Small Hydropower in Uruguay – a brief overview

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Key Facts

Population	3,473,727 (2020)[1]
Area	176,215 km[2]
Topography	Uruguay has a low and slightly sloping topography with an average elevation of 116.7 metres above sea level. The relief is homogeneous, with two large structural areas: peneplains and plains. The peneplains are gently undulating reliefs that extend over most of the country's territory and contain rounded hills with a wide base, which are known as cuchillas and reach a maximum height of 514 metres. The plains extend in the peripheral areas of the Uruguay River, the River Plate and the Atlantic Ocean.[2,3]
Climate	Throughout its entire territory Uruguay has a homogeneous climate characterized as a temperate-humid one without a dry season. The average annual temperature is 17.5°C, with a maximum average of 19°C in the north and 16°C on the Atlantic coast. The average temperature in winter is 11.5°C and in summer 23.9°C. The minimum temperatures occur in winter, generally in July; and the maximum temperatures occur in summer, generally in January.[3,4,5]
Climate Change	Uruguay is considered a vulnerable country to climate change, as per the Notre Dame GAIN vulnerability index. Climate vulnerability in the energy sector is expected to become more apparent through the following physical and social factors: rising temperatures, water cycle disruptions, and exacerbated stress on existing integrated watershed management practices. The average annual temperature is showing an increasing trend. The year 2017 was one of the warmest years on record with an average temperature of 18.7°C, a maximum average of 24.1°C and a minimum average of 13.2°C.[6] Using IPCC scenarios RCP4.5 and RCP8.5, average temperature increases by 2030 oscillate between +0.6°C and +0.9°C in the best case, and between +0.8°C a +1.1°C under the worst scenario. By the year 2100, these same scenarios predict an increase of between +1.0°C and +1.5°C under RCP4.5 and values between +1.5°C and +3.5° for RCP8.5. Studies have also detected an increase in average precipitation between 1961 and 2017 with an average increase of 10 per cent in the north of the country and 15–20 per cent in the south.[7] On average, a trend has emerged with an average increase in precipitation of 60mm

	between the 1979-2001 and 2001 – 2014 period. This trend is expected to increase moderately as the consequences of climate change increase.
Rain Pattern	Average annual rainfall is approximately 1,300–1,400 mm. Precipitation demonstrates considerable annual variability with a minimum average of 900 mm recorded in 1989 and a maximum average of 2,100 mm recorded in 2002, according to the statistical period of 1980–2009.[6] On average, precipitation is equally distributed across the four seasons of the year (300–350 mm in each season).[7] The phenomena that affect the rainfall patterns in Uruguay the most are the Niño-Southern Oscillation, which increases precipitation probability, and La Niña, which generates prolonged and deep droughts. Both phenomena could become more frequent with an increase in the average global temperature.[8]
Hydrology	The main water basins in the country are the Uruguay River in the west, the River Plate in the south-west, the Black River in the centre of the country, the Santa Lucia River in the south, the Atlantic Ocean in the south-east and the Merin Lagoon in the centre-east. The Uruguay River (100,000 km^2 basin in Uruguay), the River Plate, the Black River and the Santa Lucia River belong to the main basin of the River Plate.[9] The River Plate Basin has a total area of 3,100,000 km^2, making it the fifth largest in the world, and covers five countries: Argentina, Bolivia, Brazil, Paraguay and Uruguay.[10] The Merin Lagoon and the basin of the Atlantic Ocean pour directly into the Atlantic Ocean.[11]

Electricity Sector Overview

In 2019, the installed electricity capacity of Uruguay stood at 4,920 MW. Of the total, 31 per cent came from hydropower, 31 per cent from wind power, 9 per cent from biomass, 5 per cent from solar photovoltaics (PV) and the remaining 24 per cent from fossil fuel thermal plants (Figure 1).[12] The installed capacity increased by 80 per cent in the last 10 years (compared to 2,690 MW in 2010), mainly due to the installation of 1,473 MW of wind power capacity, 253 MW of solar power and 540 MW of thermal power (combined cycle).[12]

