumption in 2020 amounted to 29,039 GWh, of which household consumption accounted for 13,718 GWh (47 per cent).[4]

In line with its goal of full membership in the European Union (EU), the Republic of Serbia ratified the Energy Community Treaty with the EU in 2006, committing to transposing EU legislation on the energy sector.[7]

The basic law regulating the electric power sector in Serbia is the Energy Law, first adopted in 2004 and with significant amendments passed in 2011, 2014 and 2021.[8,9] Among other changes, the aforementioned amendments implemented the unbundling of the public energy company Elektroprivreda Srbije (EPS) into separate companies individually responsible for the generation, transmission and distribution of electricity. EPS is the largest power producer in Serbia. The transmission system operator (Elektromreža Srbije) and the distribution system operator (Elektrodistribucija Srbije), previously part of EPS, currently operate as independent entities.

The electricity system of Serbia is controlled by an independent regulatory body, the Energy Agency of the Republic of Serbia (AERS). Electricity suppliers, which can be private or state-owned companies, trade on the free electricity market. Producers and final customers of electricity are free to choose their supplier and contract electricity purchases.

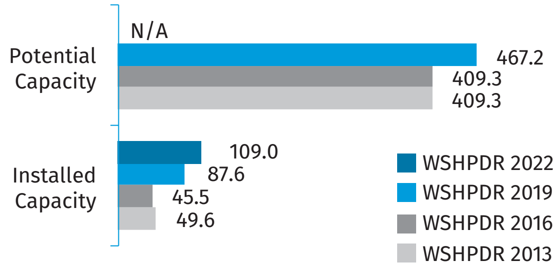
Average electricity tariffs for end users with low-voltage connections in Serbia in 2020 were 7.14 RSD/kWh (0.068 USD/kWh) for households, 6.80 RSD/kWh (0.065 USD/kWh) for public lighting and 9.39–12.21 RSD/kW (0.09–0.12 USD/kWh) for 0.4 kV stage I and stage II connections (before VAT). Tariffs for households with an annual consumption of 2,500–5,000 kWh were 0.074 EUR/kWh (0.08 USD/kWh).[4]

SMALL HYDROPOWER SECTOR OVERVIEW

While the term “small hydropower (SHP) plant” is not used in any energy legislation in Serbia, the Decree on Incentive Measures for Privileged Electric Power Producers, adopted in 2013, established incentive measures for hydropower plants of up to 30 MW installed capacity.[10]

As of December 2020, the total installed capacity of SHP plants of up to 10 MW in Serbia was 109 MW from 138 plants.[4,11] While the *World Small Hydropower Development Report (WSHPDR) 2019* overestimated installed SHP capacity in Serbia, the installed capacity of SHP plants in the country has increased since 2019 as a result of the commissioning of new plants. Up-to-date figures on potential SHP capacity in the country are not available (Figure 3).[12]

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



Source: AERS,[4] MRE,[11] *WSHPDR 2019*,[12] *WSHPDR 2013*,[13] *WSHPDR 2016*[14]

Note: Data are for SHP up to 10 MW.

Estimates of SHP potential in Serbia are largely based on results of studies conducted in the late 1980s, including the Cadastre of Small Hydropower Plants published in 1987. These studies identified a total of 870 potential sites in Central Serbia and Vojvodina for SHP up to 10 MW, with a total capacity of 467.2 MW.[15,16,17,18] However, the studies did not consider environmental, social, and economic criteria as well as the cumulative impacts of SHP plants. Additionally, the impact of SHP plants on the environment has been a topic of increasing concern for environmentalist groups in Serbia and the public at large.[18] Consequently, a project to produce a new cadastre of potential SHP sites that would account for these factors was launched in 2016. The project has been endorsed by the European Commission and is still in the process of being implemented.[19]

The installed capacity of small hydropower plants in Serbia has increased in recent years, but no SHP plants of above 10 MW capacity have been built since 2010.[11] Provisions in the Energy Law have established the Privileged Power Producer (PPP) status for renewable energy producers, enabling PPPs to access feed-in tariffs (FITs) and other incentives, as well as the Preliminary Privileged Power Producer (PPPP) status for developers who commit to constructing renewable energy projects within three years of being granted the PPPP status and who are then eligible to access incentives including FITs at the level set when receiving the status.[8] As of December 2020, 121 SHP plants up to 10 MW, with a total capacity of 77.27 MW, had been granted PPP status.[11] A list of the most recently commissioned plants is displayed in Table 1.

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

Name	*Location*	*Capacity (MW)*	*Launch year*
Šljivovica	Priboj	1.300	2021
Jovanovići	Arilje	0.515	2021
Ravni	Uzice	0.470	2021
Lozno	Novi Pazar	0.320	2021
Tlamino	Bosilegrad	0.260	2021
Rogopeč 1	Ivanjica	1.763	2020
Reka	Bosilegrad	0.815	2020
Manjak	Vladicin Han	0.470	2020
Duavica	Vranje	0.341	2020
Pršići	Brus	0.138	2020

Source: MRE[20]

Plans for the construction of an additional 50 SHP plants up to 10 MW were laid out in the National Renewable Energy Action Plan (NREAP) of Serbia in 2013.[19,21] Several ongoing SHP projects recently granted the PPPP status are listed in Table 2.

