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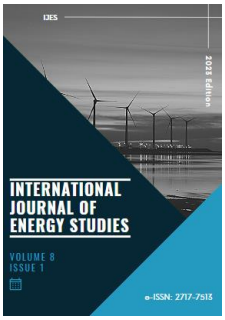



Review Article

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## Small hydropower development in Turkey: An overview of 2021


**Alaeddin BOBAT**

*Kocaeli University, Faculty of Agriculture, Arslanbey Campus 41285 Kartepe, Kocaeli, Turkey, ORCID: 0000-0003-4654-0208*

*(*Corresponding Author: bobatus@gmail.com)*


**Highlights**

- A very small part of the installed capacity such as about 1.757 MW belongs to small hydroelectric power plant.
- Most of these small power plants are also concentrated in the eastern Black Sea Region.
- The vast majority of SHPs in Turkey (96.23%) are private, and very few of them (3.27%) are built by the public sector.
- Installed capacity increased from 175 MW in 2013 to 1.156,4 MW in 2016; continued to increase to 2.961,3 in 2019; but decreased to 1.662,2 MW in 2021.
- The potential capacity was 6.500 MW between 2013 and 2019, and decelerated to 4.891.5 MW in 2021.


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## ABSTRACT

Hydropower plants with an installed capacity of less than 10 MW are widely considered as small hydropower (SHP) in Turkey. There are currently 371 SHPs in operation as of 31 December 2021. Of these, 14 are operated by the DSI and 357 are operated by the private sector; and the installed capacity of the operating SHPs is 1.756,69 MW, their total generation potential is 6.643,44 GWh/year. Moreover, 12 SHPs are under construction. In addition, 625 SHP projects of 2.645,56 installed capacities and of 8.728,460 GWh/year generations potential were cancelled. Regionally, 34.50 % of SHPs (128 SHP) is located in the Black Sea Region of Turkey. 20.75 % of them (77 SHP) is located in the Mediterranean Region; 16.71 % (62 SHP) in the Eastern Anatolia Region; 12.94 % (48 SHP) in the Central Anatolia Region; 8.09 % (30 SHP) in the Marmara Region; 6.2% (23 SHP) in the Aegean Region and 0.08 % in the South-East Region. This article intends to discuss SHP's in 2021 of Turkey as a whole and examine the place and importance of SHP's in the sector.



**Keywords:** Hydropower, SHP, development, Turkey

## 1. INTRODUCTION

Hydroelectric power plants; it is the most important renewable energy source in terms of obtaining energy from water, creating no greenhouse gas emissions, building with local facilities, long technical life and lack of fuel costs, low operating maintenance costs, creating employment opportunities, revitalizing economic and social structure in rural areas [1,2].

In recent years to meet Turkey's growing demand for energy and to minimize its dependence on foreign energy there has been a great trend towards hydroelectric energy. The most important contribution of using hydropower to the economy and the environment is to reduce dependence on external energy and mobilize clean energy sources [3,4].

Hydropower development in Turkey has been carried out for about a century for different purposes, namely electricity generation, land irrigation, water supply for domestic and industrial utilization and flood control in the surrounding area. Therefore, since its inception, the construction of water storage facilities and hydro plants has always been given priority by the Republic of Turkey.

Because of increasing concern regarding greenhouse gas emissions and global warming phenomena in recent years, there is worldwide renewed interest in hydropower investments, especially in small hydro development. Small hydro plants offers significant benefits in terms of faster deployment, distributed generation, small business opportunities, and significantly reduced concerns about regional environmental/ecological system disturbances, although their cost of energy generation is usually higher than from large hydro plants [2-4].

Hydroelectric power together with other renewables already accounts for about 50% of electricity demand, and there is much additional potential for growth. Turkey’s electric power demand has been developing steadily, averaging 8-10 % annual growth over the past 20 years. Turkey is rapidly growing in terms of both its economy and its population. In parallel, its demand for energy, particularly for electricity, is increasing fast. Turkey's electricity consumption increased by 7.7% compared to the previous year to 329.6 billion kWh in 2021, while electricity generation increased by 8.1% compared to the previous year to 331.5 billion kWh [5-8].

