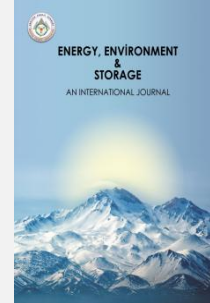




# Energy, Environment and Storage

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## Hydroelectric Power Overview in 2021 of Turkey

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**ABSTRACT:** Hydroelectric power together with other renewables already accounts for about 50% of electricity demand, and there is much additional potential for growth. 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 electric power demand has been developing steadily, averaging 8-10 % annual growth over the past 20 years. 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. According to the Strategic Plan of the Ministry of Energy and Natural Resources for 2019-2023, while the total installed capacity will be about 32.9% in 2023, but this figure has already been reached. In cooperation with the public - private sector, 743 Hydroelectric Power Plants (public +private) with an installed capacity of 31,647 MW and a power generation potential of 108,932 GWh/year have been completed and put into service. Construction of those made by the public from these facilities is carried out by the DSI (State Hydraulic Works) and their operation is transferred to EUAS (Electricity Generation Corporation), while those made by the private sector, except for the EMRA license, other (water Use agreement, project, construction, water structures acceptance, etc.) operations are performed by DSI. From 743 facilities, 68 plants with an installed power of 13,766 MW with a power generation potential of 49 GWh/year by DSI, 675 plants with an installed power of 17,881 MW and a power generation potential of 60 GWh/year were built by the private sector and put into operation. This study aims to overview the status of hydropower in 2021 data of Turkey.

**Keywords:** Hydroelectric, Turkey, Status, Overview

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### 1. INTRODUCTION

Water is a valuable resource that is gradually decreasing. Population growth, industrialization and urbanization have led to a significant increase in water consumption in the world. Contrary to the general perception, Turkey is neither a country rich in freshwater resources nor the richest country in its region [1,2]. On the other hand, energy, especially renewables, means development, prosperity, stability and quality of life for every country. Turkey's electricity consumption increased by 7.7% compared to the year 2020 to 329.6 billion kWh in 2021, while electricity generation increased by 8.1% compared to the year 2020 to 331.5 billion kWh. The provision of energy on site, on time and at reasonable prices is indispensable for development. The development status of countries is gaining value with the presence of sustainable energy sources. Sustainable energy is to be able to meet the needs of today without jeopardizing the resources necessary to meet the needs of future generations [3-7].

In parallel with the significant development of the Turkish economy in recent years, it is observed that the consumption of electrical energy has also increased. 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 for household and in industrial usages. 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 our country'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 [8-10].

The annual electricity consumption per capita in Turkey is at the level of 3.300 kWh, and this amount remains below the average electricity energy consumption of European countries. Since industrialization is a goal for ensuring the economic and social development of our country, it is of great importance that the energy needed by this industry and other users is met on the spot, on time and reliably. In this term, if economic recessions are not taken into account, electricity consumption in Turkey increases by 4-10% every year. In order to meet this demand, Turkey has to separate to spend 4 billion US dollars every year for new energy generation projects [6,11,12].

Since to have self-sufficient, continuous, reliable and economic electric power is a vital issue for Turkey as in the entire world, Turkey has to be definitely taken account of hydropower and other renewable energy alternatives which are local, independent and domestic energy sources in the form of being maximum benefit.

In addition, Turkey has to build more dams and hydroelectric power plants than other countries because it is not a country that receives rainfall every season due to its geographical location. Hydroelectric power plants are important due to their advantages such as environmental friendliness, revitalization of the economic and social structure in rural areas, low potential risk and the ability to respond to sudden changes in demand.

This article aims to consider hydropower as a whole and evaluate the data for the year 2021. In this context, first of all, Turkey's 2021 energy data are reviewed, and then hydropower is investigated in detail.

**2. ENERGY IN TURKEY : SUMMARY DATA OF 2021**

Structural arrangements made in recent years to encourage the use of renewable energy sources instead of imported sources in electricity generation continued to show their results despite the developments experienced during and as a result of the Covid-19 pandemic in the markets. In this context, the share of renewable energy sources, which was 51.4 % in 2020, including unlicensed electricity, increased to 53.34% in 2021. In addition, despite the pandemic conditions, two new products were put into service in Turkey’s electricity market in 2021, namely the Forward Electricity Market (VEP) and the Renewable Energy Source Guarantee (YEK-G) System and the Organized YEK-G Market[13, 14].