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

Name	*Location*	*Capacity (MW)*	*Planned launch year*
Brusnik	Arilje	1.264	2024
Jeliće	Tutin	0.128	2024
Piskanja	Raska	2.800	2023
Pročovci 3	Trgoviste	0.910	2023
Bučalo	Vranje	0.240	2022

Source: MRE[20]

RENEWABLE ENERGY POLICY

In 2014, Serbia introduced a new system of support measures for projects for electricity generation from renewable energy sources (RES) through secondary legislative documents building on the existing Energy Law. These documents outline conditions for granting the FIT and the commercial and procedural provisions for producing electricity from RES. These provisions included the definition of RES; capacity limits for FIT eligibility as well as the period of eligibility, set at 12 years from the FIT application process; and the disbursement procedure for FITs, based on a specific contract between the electricity producer and the public supplier.

The FIT incentive system for generation from RES was in force between 2010 and 2021. During this period, 272 projects with a total installed capacity of 520 MW received the PPPP status.[20] In April 2021, the Parliament of Serbia adopted the new Law on the Use of RES, which among other measures defined a system of market premiums as the primary measure of support for RES projects, largely replacing the FIT system. The market premium is paid on top of the sale price of electricity on a per kWh basis. Unlike the FIT, the market premium is not set in advance but is arrived at through a system of auctions and changes continually.

FITs will remain as the support measure for small plants, defined as those with a capacity of less than 500 kW (less than 3 MW in the case of wind farms).[22] As of 2020, FITs for SHP plants up to 200 kW of capacity were 0.133 EUR/kWh (0.150 USD/kWh and for SHP plants of 200–500 kW they were 0.112-0.133 EUR/kWh (0.126-0.150 USD/kWh).[4]

Additionally, the new RES law allows households and companies to produce electricity as prosumers by producing electricity from solar panels and other RES for own use and for sale to the electricity market. Finally, provisions in the new RES law have prohibited the construction of hydropower plants in protected natural areas and recognized new forms of renewable energy, including “green” hydrogen.[22]

The Republic of Serbia ratified the Green Agenda for Western Balkans with the EU in Sofia in November 2020. Serbia has obliged to implement activities outlined in the Agenda, including actions on climate change, energy, mobility, circular economy, depollution, sustainable agriculture and food production, and biodiversity.

In March 2021, the Parliament of Serbia adopted the Law on Climate Change. This law established the system for limiting greenhouse gas (GHG) emissions; the adoption of a low-carbon development strategy and the procedures for monitoring, reporting and continual improvement of the strategy; the programme for adaptation to climate change; and a system of issuing permits for GHG emissions to the plant operators, including monitoring, reporting, verification and accreditation of verifiers, administrative fees, supervision and other issues relevant to limiting GHG emissions.[23] Serbia is additionally preparing a National Energy and Climate Plan for 2021–2030 with a vision to 2050, as well as an Energy Development Strategy until 2040 with a projection to 2050.

SMALL HYDROPOWER LEGISLATION AND REGULATIONS

Licensing requirements for the construction and operation of SHP plants in Serbia include a location permit, construction permit, water permit, operating permit, energy licence and the right to engage in power generation.[24] An environmental impact assessment (EIA) may be required for SHP plants exceeding 2 MW or those situated in a protected natural area and additional supporting documents may also be required during the associated administrative procedures. Environmental issues must be considered in the planning, construction and utilization of SHP plants, as outlined in relevant legislation harmonized with the EU regulatory frameworks including the Law on Nature Protection, Directives on the Environmental Impact Assessment and the Strategic Environmental Assessment, the Water Framework Directive, Council Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora, Nature 2000 and the Aarhus Convention. This body of legislation collectively mandates that environmental impacts including changes in water quality, sedimentation, impacts on wildlife, landscape and the flow regime of the watercourse must all be taken into consideration during development projects such as SHP construction.[25] A regulation for determining the minimum sustainable flow in rivers according to the Law on Waters has not yet been adopted.[26]

Finally, in line with the Aarhus Convention, the public must be involved in the planning, assessment and decision-making regarding the operational regime of SHP plants. In the past, environmental damage attributed to the construction and operation of SHP plants in Serbia, stemming from poor enforcement of regulations, has resulted in protests by local communities, including those targeting SHP plants at Stara Planina and Rakita, among others, and leading to a prohibition on SHP construction in protected natural areas by the Law on the Use of RES and amendments to the Law on Nature Protection.[22,27,28] Thus, the wider eco-social context of Serbia must be systematically taken into consideration as part of SHP construction and operation.

COST OF SMALL HYDROPOWER DEVELOPMENT

Total investment costs for SHP plants in Serbia typically consist of the following elements[29]:

- preparation and construction work (40–70 per cent of total cost);
- cost of hydromechanical equipment (1–2 per cent);
- cost of electro-mechanical equipment of (20–40 per cent);
- cost of connection to the electric power system (up to 20 per cent);
- other costs, including cost of administration, purchase, design and supervision (5–10 per cent).[29]

Most of the equipment installed as part of the SHP plant construction process in Serbia is not manufactured locally and must be imported.

EFFECTS OF CLIMATE CRISIS ON SMALL HYDROPOWER DEVELOPMENT

Models of the impact of climate change on discharge in mountainous catchments in Serbia predict significant seasonal shifts in the monthly precipitation volume and discharge under both moderate and extreme climate change scenarios, relative to the 1971–2000 baseline period. In particular, while no significant changes are predicted on an annual basis, increases in precipitation and discharge in the winter months of up to 50 per cent are possible by the end of the 21st century, increasing the flood risk during this period. Corresponding reductions of discharge and precipitation during the warm period are considered likely to impact several economic sectors, including hydropower generation.[30]

BARRIERS AND ENABLERS FOR SMALL HYDROPOWER DEVELOPMENT

Since 2019, SHP projects have encountered delays in implementation and increased scrutiny from the public and non-governmental organizations. The obstacles to SHP development in Serbia include the following:

- Long and complicated administrative procedures related to the issuance of necessary permits for SHP plants;
- Lack of supervision and control from authorities during the construction of SHP plants and their operational regime;
- Lack of corresponding expertise within authorities, especially at the local level;
- Previous failures in construction and operational work of SHP plants leading to the endangerment of wildlife such as fish and birds, negative impacts on the flow regime and landscape, and other negative outcomes;
- The lack of public consultation and exchange of information between all stakeholders, including the local and regional authorities, the investor, the local community, and the non-governmental sector, among others, and the resultant resistance to SHP development from civil society organizations and the public.