In cooperation with the public - private sector, 743 Hydroelectric Power Plants with an installed capacity of 31.647 MW and a power generation potential of 109 billion kWh has been completed and put into service. From 743 facilities; 68 plants with an installed power of 13.766 MW with a power generation potential of 49 billion kWh by DSI; 675 plants with an installed power of 17.881 MW and a power generation potential of 60 billion kWh had been built by the private sector and put into operation as of December 31$^{th}$, 2021 [9,10]. A very small part of the installed capacity such as about 1.757 MW belongs to small hydroelectric power plant and most of these small power plants are also concentrated in the eastern Black Sea Region [11].

In this article, Small Hydropower Plants (SHPs) in Turkey are discussed as a whole and the place and importance of SHPs in the sector is examined.

## 2. SMALL HYDROPOWER DEVELOPMENT IN 2021 OF TURKEY

Hydropower installations can be classified by size of power output, although the power output is only an approximate diversion between different classes. There is no international consensus for setting the size threshold between small and large hydropower. Classification according to size has led to concepts such as "*small hydro*" and "*large hydro*", based on installed capacity measured in MW as the defining criterion. Small-scale hydropower plants (SHP) are more likely to be run-of-river (RoR) facilities than are larger hydropower plants, but reservoir (storage) hydropower stations of all sizes will utilize the same basic components and technologies. Compared to large-scale hydropower, however, it typically takes less time and effort to construct and integrate small hydropower schemes into local environments. For this reason, the deployment of SHPs is increasing in many parts of the world, especially in remote areas where other energy sources are not viable or are not economically attractive. Nevertheless, there is no worldwide consensus on definitions regarding size categories. Many countries have made a definition according to their own legal and technical rules [12]. Although there is also no legal definition in Turkey, hydropower plants with an installed capacity of less than 10 MW are widely considered as small hydropower (Table 1).

**Table 1.** SHP definitions by installed capacity (MW) in various countries

| **Country** | **MW** | **Country** | **MW** |
|---|---|---|---|
| Brazil | ≤ 30 | Armenia | ≤ 30 |
| Canada | < 50 | Azerbaijan | ≤ 10 |
| China | ≤ 25 | Georgia | ≤ 13 |
| EU Linking Directive | ≤ 20 | Iraq | ≤ 10 |
| India | ≤ 15 | Jordan | ≤ 12 |
| Norway | ≤ 10 | Lebanon | ≤ 10 |
| Sweden | ≤ 1.5 | Syria | ≤ 10 |
| Turkey | < 10 | USA | 5 ≤ W ≤ 100 |

Turkey's hydraulic potential is 55.000 MW, and the share of hydraulic installed power has reached 31.647 MW from 11.175 MW in 2000 as of 31 December 2021, in total installed power is about 33 %.

As of December 31th, 2021, 371 SHPs are operated in Turkey. 14 of these facilities are owned by DSI (State Hydraulic Works) and 357 of them are privately owned.

The installed capacity of the operating SHPs is 1.756,69 MW, their total generation potential is 6.643.544 GWh/year. Moreover, a total of 12 SHP is under construction by the private sector. The installed capacity of the SHPs under construction will be 60.07 MW, and the generation potential will be 229.728 GWh/year. 85 SHP projects are at the stage of inspection. In addition, 625 SHP projects of 2.645,56 MW installed capacities and of 8.728.460 GWh/year generations potential were cancelled (Table 2) [10-11].

The vast majority of SHPs in Turkey (96.23%) are private, and very few of them (3.27%) are built by the public sector (Figure 1).

SHP capacities vary decently between 2013 and 2021. Installed capacity increased from 175 MW in 2013 to 1.156,4 MW in 2016; continued to increase to 2.961,3 in 2019; but decreased to 1.662,2 MW in 2021. The potential capacity was 6.500 MW between 2013 and 2019, and decelerated to 4.891.5 MW in 2021 (Figure 2) [13-16].