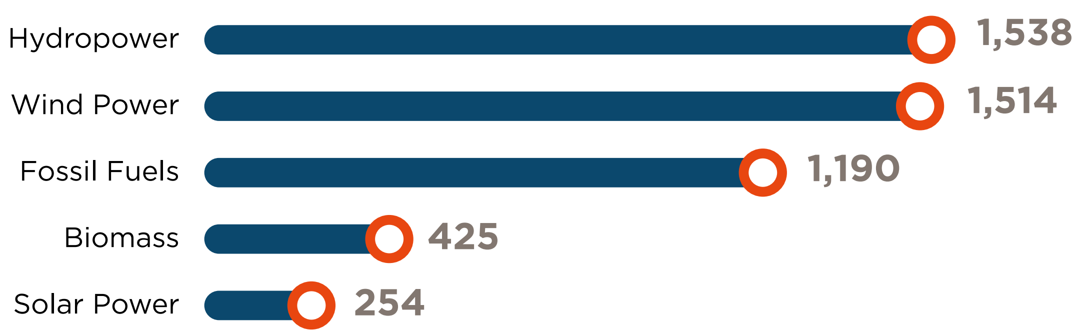

Figure 1. **Installed Electricity Capacity by Source in Uruguay in 2019 (MW)**
Source: MIEM[12]

Most of the hydropower potential in Uruguay (estimated at 1.8 GW), has been utilized, making it the country with the highest hydropower potential utilization rate in the region (85 per cent).[13] Of the 1,538 MW of the total installed hydropower capacity, 108 MW correspond to the Baygorria hydropower plant, 152 MW to Gabriel Terra, 333 MW to Constitucion and 945 MW to Salto Grande (50 per cent of the plant's capacity of 1,890 MW belong to Uruguay).[14]

Electricity generation in 2019 amounted to 16,088 GWh, of which 50 per cent was from hydropower, 30 per cent from wind power, 15 per cent from biomass, 3 per cent solar power and 2 per cent fossil fuel thermal power (Figure 2).[12] The maximum demand was 11,023 GWh and the maximum power was 2,121 MW. Electricity consumption per capita in 2019 stood at 3.22 MWh and has showed an average annual growth of 2 per cent over the last decade. The electrification rate in the country is 99.8 per cent, with 99.9 per cent in urban areas and 98.9 per cent in rural areas.[12]

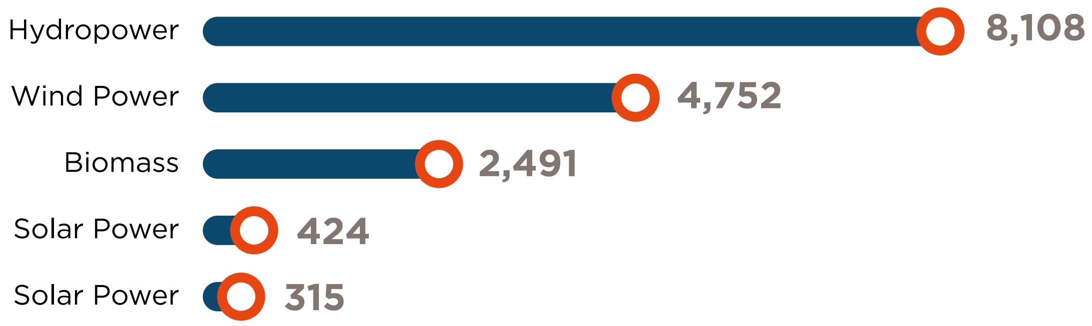

Figure 2. **Annual Electricity Generation by Source in Uruguay in 2019 (GWh)**
Source: MIEM[12]

The electricity system of Uruguay is interconnected with that of Argentina via the 132/150 kV Concepción-Paysandú interconnection of 100 MW and the 500 kV Salto Grande transmission quadrilateral, which is composed of the 1,890 MW Salto Grande interconnection line and the 1,386 MW Colonia Elía-San Javier interconnection line. Uruguay is also connected to the electricity system of Brazil via two 50Hz/60Hz frequency converters: Santa Ana de Livramento with a capacity of 70 MW and the Melo converter with a capacity of 500 MW. From 2013 to 2019, Uruguay was a net exporter of electricity (Figure 3).[15] In 2019, the country exported 3,012 GWh of electricity (80 per cent to Argentina and 20 per cent to Brazil).[16]