The main opportunity for future SHP development in Serbia lies in their installation on multipurpose hydro-technical systems, where such development is appropriate. These include:

- Outputs for environmental and regulatory flows on non-powered dams;
- Elements of pressurized water systems such as pressure break tanks, where installation of SHP plants is conducive to the pressure regulation function of the system.

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Slovenia

International Center on Small Hydropower (ICSHP)

KEY FACTS

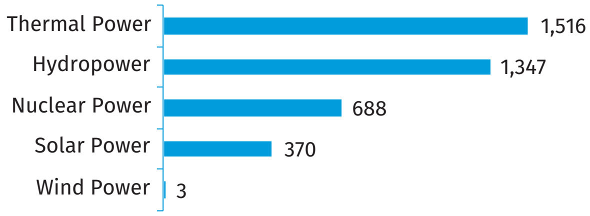
Population	2,102,419 (2020)[1]
Area	20,271 km^2 [2]
Topography	The terrain of Slovenia is predominantly elevated and is divided into four major regions. The largest and highest region is the Alps situated in the north and north-west. It is there where the highest peak, Triglav at 2,864 metres, is located. Just south of the Alps is the Karst Plateau region, featuring several caves and underground rivers. In the north-east and east of the country are the Subpannonia lowlands with rolling hills. The smallest region is the Slovene Littoral along the south-western border with Italy, featuring river valleys and a small rocky coastline.[2]
Climate	Slovenia has a temperate climate with variations between regions. The northern mountainous region is cooler with continental influences. Winters are cold, with typically below freezing temperatures, and summers are cool, with temperatures remaining close to 20 °C. The south is warmer with Mediterranean influences. Summers are hot with an average temperature of 27 °C in July and winters are mild, rarely dropping below 10 °C.[2]
Climate Change	There have been notable effects of climate change in Slovenia in the past 50 years. Since 1961, the average temperature has increased by 1.7 °C, which is more than the European average. Additionally, annual precipitation has decreased by between 10 and 15 per cent with a 55 per cent decrease in snow depth. By 2100, temperatures are expected to increase by an additional 1–4 °C, especially during winters. Precipitation patterns are expected to continue changing, but the exact amounts are difficult to predict. Generally, rainfall could decrease during summer and autumn and increase during winter and spring.[3]
Rain Pattern	Rainfall varies by region and season. Rainfall is the highest in the western Alps, reaching over 3,000 mm per year, central regions have approximately 1,400 mm per year and the south-eastern region has the lowest rainfall, with an annual average of 800 mm. Rainfall is highest during the autumn and winter months for almost all parts of the country, except for in the east, where the most rainfall happens during the summer months.[3]
Hydrology	Many of the rivers in Slovenia begin in the north and flow south-east to empty into the Danube River and ultimately, the Black Sea. Major rivers include the Drava and Mura in the north-east that begin in Austria, the Sava that begins in the north-western Alps and cuts south-east through the central region and the Soča, the only major river that flows south-west and empties into the Gulf of Venice. Rivers typically have a strong, fast flow due to the country's steep slopes.[2]

ELECTRICITY SECTOR OVERVIEW

In 2020, total installed capacity in Slovenia was 3,924 MW. Of this, thermal power accounted for 1,516 MW (39 per cent), hydropower for 1,347 MW (34 per cent), nuclear power for 688 MW (18 per cent), solar power for 370 MW (9 per cent) and wind power for 3 MW (0.08 per cent) (Figure 1).[4] The fastest growing source of energy has been solar power, accounting for 87 per cent of newly connected capacity between 2019 and 2020.[5]

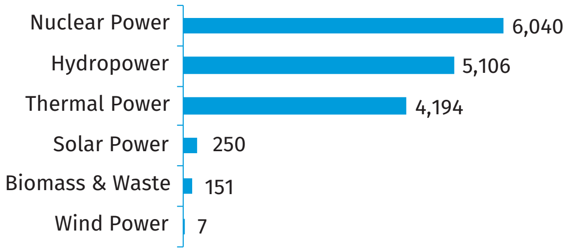
In 2020, total electricity generation in Slovenia was 15,748 GWh, of which 35 per cent was using renewable energy. Nuclear power generated 6,040 GWh (38 per cent), hydropower 5,106 GWh (32 per cent), thermal power 4,194 GWh (27 per cent), solar power 250 GWh (2 per cent), biomass and waste 151 GWh (1 per cent) and wind power 7 GWh (0.04 per cent) (Figure 2). In the same year, Slovenia imported 7,120 GWh, mostly from Austria, and exported 6,103 GWh, mostly to Croatia and Italy. Total consumption of electricity by end users was 12,506 GWh, of which 8,947 GWh was consumed by all types of businesses and 3,559 GWh was consumed by households. Losses due to transport in transmission and distribution systems were 849 GWh.[5] The electrification rate of Slovenia is 100 per cent.