**Table 2.** SHP's development in 2021 of Turkey

| Stage of Project | Operator (Public/Private) | Number | Installed Capacity (MW) | Generation Potential (GWh/year) |
|---|---|---|---|---|
| In Operation | DSI(Public) | 14 | 42.57 | 145.100 |
| | Private | 357 | 1.714,12 | 6.498.444 |
| | Total | 371 | 1.756,69 | 6.643.544 |
| Under Construction | Private | 12 | 60.07 | 229.728 |
| | Total | 12 | 60.07 | 229.728 |
| Inspection and Project | Private | 85 | 428,88 | 1.525.271 |
| | Total | 85 | 428,88 | 1.525.271 |
| Total potential(Operation-construction-inspection-project) | | 468 | 2.246,63 | 8.398.543 |
| Cancelled SHP projects | | 625 | 2.645,56 | 8.728.460 |
| Total potential of SHPs | | 1.093 (58%) | 4.892,19 (9%) | 17.127.003 (9.5%) |
| Potential General | | 1.863 | 55.000 | 180.000 |

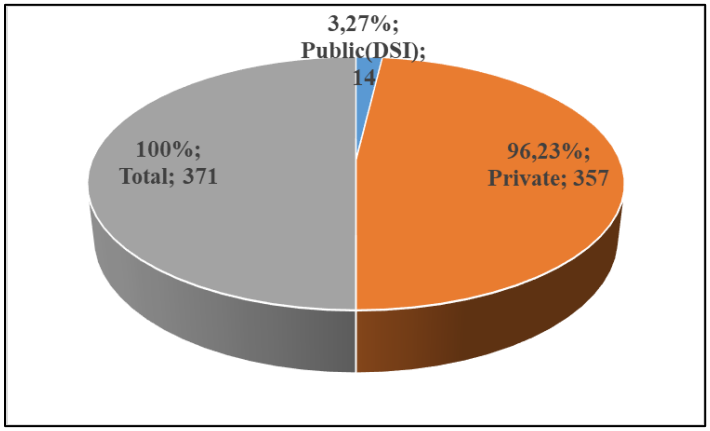


**Figure 1.** Breakdown of SHPs by Organization

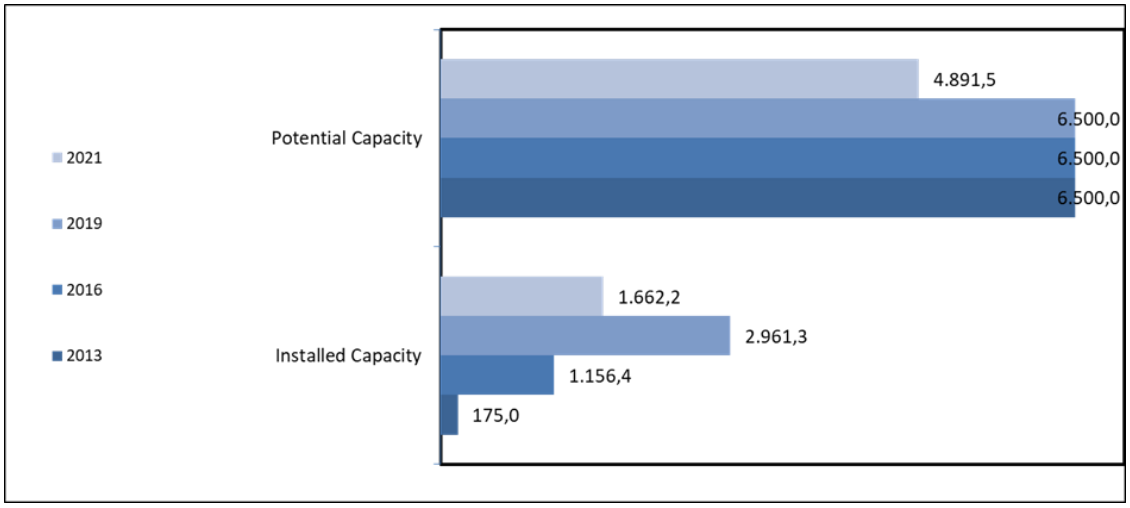


**Figure 2**. The changes in SHP capacities between 2013 and 2021

The construction of those built by the Public from these facilities is carried out by DSI and the operation is transferred to EUAS. The SHPs in Turkey belonging to public is operated by EUAS. The reason for these changes is the commissioning of new projects and the cancellation of some projects. Also, this amount indicates economically operable SHPs and the described projects.

## 3. REGIONAL AND URBAN BREAKDOWN OF SHPs IN TURKEY

The regional distribution of facilities is also highly variable in Turkey. Regionally, 34.50 % of SHPs (128 SHP) is located in the Black Sea Region of Turkey [11]. 20.75 % of them (77 SHP) is located in the Mediterranean Region; 16.71 % (62 SHP) in the Eastern Anatolia Region; 12.94 % (48 SHP) in the Central Anatolia Region; 8.09 % (30 SHP) in the Marmara Region; 6.2% (23 SHP) in the Aegean Region and 0.08 % in the South-East Region(Figure 3).

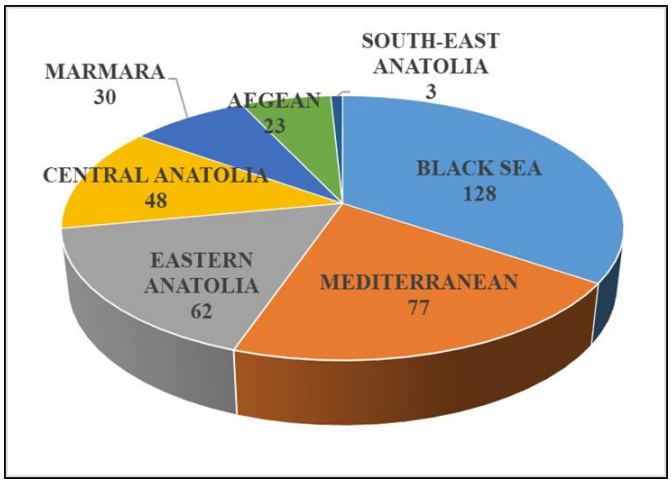


**Figure 3.** Regional Breakdown of SHPs in Turkey

From these data, it is understood that the facility is most concentrated in the Eastern Black Sea Region.