Turkey is a country where the resources and ability to fully provide its own generated energy. While total installed capacity was 69.516 MW in 2014, this capacity reached 99.819 MW as of 31 December 2021. The installed capacity has increased thanks to the installation of new natural gas, solar power, and hydropower and wind power plants. Within the energy mix, hydropower has become the primary source of energy, accounting for 31.55 % of the installed capacity[13-16].

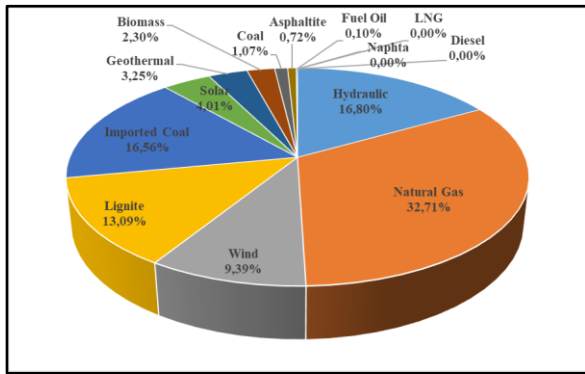
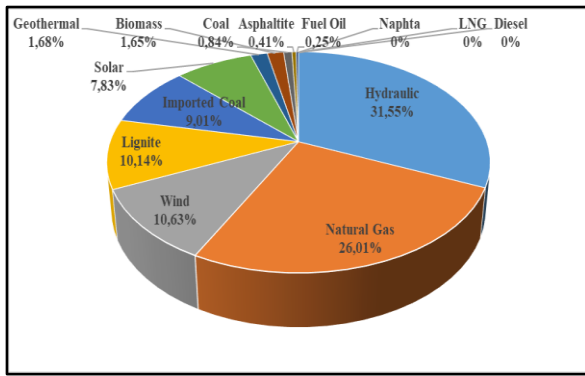
From the other energy sources, 26.01 % can be attributed to gas fired power plants, 19.99 % to coal (coal+lignite), almost 10.63 % to wind, 7.83 % to solar power, 1.68 % to other renewable sources (geothermal and waste heat), 1.66 % to biomass and 0.26 % to other fuels (oil, diesel, naphtha) (Table 1, Figure 1).

In 2021, the actual consumption amount increased by 7.73% compared to 2020 and reached 328,405 GWh. In 2021, electricity imports increased by 23.34% compared to last year and amounted to 2.33 TWh. In 2021, electricity exports increased by 68.56% compared to last year and amounted to 4.19 TWh. The share of renewable energy sources including hydraulics in total installed power increased from 48% by the end of 2020 to 50.02% in 2021. The proportion of total thermal power installed decreased from 52% in 2020 to 49.98% in 2021 [13-16].

The share of hydropower in electricity generation was around 16.80% in 2021, while the share of renewable energy including hydropower remained around 35.75%(Table 1,Figure 1)

**Table 1.** Breakdown of Installed Capacity and Generation by Sources in 2021 [13]

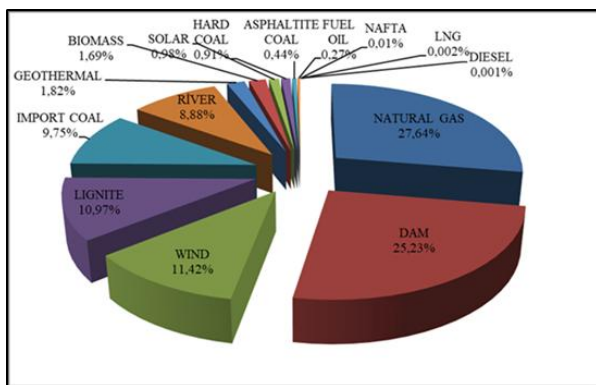
Fuel/Source Type	Total InstalledCapacity* (MW)	Ratio (%)	Total Generation* (MWh)	Ratio (%)
Hydraulic	31,492.58	31.55	55,695,231.65	16.80
Natural Gas	25,964.56	26.01	108,438,726.84	32.71
Wind	10,606.98	10.63	31,137,427.23	9.39
Lignite	10,119.92	10.14	43,400,430.26	13.09
ImportCoal	8,993.80	9.01	54,888,840.62	16.56
Solar	7,815.63	7.83	13,294,280.97	4.01
Geothermal	1,676.17	1.68	10,770,879.81	3.25
Biomass	1,644.52	1.65	7,616,648.91	2.30
Coal	840.77	0.84	3,539,791.50	1.07
Asphaltite	405.00	0.41	2,372,954.47	0.72
FuelOil	251.93	0.25	336,644.04	0.10
Naphta	4.74	0.00	0.00	0.00
LNG	1.95	0.00	0.00	0.00
Diesel	1.04	0.00	78.33	0.00
<b>Total</b>	<b>99,819.57</b>	<b>100.00</b>	<b>331,491,934.64</b>	<b>100.00</b>



\* Licensed and unlicensed power plants are included.