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



Source: Ministry of Infrastructure[4]

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



Source: Energy Agency[5]

The Energy Agency is the country's market regulator responsible for ensuring the transparency of market operations, determining methodologies for the energy sector and issuing guarantees of origin and commercial green certificates for the production of electricity from renewable energy sources. Borzen is the market organizer tasked with promoting the development of the country's electricity market and market mechanisms in accordance with the European Union (EU) guidelines. It also contributes to the proper functioning of the country's power system, the alignment of Slovenian and EU legislation and integration of the country's electricity market into the integrated European electricity market.[6]

In Slovenia, while the sector allows private companies to supply electricity, the large electricity producers are owned by the state. The majority of the country's power plants are owned by either of the two publicly owned parent companies, Holding Slovenské Elektrárne (HSE) and GEN Energija. The one nuclear power plant is owned by Nuklearna Elektrarna Krško (NEK), which is equally shared between Slovenia and Croatia.[7] Small electricity producers (up to 10 MW), distribution companies and energy market suppliers can be publicly, privately or mixed owned. The transmission system is fully operated by the state-owned company ELES. The total length of the transmission electric network in Slovenia is 2,859 kilometres. It connects major producers, big consumers and neighbouring countries Austria, Croatia and Italy, with plans to include Hungary in the near future.[5] The total length of the distribution network is approximately 65,000 kilometres (70 per cent is a low-voltage network), which efficiently covers the country's territory and also reaches existing small producers.[6]

The electricity sector is governed through the Energy Act of 2014, which was last amended in 2015. The act replaced the previous one from 2007 in order to properly implement EU directives and comply with new decisions of the Constitutional Court of Slovenia regarding how network charges are determined. The current law clarifies the principles of energy policy, energy market operation rules and manners, measures to achieve a secure energy supply and improve energy efficiency and energy saving. It also promotes the usage of renewable energy sources, giving further framework for a support scheme for such energy production that was initially introduced in 2009.[5,6]

In the decade that the support scheme has been in operation, 3,839 facilities have been included in it. The large majority, or over 3,200, has been solar power plants, but has also included various hydropower, biomass, wind power and cogeneration of combined heat and power (CHP) plants. In 2020, 962.2 GWh of electricity was generated by the plants included in the support scheme and an additional 44.62 MW was added to the grid due to new projects supported by the scheme. Compared to 2019, electricity production by plants included in the support scheme increased by 1.5 per cent and compared to 2018, by 2.6 per cent.[5]

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. In 2020, Slovenia joined the interregional day-ahead market with Austria, Croatia and Italy as well as the single intraday market with Austria and Croatia, with plans to do so with Italy in the future. Wholesale electricity is traded quickly and easily through these markets, ultimately determining the base prices. In 2020, the average wholesale price for electricity was 37.55 EUR/MWh (39 USD/MWh). Within the country, electricity prices for final consumers include the base price, a network charge, levies, excise duties and a value-added tax (VAT). The average final price for the typical household in 2020 was 0.157 EUR/kWh (0.16 USD/kWh). The final price for businesses ranged between approximately 0.06 EUR/kWh (0.07 USD/kWh) and 0.16 EUR/kWh (0.17 USD/kWh) depending on type of business customer and usage.[5]

SMALL HYDROPOWER SECTOR OVERVIEW

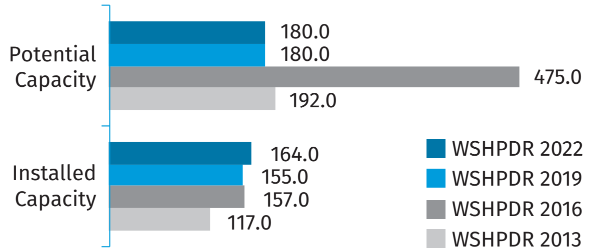
This chapter is using the definition of small hydropower (SHP) as hydropower plants of up to 10 MW. However, there are different definitions of SHP in Slovenia. From the water management perspective, SHP is defined as a hydropower plant with an installed capacity of less than 10 MW. From the perspective of electricity generation from renewable energy sources, there are four categories:

- Micro: less than 50 kW;
- Small: between 50 kW and 1 MW;
- Medium: between 1 MW and 10 MW;
- Large: more than 10 MW.[6]

The installed capacity of SHP plants in Slovenia in 2020 was 164 MW.[4] The total technically and economically feasible potential of SHP in Slovenia is estimated to be approximately

180 MW, indicating that 91 per cent has already been developed.[6] Compared to the *World Small Hydropower Development Report (WSHPDR) 2019,* total installed capacity has increased by 9 MW and potential has remained the same (Figure 3).

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



Sources: Ministry of Infrastructure,[4] *WSHPDR 2019,*[6] *WSHPDR 2016,*[8] *WSHPDR 2013*[9]

Between 2019 and 2020, approximately 0.95 MW of SHP was newly connected to the grid, accounting for almost 2 per cent of all newly connected capacities for the year. The majority of SHP in Slovenia is produced by small electricity production companies and in 2020, these companies accounted for 127 MW of the installed SHP.[5] The major companies, HSE and GEN Energija, typically operate large hydropower but there are a few SHP plants owned by them as well. While it is difficult to obtain up-to-date data about the small production companies and their projects, the newest SHP plant that is operated by Dravske elektrarne Maribor, owned by HSE, was the 0.023 MW Rogoznica plant commissioned in 2019.[10]

The last comprehensive analysis and planning of potential SHP projects on the national scale was carried out by the Energy Directorate in 2007. The study identified 33 SHP sites with capacities of 1–10 MW and 6 sites with smaller capacities. Most of these sites, however, are not in line with the objectives of the Water Framework Directive (e.g., achieving good ecological status) and are located in protected areas of the Natura 2000 EU network.[6]

The National Renewable Energy Action Plan 2010–2020 (NREAP 2010–2020) set the goal of increasing the installed capacity of SHP plants to reach 177 MW by 2020, a goal that is 93 per cent reached.[11] The major challenge for SHP development is to harmonize renewable energy and the ecological objectives. Slovenia has many sites protected under Natura 2000, which stipulates special care to be taken in regards to the environment at these sites, often preventing infrastructure development including hydropower plants. The regulatory basis does, however, include 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 and the Habitats Directive offer the clause that, for new development to take place, public interest should be considered and the overall sustainable development benefits of new electricity production must outweigh the environmental damage and that such societal benefits would not be achieved in a different, more ecologically sustainable way.[12] 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.