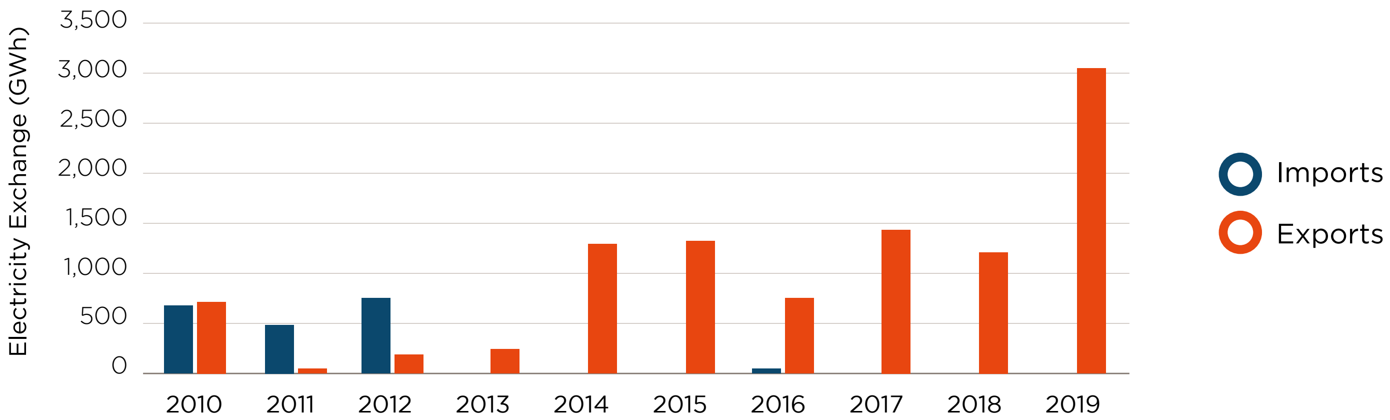

Figure 3. **Electricity Exports and Imports of Uruguay in 2010–2019 (GWh)**
Source: MIEM[15]

The electricity transmission system of Uruguay is composed of 5,790 kilometres of high-voltage lines (500 kV, 230 kV, 150 kV and 60 kV). The electricity distribution system consists of 4,960 kilometres of 60 kV and 30 kV lines; 53,097 kilometres of 22 kV, 15 kV and 6 kV lines; and 28,178 kilometres of 230 V and 400 V lines. There are 3,902 medium-voltage substations and 4,684 medium-voltage/low-voltage substations.[16]

The electricity mix of Uruguay has undergone a significant transformation over the last 10 years. Until 2007, it was mainly composed of hydropower and thermal power generation from fossil fuels. This created high dependence on rain patterns, electricity exchanges with the neighbouring countries and fuel imports. In 2007, Uruguay incorporated a significant proportion of biomass into its electricity mix, while the first wind farm in the country began to operate in 2009. Already in 2017 the country's mix of electricity sources was highly diversified, with more than 1,500 MW of wind power capacity, 420 MW of biomass and 240 MW of solar power. The clear regulatory framework, tax incentives for the private sector and financial innovation that increased the bankability of the projects were key for this transformation.[17]

Currently, there are 43 wind farms that generate and sell electricity to the public electric utility the National Administration of Power Plants and Electrical Transmissions (UTE) through power purchase agreements (PPA). Of these, 38 are fully privately owned under a public-private partnership (PPP).[17] The financial models of these projects vary: three wind farms were fully publicly financed, four received partial public financing (from 6 per cent to 50 per cent), 40 were fully privately financed and three are owned by UTE. For the last group of projects UTE emitted fix-rate bonds and shares to finance between 10 per cent and 24 per cent of each project.[17]

The electricity sector of Uruguay is governed by Law 18.632/97 New Regulatory Framework for the Electricity Sector. The sector is regulated by the Energy and Water Services Regulation Unit (URSEA), which was assigned greater control competence by the 2020 Emergency Consideration Law (Law 19889), and the National Energy Directorate under the Ministry of Industry, Energy and Mining (MIEM). The entity in charge of planning and operating the electricity system is the Electricity Market Administration (ADME).

The public electricity utility, UTE, is a decentralized and vertically integrated state agency founded in 1912 and governed by an Organic Law (Law 15,031/80). The responsibility of UTE is to guarantee the sustainably of the electricity services provision to its 1,512 million customers (2019).[16] UTE owns generation assets and has a monopoly on electricity transmission and distribution in the country. In the generation subsector, UTE participates with approximately 38 per cent of the system's installed capacity and an additional 7 per cent as a co-owner. Furthermore, the Salto Grande binational hydropower project accounts for 19 percent of the total installed capacity, while the rest is owned by the private sector.[16] Private parties are free to participate in the generation sector and can either sell their electricity on the spot market or sign PPAs with the electric company. The generation units of UTE are dispatched according to their marginal cost.