**Figure 1.** Breakdown of Total Installed Capacity(left) and Generation(right) by Sources in 2021[13]

While the share of natural gas power plants (including liquid and natural gas fired power plants) within the licensed installed capacity was 28.80% at the end of 2020, it decreased to 27.64% in 2021, the share of dam-hydroelectric power plants decreased from 25.74% to 25.23%. The share of river-hydroelectric power plants decreased from 9.04% to 8.88%. Also, while the share of power plants based on import coal decreased from 10.09% to 9.75%, the share of lignite power plants decreased from 11.36 % to 10.97%. In 2021, the licensed installed capacity increased by 3.60% compared to last year and reached 92.272,58 MW. Between 2020 and 2021 the installed capacity has developed on the basis of renewable energy (Table 2, Figure 2). On the other hand, the share of wind power plants, which was 9.80% in licensed installed capacity, increased to 11.42% and the share of geothermal power plants increased from 1.80% to 1.82% in 2021[13-16]

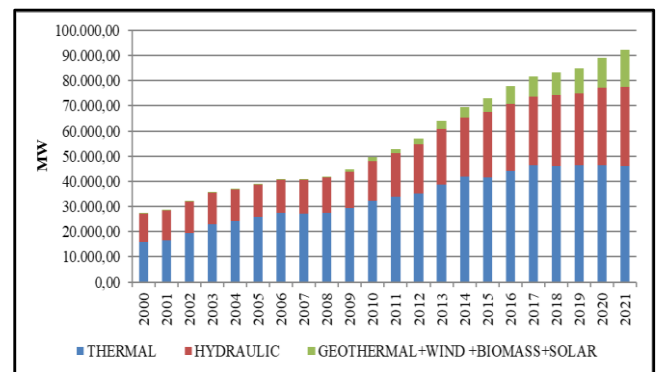


**Figure 2.** Distribution of Licensed Installed Capacity by Energy Sources in 2021[13]

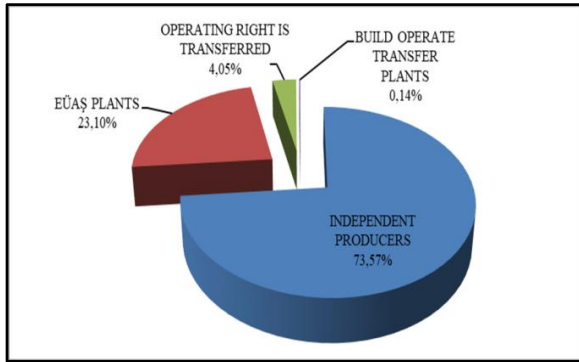
**Table 2.** Changes in Licensed Installed Capacity by Sources between 2020 and 2021 [13-16]

Fuel/Source Type	2020 (MW)	Ratio (%)	2021 (MW)	Ratio (%)	Change(%)
Natural Gas	25,639.26	28.80	25,501.51	27.64	-0.54
Hydraulic(Dam)	22,925.03	25.70	23,280.37	25.23	1.55
Wind	8,761.57	9.80	10,533.90	11.42	20.23
Lignite	10,119.92	11.40	10,119.92	10.97	0.00
Import Coal	8,986.85	10.10	8,993.80	9.75	0.08
Hydraulic(River)	8,050.23	9.00	8,198.23	8.88	1.84
Geothermal	1,613.19	1.80	1,676.17	1.82	3.90
Biomass	1,031.88	1.20	1,555.41	1.68	50.74
Solar	409.80	0.50	907.85	0.98	121.53
Coal	810.77	0.90	840.77	0.91	3.70
Asphaltite	405.00	0.50	405.00	0.44	0.00
Fuel Oil	305.93	0.30	251.93	0.27	-17.65
Naphta	4.74	0.00	4.74	0.01	0.00
LNG	1.95	0.00	1.95	0.00	0.00
Diesel	1.04	0.00	1.04	0.00	0.00
<b>Total</b>	<b>89,067.13</b>	<b>100.00</b>	<b>92,272.58</b>	<b>100.00</b>	<b>3.60</b>

The share of renewables such as geothermal, wind, solar and biomass resources in installed capacity has increased every year (Figure 3). The share of EÜAŞ power plants in total installed capacity, 24.05% in 2020, decreased to 23.10%. Also, the share of power plants operating under existing contracts in total installed capacity decreased from 4.21% to 3.33% compared to the previous year. On the other hand, while the share of independent companies operating under free market conditions was 72.62% in 2020, it increased to 73.57% in 2021 (Figure 4).