Consequently, the national plans for the upcoming decades do not strongly push for SHP development. The Integrated National Energy and Climate Plan of 2020 states that priority should be given to upgrading and modernizing existing SHP plants. However, it also foresees a possible increase of SHP installed capacity to reach a total of 177 MW by 2040. The same plan foresees a much higher increase of large hydropower installed capacity, possibly reaching up to 1,979 MW by 2040.[13] Similarly, development of SHP is not addressed in the Slovenian Network Development Plan 2021–2030, which outlines four scenarios of future energy development with varying levels of optimism for renewable energy shares. Most scenarios envisage an increase in large hydropower, while none of the scenarios include SHP. The fourth scenario includes the largest increase of hydropower, foreseeing an additional 562 MW of large hydropower spread between five hydropower plants to be incorporated into the grid by 2030.[5]

Despite the fact that no explicit plans to expand SHP exist in Slovenia, there is still feed-in financial support 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).[14]

Table 1. **Financial Support of Hydropower Projects in 2020**

Scale of the project	*Tariffs (EUR/MWh (USD/MWh))*	
	Operating support	*Guaranteed purchase*
< 50 kW	53.44 (55.88)	105.47 (110.28)
50 kW – 1 MW	40.58 (42.43)	92.61 (96.83)
1 MW – 10 MW	27.89 (29.16)	82.34 (86.09)
> 10 MW	22.12 (23.22)	N/A

Source: Borzen[14]

RENEWABLE ENERGY POLICY

In compliance with the EU Directive 2009/28/EC, Slovenia published the National Renewable Energy Action Plan (NREAP) in 2010, which covered topics such as the national policy on renewable sources of energy, the expected gross final energy consumption in the period between 2010 and 2020, individual targets and trajectories for each renewable energy source, measures for achieving the binding target shares of renewable energy sources and an estimation of the costs of carrying out measures as well as of the impacts on the environment. The plan defined the target of 25 per cent of renewable energy in final energy consumption by

2020. The actual renewable energy share in final energy consumption in 2020 was 22 per cent, approaching the goal but not meeting it. Specific renewable energy targets for annual generation included for hydropower to generate 5,121 GWh, biomass and waste 676 GWh, solar power 139 GWh and wind power 191 GWh and for renewable energy to reach 39.1 per cent of total electricity generation.[15] Actual generation in 2020 shows that the solar power target was greatly surpassed, the biomass and waste and wind power fell considerably short of their targets and hydropower reached 99 per cent of its target. Overall renewable energy electricity generation missed the target by 4 percentage points.[5]

The competent authority responsible for the energy sector is the Energy Directorate within the Ministry of Infrastructure. In the NREAP measure No. 38 "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. 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.[14]

More recently, the country has adopted the Development Strategy 2030 in 2017 and the Integrated National Energy and Climate Plan in 2020, both of which lay down the outlook for the energy sector for the upcoming decades. The key objectives of these plans include for renewable energy to reach 27 per cent in final energy consumption and 43 per cent in electricity generation by 2030. The plans also seek to improve energy efficiency and security to lead the path towards a decarbonized economy. Individual targets for renewable energy include for generation of solar power to reach 1,866 GWh in 2030 and 5,361 GWh in 2040, wind power to reach 248 GWh in 2030 and 577 GWh in 2040 and hydropower to reach 4,966 GWh in 2030 and 7,014 GWh in 2040. The future of biomass depends on whether installed capacity of it can transform to be purely biomass or remain as a cogeneration input in existing thermal power plants.[13]

BARRIERS AND ENABLERS FOR SMALL HYDROPOWER DEVELOPMENT

The major barriers to SHP 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;
- A lack of human and financial resources, which 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 unclear and non-straightforward decision making;
- 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.[6]

The major enablers for SHP development in Slovenia include:

- There are feed-in financial incentives such as operating support or guaranteed purchase offered;
- Total SHP potential capacity has not yet been reached, leaving room for feasible SHP development;
- According to the national plans, there is opportunity in upgrading and modernizing existing SHP plants.