Electricity tariffs are proposed by UTE and approved by the Government with the authorization (not binding) of URSEA and the Office of Planning and Budget (Law 16.832). URSEA is responsible for calculating the technical reference fee. There are several types of residential tariffs: simple residential, basic residential, general simple, double hour, triple hour and general seasonal hour (Table 1).[18] The double hour, triple hour and general seasonal hour tariff categories were established to encourage greater demand management and system efficiency. There are also several energy efficiency programmes that have an impact on the affordability of the electricity services. In addition, there are various tariffs for medium- and large-scale consumers.

Table 1. **Residential Electricity Prices by Category in Uruguay in 2021**

Tariff category	Price (US$)		Description
	Fixed charge	Variable per kWh	
Residential simple	5.42 + 1.68 per kW of power contracted	0.14	Consumption of 1–100 kWh per month
		0.18	Consumption of 101–600 kWh per month
		0.22	Consumption > 601 kWh per month
Residential double schedule	9.78 + 1.68 per kW of power contracted	0.23	Peak hours: 4 consecutive hours between 17:00 and 23:00
		0.09	Off-peak hours (Saturday, Sundays, holidays)
Residential triple schedule	9.78 + 1.68 per kW of power contracted	0.23	Peak hours: 4 consecutive hours between 17:00 and 23:00
		0.12	Shoulder hours: rest of the hours
		0.05	Valley hours: 0:00 to 7:00
Residential basic	8.79	0.18	Consumption of 101–140 kWh per month
		0.33	Consumption of 141–350 kWh per month
		0.22	Consumption > 351 kWh per month

Source: UTE[18]

Small Hydropower Sector Overview

In Uruguay, small hydropower (SHP) plants are defined as hydropower plants with an installed capacity between 1 MW and 50 MW. Pico-hydropower is defined as less than 5 kW, micro-hydropower as between 5 kW and 100 kW and mini-hydropower as between 100 kW and 1 MW.[19] Currently, in Uruguay there are no hydropower plants in operation of less than 50 MW of capacit. Installed and potential capacity of SHP have remained unchanged since 2013 (Figure 4). Compared to the World Small Hydropower Development Report (WSHPDR) 2019, both the installed and potential capacity have remained unchanged (Figure 4).

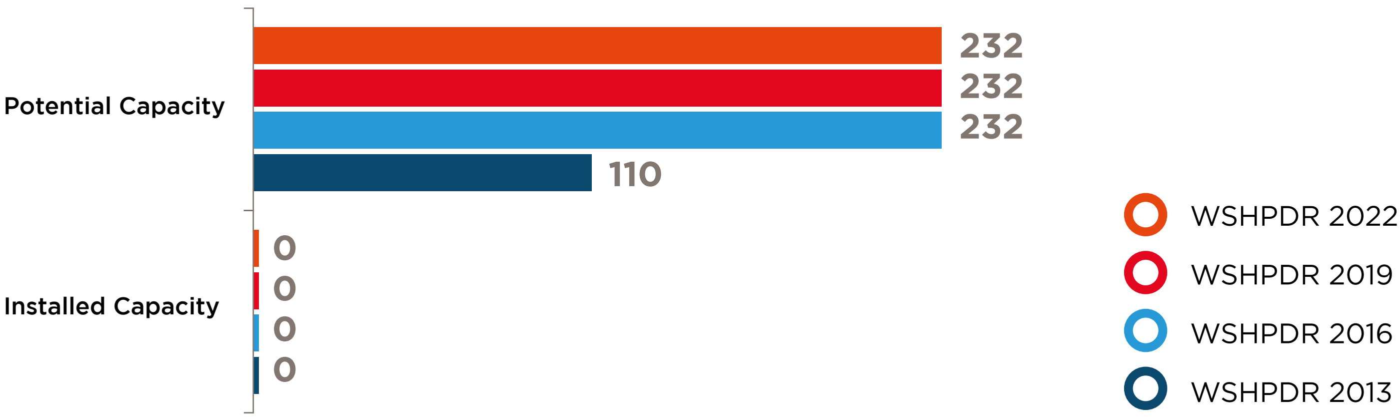

Figure 4. **Small Hydropower Capacities in the WSHPDR 2013/2016/2019/2022 in Uruguay (MW)**
Source: Schenzer et al.,[19] WSHPDR 2013,[20] WSHPDR 2016,[21] WSHPDR 2019[22]
Note: Data for SHP up to 50 MW.