The most facilities in the Eastern Black Sea Region are located in Trabzon. The number of facilities in Trabzon is 33. It is followed by Kahramanmaraş in the Mediterranean Region with 21 facilities. The number of facilities in Sivas and Giresun provinces is equal to each other and there are 18 facilities in both provinces. The provinces with 10 and more SHPs are Bursa, Sakarya, Osmaniye, Erzurum, Malatya, Antalya, Sivas, Kahramanmaraş, Trabzon, Giresun, Kastamonu and Artvin (Figure 4).


**Figure 4.** Urban breakdown of SHPs in Turkey

## 4. CONCLUSION AND RECOMMENDATIONS

The need for saving water and energy has grown as one of the world main concerns over the last years and it will become more important in the near future. Excessive increase in oil and natural gas prices in last 15 years has made renewable energy sources become important than ever. Hydropower is a renewable energy source most widely used all around the world [17].

The biggest obstacle to growth for the Turkish economy is the excessive need for import-dependent energy. Especially in recent years, with the widespread use of natural gas in Turkey, natural gas consumption has increased both in homes and in industry. Especially considering the decrease and disruptions in energy supply security after the Russian-Ukrainian war, it has become very important to use the renewable energy potential, which is Turkey's own resources, to the maximum extent. Since Turkey lacks important energy sources such as natural gas and oil, it has to endure a large current account deficit, especially in energy expenses. To meet this increasing demand for electrical energy and to minimize the current account deficit, Turkey has to commission all the renewables. In this context, the development of hydroelectric potential and its presentation for the benefit of the country's economy will be possible by increasing the share of hydroelectric energy in total energy generation along with other renewable energy sources.