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Spain

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KEY FACTS

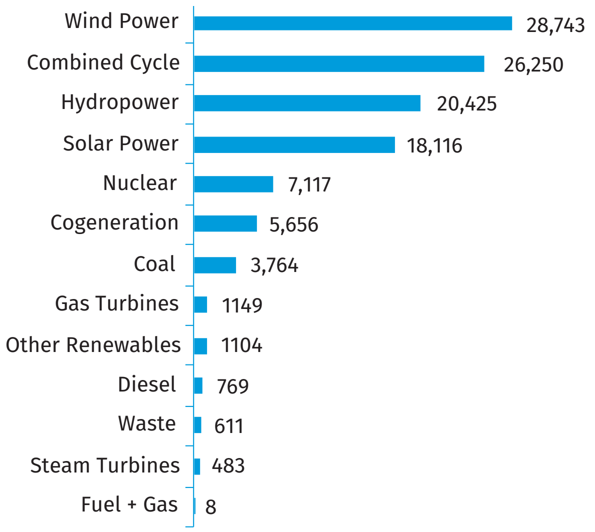
Population	47,351,567 (2020)[1]
Area	505,000 km^2 [2]
Topography	Spain has a diverse terrain characterized by a central plateau surrounded by various mountain ranges. The Meseta Central Plateau, with an average elevation ranging from 500 metres to 700 metres above sea level, is divided in the middle by the Central Sierra Mountains. To the north of the plateau are the Cantabria Mountains, to the north-east and east is the Iberian Cordillera and to the south are the Sierra Morena Mountains. The Pyrenee Mountains run along the north-eastern and eastern boundaries of the country bordering with France and the Baetic Cordillera runs parallel to the southern coast. Coastal plains run along the Mediterranean Sea to the south. The Balearic Islands in the Mediterranean are a part of the Baetic Cordillera and the Canary Islands in the Atlantic Ocean are of volcanic origin. The highest point on the mainland is Mulhacen at 3,481 metres and the highest point of the whole territory is Teide Peak on the Canary Island of Tenerife at 3,718 metres.[2]
Climate	The climate varies between regions due to the peninsula's size and diverse terrain. The north of Spain has a temperate maritime climate influenced by the Atlantic Ocean with cool winters, warm summers and heavy rainfall. Winters remain mild along the coasts but are cold in high elevations. The central region has a temperate continental climate influenced by the Mediterranean with mountains creating pockets of humid and arid zones. The south has a warm, Mediterranean climate occasionally affected by the hot, dry North-Saharan airstream. Summers are hot, often reaching above 30 °C and winters are mild.[2,3]
Climate Change	Climate change is expected to affect the country's average temperatures and rainfall. There has been a noticeable increase in average and minimum temperatures since the 1970s in most of the country. In the southern plateau region, maximum temperatures have also increased with significance, up to 1.62 °C. Warming is expected to continue, especially in the summers and in inland regions and by the end of the 21st century, temperatures are expected to have increased by between 3 °C and 6 °C. Rainfall patterns are expected to become more extreme. In the northern rainy zone precipitation will most likely further increase and in the southern semi-arid zone precipitation will most likely further decrease.[3]
Rain Pattern	Average annual rainfall in Spain has a wide range and can be categorized into three zones. The rainy zone covers the northern and north-eastern regions where annual rainfall is above 1,000 mm, surpassing 2,000 mm in some areas. The dry zone covers most of the country, covering the Meseta Central Plateau region and spanning east to the coast and border with France. Average rainfall in this zone is approximately 500 mm per year. Semi-arid zones receive the least amount of rainfall and can be found in the south of the mainland near the coast and much of the Canary Islands. Average annual rainfall in the semi-arid zones is less than 300 mm and, in some parts, barely reach 150 mm.[3]
Hydrology	There are approximately 1,800 rivers in Spain, though many stay dry for much of the year. There are five major rivers, most of which begin in the interior mountains and flow westwards to empty in the Atlantic Ocean. The Tagus, Douro and Guadiana Rivers begin in Spain but flow through Portugal to reach the ocean while the Guadalquivir remains in the country's territory to reach the Atlantic in the south. The Ebro River is the longest river within the country's boundaries and is the only major river that empties into the Mediterranean. Beginning in the high altitudes of the north-eastern Pyrenee Mountains and flowing southwards, it is also the river that has the most continuous flow regardless of the season.[2]

ELECTRICITY SECTOR OVERVIEW

As of April 2022, total installed capacity in Spain was 114,196 MW comprising several sources. Wind power accounted for just above 25 per cent (28,743 MW), combined cycle accounted for 23 per cent (26,250 MW), hydropower for 18 per cent

(20,425 MW), solar power for 16 per cent (18,116 MW), nuclear for 6 per cent (7,117 MW), cogeneration for 5 per cent (5,656 MW), coal for 3 per cent (3,764 MW), gas turbines for 1 per cent (1,149 MW), other renewable sources for 1 per cent (1,104 MW) and the remaining 2 per cent was split between diesel (769 MW), waste (611 MW), steam turbines (483 MW) and fuel+gas power plants (8 MW) (Figure 1).[4] Of total capacity, 57 per cent was from renewable sources and 43 per cent from non-renewable sources. Compared to the installed capacity at the year-end of 2020, the total has increased by 3,371 MW and the renewable energy share has increased by 3 per cent, primarily as a result of the increase of solar power by more than 4,100 MW, the increase of wind power by more than 1,200 MW and the decrease of coal by approximately 1,900 MW.[4]

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

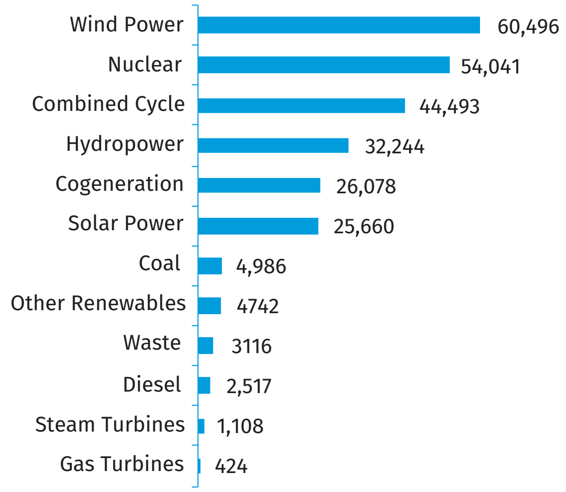


Source: REE[4]