Within the framework of the Energy Policy 2005–2030, in 2006 UTE opened a tendering process for PPAs for up to 60 MW of renewable energy capacity from wind power, biomass and SHP (Decree 77/006). The objective was to award 20 MW per technology on an equitable basis. However, although UTE received bids that exceeded the target for the first two technologies, no bids were received for SHP. Following this situation, no new initiatives have been undertaken by the Government for new SHP projects.[23]

In terms of potential SHP projects for generation only, a study developed by the University of the Republic of Uruguay (UDELAR) with the support of the Inter-American Development Bank (IDB) and Fundación Ricaldoni identified 70 potential sites for a total capacity of 231.5 MW and an annual generation of 1,431 GWh. At each of the identified sites, at least 1 MW of capacity could be installed without affecting protected areas, population centres or major communication routes. Of the identified sites, two are over 10 MW (12.8 MW and 10.7 MW) and the rest are of less than 10 MW. The study selected five of the 70 potential sites to evaluate potential capacity, generation, environmental impact and economic and financial feasibility. Of these, four demonstrated to be economically feasible (Table 2).[19]

Table 2. **List of Selected Potential Small Hydropower Sites in Uruguay**

Name	Potential capacity (MW)	Capacity factor (%)	Estimated annual generation (GWh)
Arapey 80 m	7.00	7.00	7.00
Arapey 130 m	3.70	3.70	3.70
Yerbal 88 m	2.60	2.60	2.60
Arerungua 90 m	8.90	8.90	8.90

Source: Schenzer et al.,[19] WSHPDR 2016[21]
Note: Based on data from 2013

UDELAR, with the financial support of IDB, also carried out a study of 913 dams existing in the country to assess the possibility of developing new SHP plants on them and making them multipurpose.[24] As a result, 20 existing dams with the highest generation potential were selected for a pre-feasibility analysis. Considering a continuous irrigation scenario, the annual generation of the projects would vary between 60 MWh and 1,700 MWh with a mean of 380 MWh. Only 14 projects have a positive Internal Rate of Return (IRR), with an average IRR of 4.65 per cent and a maximum of 8.8 per cent. The continuous irrigation scenario is estimated to be the most beneficial one in terms of the IRR.[24] Additionally, UDELAR undertook a pre-feasibility analysis of 17 most promising new multipurpose dams with irrigation as the priority activity and hydropower generation as secondary.[24] The power range of these dams was estimated at 11–569 kW with a mean of 130 kW for continuous irrigation and at 34–1,706 kW with a mean of 385 kW if used with intermittent irrigation. According to the study, there are 14 cases with a positive IRR, ranging from 0.3 per cent to 8.8 per cent, with a mean of 3.3 per cent, when considering continuous irrigation. There are six cases with a positive IRR ranging from 0.7 per cent to 6.7 per cent with a mean of 1 per cent when considering intermittent irrigation.[24] These studies provide a solid foundation for the development of SHP projects in Uruguay, both on new and existing dams. Nonetheless, as mentioned in the document, the sector has been more interested in developing other renewable energy sources in recent years.

Renewable Energy Policy

In 2008, the Government of Uruguay approved the Energy Policy 2005–2030 based on four axes: institutional, supply, demand and social. For each of the axes, the policy set general and specific objectives. With regard to supply, it established specific goals for 2015, including the contribution of domestic renewable energy sources to the country's primary energy mix as well as a 15 per cent share of non-conventional renewable sources (wind power, biomass waste, micro-hydropower) in the country's electricity generation.[25] This goal has been achieved, with electricity generation from non-conventional renewable sources having surpassed 20 per cent already in 2014.[12] The Energy Policy was endorsed by all political parties with parliamentary representation, which provided clarity and certainty to private actors. Furthermore, as of the moment of writing of this chapter the Government was working on the design of the Energy Agenda 2020–2050, which was expected to be issued in 2022.

Internationally, Uruguay ratified the Paris Agreement and submitted its Nationally Determined Contribution (NDC) in 2017, setting specific mitigation measures for the energy sector.[26] The NDC includes mitigation targets for the wind power, solar power and biomass total installed capacity, which have already been exceeded by 104 per cent, 110 per cent and 110 per cent, respectively.[27] The current NDC also includes adaptation targets. In 2022, and in line with the Paris Agreement, Uruguay will present its second NDC, with more ambitious mitigation and adaptation targets. In December 2021, Uruguay also presented its long-term strategy for low greenhouse gas emissions development. This document lays a path to increase adaptation to the climate crisis and promote weather resilience.[28] The main goal of the LTS however, is to illustrate the country's aspirational goal of reaching net zero CO_2 emissions by 2050. The long-term strategy is aligned with the National Policy of Climate Change of 2017 and will help guide the definition of future national climate commitments.