Turkey utilizes diverse energy sources to meet its electricity demand. Even though fossil power plants occupy a major part of energy generation (about 57% of the total installed capacity), renewable energy sources such as hydropower, wind, geothermal and solar power are also

significant contributors to meeting the energy demand of the country. Among these renewable energy sources hydropower accounted for 33 % of electricity generation in 2021.

Total potential of SHPs in Turkey is about 4.892 MW and total generation potential is about 17.127 GWh/year. Very little of either potential is being used. Moreover, it seems that 625 SHP projects with an installed capacity of 2.645,56 MW and a generation potential of 8.728.460 GWh/year have been cancelled. SHP projects abandoned by the investor for various reasons should be re-evaluated and their construction should be started after they are made efficient. Some SHP projects should be included in the investment program by DSI considering environmental, social and cultural sensitivities [18] and the hydroelectric energy to be obtained from these facilities should be brought to the economy. Besides SHPs have found special importance due to their relatively low administrative and executive costs and a short construction time compared to large power plants. But to take investment decision, cost is an important factor. The cost of SHP schemes comprises cost of civil works and electromechanical equipment. The cost of civil works can be estimated based on actual quantities of various items as per design drawings, but cost of electro-mechanical equipment, depend on budgetary quotations of the manufactures. An average SHP plant costs USD 1.5 million per MW of installed capacity. Price per unit of generation varies tremendously due to very different precipitation regimes in different parts of the country. The cost of electromechanical components in large hydro is around 20% but in SHP it is relatively high and varies from 35-40% of the total project cost [16, 19-22].

Turkey, which has many small running waters, is actually an advantageous country in terms of small hydro powers. In most of the sites of small-hydro plants the primary requirement of the local agricultural land as their survival depends upon it. Therefore, many of small hydropower plants are normally operated to serve customer in remote area. When electricity and water are available able, the living standards will be enhanced by better education, internet, job opportunities, communication and others facilities. Also, they create job opportunities in rural areas addressing prevent migration to other places.

Over the past years SHP installed capacity has steadily increased. However, SHP still has to face barriers of different types as legal, social and environmental issues. Legally, Renewable Energy Law No. 5346 applies to small hydropower or hydropower generation facilities having a reservoir area less than 15 square kilometres making no limitation regarding installed capacity. This

guideline encourages the private sector to move towards investment in large hydropower systems for the potentially higher profits. Socially environmental reactions of public opinion against hydropower facilities could affect the investors, due to wrong or inappropriate site selection, exclusion of stakeholders, and unplanned basin management. And environmentally Turkey is among the countries most affected by climate change or variability. Therefore, SHP investments are adversely affected due to the decrease in surface waters.

EMRA amended the new unlicensed generation regulation and decided that "generations exceeding 1 million Kwh will be reflected as a '*free contribution*' to YEKDEM". In other words, from now on, investors who build small unlicensed power plants to meet the electricity needs of their own enterprises will be able to use as much electricity as their own needs and will not be able to sell their excess electricity. Surplus needs will be provided free of charge to electricity supply companies and YEKDEM system. This decision, which is a method contrary to the market economy, has the nature of an application that will disrupt renewable energy investments.

By eliminating all these negative factors, it is possible to construct and operate small hydroelectric power in a sustainable sense within a certain plan. Apart from all this, both small and large hydroelectric power plants in Turkey should not only increase energy production, but also production and distribution should be carried out in accordance with measurable standards.

## DECLARATION OF ETHICAL STANDARDS

The author of the paper submitted declares that nothing which is necessary for achieving the paper requires ethical committee and/or legal-special permissions.

## CONTRIBUTION OF THE AUTHORS

**Alaeddin Bobat:** Wrote the manuscript.

## CONFLICT OF INTEREST

There is no conflict of interest in this study.

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