Total electricity generation in Spain for the year of 2021 was 259,905 GWh. Of the total, approximately 23 per cent was generated by wind power (60,496 GWh), 21 per cent by nuclear power (54,041 GWh), 17 per cent by combined cycle (44,493 GWh), 12 per cent by hydropower (32,244 GWh), 10 per cent by cogeneration (26,078 GWh), 10 per cent by solar power (25,660 GWh), 2 per cent by coal (4,986 GWh), 2 per cent by other renewables (4,742 GWh), 1 per cent by waste (3,116 GWh), 1 per cent by diesel (2,517 GWh) and the remaining 1 per cent was made up of steam turbines (1,108 GWh) and gas turbines (424 GWh) (Figure 2).[5]

The electricity sector in Spain is fully liberalized, a process that began with the Electric System Planning Law (LOSEN) of 1994 and completed with the Electricity Sector Law of 1997. This was in accordance with the European Union (EU) Common Standards Directive 96/92/EC, which was passed in 1996 calling for all EU members to liberalize their energy markets.[6] This allowed any company to generate or distribute electricity and for consumers to be able to choose their supplier. Although there are more than 300 electricity companies in the country, three major companies controlled over 65 per cent of the market share in 2019: Endesa (32 per cent), Iberdrola (24 per cent) and Naturgy (9 per cent).[7] All electricity transmission remains the responsibility of one company, the Red Eléctrica de España (REE), who manages the country's 44,687 kilometres of high-voltage lines.[8]

Figure 2. **Annual Electricity Generation by Source in Spain in 2021 (GWh)**



Source: REE[5]

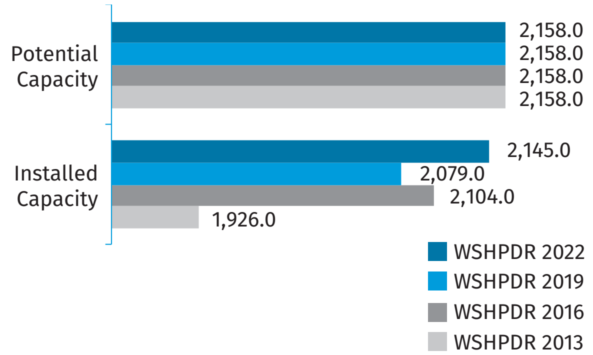
The Ministry of Ecological Transition and Demographic Challenge and the Secretariat of Energy within it oversees the energy sector as a whole and is responsible for implementing energy legislations and policies.[9] The National Commission of Markets and Competition (CNMC) is responsible for regulating the sector, supervising market competition and ensuring transparency for consumers. The CNMC also cooperates internationally as a member of the Council of European Energy Regulators (CEER) and represents Spain in the European Agency for the Cooperation of Energy Regulators (ACER).[10] The Iberian Electricity Market (MIBEL) includes both Spain and Portugal. Spot market trading is managed by the Iberian Market Operator of Spain (OMIE) and future market trading is managed by the Iberian Market Operator of Portugal (OMIP).[11]

The electrification rate in Spain is 100 per cent.[12] There are two types of markets that determine electricity tariffs and consumers are able to choose which market they would like to pay on. The free market is unregulated by the Government and prices are determined by the electricity company in which a fixed rate would be established on the consumers' contracts. On the regulated market, the Voluntary Small Consumer Price (PVPC) is offered to consumers with contracts of 10 kW or less and prices are changed hourly, fluctuating with supply and demand. Roughly half of the country's households choose the fixed rate and half choose to pay the PVPC, however, recently more households are beginning to switch to the fixed rate.[13] As of April 2022, the PVPC price was approximately 0.283 EUR/kWh (0.30 USD/kWh).[14] Since there are hundreds of electricity companies within the country, the free-market tariffs can vary greatly. The tariff offered by the country's largest company, Endesa, in 2022 was 0.23 EUR/kWh (0.24 USD/kWh).[15]

SMALL HYDROPOWER SECTOR OVERVIEW

The definition of small hydropower (SHP) in Spain is an installed capacity up to 10 MW. In 2021, the SHP installed capacity was 2,145 MW from 1,098 plants throughout the country.[16] The SHP potential is estimated at 2,185 MW.[11] In comparison with the *World Small Hydropower Development Report* (*WSHPDR*) *2019*, installed capacity has increased by 66 MW (3 per cent) and the SHP potential remained the same (Figure 3). The increase of installed capacity is due to an additional 39 MW in Andalusia, 8 MW in Galicia, 8 MW in the Basque Country, 4 MW in Castilla La Mancha, 4 MW in Castile and León, 4 MW in Catalonia and a decrease of 1 MW in Aragon since 2017.[16]

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



Sources: *WSHPDR 2019*,[11] CNMC,[16] *WSHPDR 2016*,[17] *WSHPDR 2013*[18]

Most of the SHP activity in Spain is concentrated in four autonomous communities of the country: Galicia, Catalonia, Aragon and Castile and León. Together they represent almost 62 per cent of SHP installed capacity and over 70 per cent of SHP electricity generation in the country (Table 1).[16]

SHP development first entered Spain at the end of the 19th century and was a favourable form of power generation until its peak in the mid-20th century. In 1964 there were 1,740 SHP plants in the country, however, large hydropower was then seen as more economically beneficial. The popularity of SHP declined and plants were dismantled, so that by 1978, 735 SHP plants remained. SHP development made a comeback in the 1980s after the Energy Conservation Law 82/1980 was passed stating benefits of hydropower up to 5 MW. The same year a hydropower feasibility study was carried out that found in addition to what was already developed at the time, there was a 34,000 GWh potential for all hydropower, of which 6,700 GWh was untapped SHP potential.[19]

Table 1. **Installed Small Hydropower Capacity and Generation by Region in Spain in 2021**