Small Hydropower Legislation and Regulations

Within the framework of the National Water Policy (Law 18,610), Decree 205/017 approved the National Water Plan. It establishes several programmes and projects for integrated water management. These are focused on sustainability and risk control, development of management plans and information and capacity building systems. The plan also establishes the importance of large-scale hydropower but recognizes that there is no potential for additional new large- and medium-scale projects. Additional hydropower capacity may come from the modernization and repowering of existing large-scale plants or smaller-scale projects. Ultimately, the plan recognizes that viable SHP projects are those resulting from new or existing multipurpose reservoirs. For multipurpose dams with potential capacity of less than 10 MW (irrigation and generation), irrigation is to remain the priority water use.[29]

Law 16466 (Environmental Impact Assessment Law) establishes that for the construction or modernization of any power plant of more than 10 MW of any kind, including SHP plants, an environmental impact assessment (EIA) must be carried out. EIAs are also required for the construction of dams with a reservoir capacity greater than 2 million m^3 or whose water mirror exceeds 100 hectares and with water intakes with a flow greater than 500 litres per second.[30]

Furthermore, Decree 173/010 regulates bidirectional electricity exchange with the distribution network for micro-generators. It allows subscribers to generate electricity for self-consumption and to inject the surplus into the distribution network if the maximum current generated in low voltage does not exceed 16 A or 25 A for single-wire ground return.[31]

Finally, a range of investment promotion policies also apply to potential SHP projects. Thus, Law 16906 on Investments and Industrial Promotion declares of national interest the promotion and protection of investments made in the national territory. It provides important incentives and tax benefits to companies that make investments. In particular, Decree 354/009 declares of national interest the investments in projects of domestic and renewable energy generation, including SHP. Such projects will receive the benefits established by Law 16906. According to Decree 354/009 and then Decree 2/012, Decree 143/018 and Decree 268/020, projects score in various defined policy areas and according to the final score companies can exempt a percentage of the value of the investment project in taxes.[32,33,34]

Barriers and Enablers for Small Hydropower Development

The main barriers to the implementation of SHP projects in Uruguay include the following:

- The annual variability of rainfall in the country is greater than the annual variability of wind and sun. The average solar and wind power generation in a quarter will be similar to any other quarter in the same historical series. However, to find two similar hydraulic years in terms of average production, a 20-year moving window should be used.[35] The variability of hydrological conditions therefore implies an additional risk for SHP developers compared to wind or solar energy.
- High transactional costs for projects that require new dams and reservoirs due to the need to obtain several approvals with different agencies (National Energy Directorate, National Water Directorate, Ministry of Environment, General Directorate of General Resources, UTE, etc.) and the lack of experience in the processing of this kind of projects.[36]
- Higher investment costs compared to other non-conventional renewable energy technologies such as wind and solar power, which have seen a significant cost reduction in recent years.[36]
- The small scale of potential projects and the difficulty of standardization affect the interest of suppliers to participate and the chances of obtaining competitive prices.
- There are socio-environmental restrictions for the construction of projects involving the development of new reservoirs or dams.
- High perceived risk of hydropower development, compared with other non-conventional renewable energy projects such as wind and solar power, which affects investment conditions.
- Limited tariff incentives that remunerate all the services that SHP plants can provide, such as peaking power, for instance.
- Limited experience and knowledge of the different stages of SHP projects (planning, implementation, operation, and maintenance).[22]

In spite of the listed barriers, opportunities for SHP development in Uruguay exist, in particular taking into account the following factors:

- Availability of untapped SHP potential and data on sites suitable for development;
- The policy framework favouring the exploitation of domestic renewable energy technologies, including SHP.

Further initiatives that could be considered to support the implementation of SHP projects in the country, with a focus on multipurpose projects which are the most promising ones, could include:

- Review of the regulatory framework to allow appropriate retribution to all services that SHP can provide;
- Development of guidelines to facilitate and/or clarify permitting processes;
- Promotion of the development of SHP on already built multipurpose projects where significant investments on civil works are already done;
- Promotion of knowledge of SHP development.

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