Region	*Capacity (MW)*	*Share of total (%)*	*Generation (GWh)*	*Share of total (%)*
Andalusia	180	8.4	136	2.6
Aragon	257	12.0	633	12.1
Asturias	76	3.5	214	4.1
Canary Islands	1	0	3	0.1
Cantabria	72	3.4	184	3.5
Castilla La Mancha	127	5.9	363	7.0
Castile and León	258	12.0	626	12.0
Catalonia	289	13.5	798	15.3
Valencia	31	1.4	26	0.5
Extremadura	23	1.1	18	0.4
Galicia	521	24,3	1,545	29.7
La Rioja	27	1.3	72	1.4
Madrid	44	2.1	67	1.3
Murcia	14	0.6	47	0.9
Navarre	167	7.8	348	6.7
Basque Country	58	2.7	124	2.4
Total	**2,145**	**100.0**	**5,206**	**100.0**

Source: CNMC[16]

RENEWABLE ENERGY POLICY

The resurgence of the SHP sector in Spain was due to the Government's support of the producers of renewable energy. This began with the Energy Conservation Law 82/1980 that suggested reducing fossil fuel consumption and encouraging the adoption of renewable energy with mention of hydropower under 5 MW and solar power.[20] It was then added to by the Royal Decree 2366/1994 which included all other forms of renewable energy and changed hydropower to 10 MW as an important energy source that should be developed more.[21] The Electricity Sector Law 54/1997 set a special regulation for sources of renewable energy with an installed capacity below 50 MW and recognized the environmental benefits of these sources by granting financial benefits including premium pricing, so that renewable energy sources can compete with traditional sources of energy.[22]

The Royal Decree 436/2004 of 12 March 2004, as developed upon the Electricity Sector Law, set the legal and economic framework for a Special Regime for the production of electricity from RES 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.[11] This decree set a new system aimed at renewable energy plants in order to achieve the targets of the Renewable Energy Plan 2005–2010. This plan established the goal to have 29.4 per cent of electricity generated using renewable sources by 2010, which was achieved with a 33 per cent share of renewable energy in generation in 2010.[5]

The Spanish economic crisis of 2008–2014, 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.[11]

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 from renewable energy sources, cogeneration and waste.[11]

Royal Decree-Law 23/2020 of 23 June 2020 approves measures in the field of energy and in other areas for economic reactivation. It enables the Government to establish another remuneration framework, alternative to the specific remuneration regime, in order to favour the predictability and stability in the income and financing of the new electrical energy production facilities that are built from renewable energy sources, which is essential to promote the development of new renewable energy projects with the urgency that is necessary to reach the community and international commitments assumed by Spain in this matter. This remuneration framework, called the Renewable Energy Economic Regime, is based on the long-term recognition of a fixed price for energy and is granted through competitive bidding procedures in which the product to be auctioned will be electricity, installed power or a combination of both, and the variable on which it will be offered will be the remuneration price of said energy.[23]

The 2020 targets for the renewable energy sector were 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.[11]

The Resolution of 25 March 2021 published the Agreement of the Council of Ministers of 16 March 2021, which adopted the final version of the National Integrated Energy and Climate Plan 2021–2030. Its objectives include: a 23 per cent reduction in greenhouse gas emissions compared to 1990; a 42 per cent share of renewable energy sources in the final use of energy; an increase of 39.5 per cent in energy efficiency; and a 74 per cent contribution of renewable energy to total electricity generation.[24] Two months later, Law 7/2021 of 20 May 2021, on climate change and energy transition, was approved.[25]

SMALL HYDROPOWER LEGISLATION AND REGULATIONS

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 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. 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. The move was a result of a tariff deficit of roughly EUR 26 billion (USD 30.2 billion) in 2012, which was largely driven by the incentives for renewable energy sources.[11]

The 2014 Royal Decree 413/2014 (RD 413/2014) replaced renewable energy FITs with a 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.[11]

In the National Integrated Energy and Climate Plan 2021–2030, there is only one single reference to the SHP technology: “During the 2021–2030 decade, approximately 22 GW of renewable electrical power will have exceeded its regulatory useful life. Without a specific plan for the technological renewal of these projects, it is foreseeable that there will be a reduction in the installed capacity of renewable origin, mainly made up of old wind farms and mini-hydropower plants [...]. In order not to lose their energy contribution, it is necessary to contemplate a specific plan for the technological renovation of these facilities”.[24]

BARRIERS AND ENABLERS FOR 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;
- Some potential hydropower sites have not been studied in detail, thus there is lack of knowledge regarding their actual potential;
- In order to use water for hydropower purposes, licences need to be issued, which is a complex administrative process and requires an environmental

authorization approval. The excessive waiting time to get approvals from regional and local organs 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.[11]

Enablers for SHP development in Spain include:
- A fully liberalized market allows for any company to generate and distribute electricity;
- In order to reach the goal of 100 per cent of electricity sourced with renewable energy by 2050, SHP could help reduce fossil fuel energy generation.

In the mid-term future, a good part of the thousand existing SHP plants in Spain will be at the end of their concession. For this reason, it is necessary to work on the regulation of this concessional end to guarantee the investments that allow the operation of the plants. Administrative simplification or a call for auctions for technological renewal projects are measures that must be considered.[26]

Note: The authors wish to mention and express gratitude for the help received through the following project: Sostenibilidad Territorial del Modelo Energético Bajo en Carbono. Territorios y Energías Renovables - TERRYER (In English: Territorial Sustainability of the Low Carbon Energy Model. Territories and Renewable Energies - TERRYER). Ministerio de Economía y Competitividad, Gobierno de España (Entity: Department of Economy and Competitiveness, Government of Spain). Reference: CSO2017-84986-R - http://grupo.us.es/terryer/index.php.

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