**Figure 3.** The Development of Licensed Installed Capacity by Source over the Years (MW) [13]

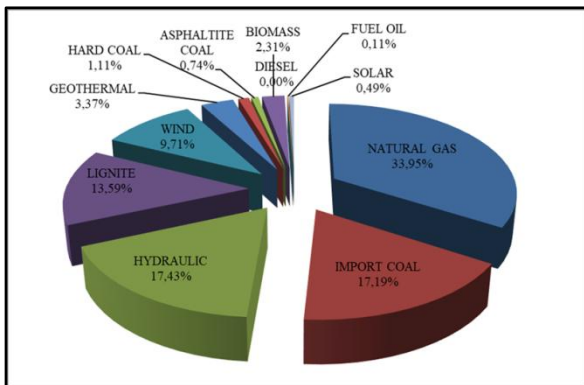


**Figure 4.** Breakdown of Licensed Installed Capacity by Operators in 2021 [13-16]

The share of licensed electricity generation in 2021 increased by 8.57% compared to 2020 and reached 319.275,22 GWh. While the generation from licensed renewable sources decreased between 2020 and 2021 electricity generation from fossil fuel sources increased (Table 3, Figure 5).

**Table 3.** Changes in Licensed Electricity Generation by Energy Sources between 2020 and 2021 [13]

Fuel/Source Type	2020 (GWh)	Ratio (%)	2021 (GWh)	Ratio (%)	Change(%)
Natural Gas	69,277.54	23.60	108,394.45	33.95	56.46
Hydraulic	78,087.88	26.60	55,656.34	17.43	-28.73
Importad Coal	62,466.47	21.20	54,888.84	17.19	-12.13
Lignite	38,163.85	13.00	43,400.43	13.59	13.72
Wind	24,561.36	8.40	30,990.13	9.71	26.17
Geothermal	9,929.41	3.40	10,770.88	3.37	8.47
Biomass	5,228.50	1.80	7,371.77	2.31	40.99
Cola	3,415.83	1.20	3,539.79	1.11	3.63
Asphaltite	2,222.88	0.80	2,372.95	0.74	6.75
Solar	416.98	0.10	1,552.91	0.49	272.42
FuelOil	313.04	0.10	336.64	0.11	7.54
Diesel	1.00	0.00	0.08	0.00	-92.17
<b>Total</b>	<b>294,084.73</b>	<b>100.00</b>	<b>319,275.22</b>	<b>100.00</b>	<b>8.57</b>

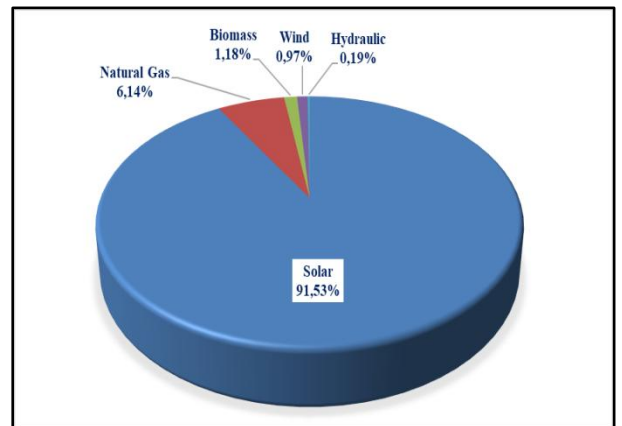


**Figure 5.** Breakdown of Licensed Electricity Generation by Sources in 2021 [13-16]

In 2021, the unlicensed installed capacity increased by 10.60% compared to the previous year and became 7,546.99 MWe. 91.53% of this amount is based on solar energy. The amount of capacity that entered the facility, which was 6,823.47 MWe at the end of 2020, increased by 10.6%. As in 2020, the highest share belongs to solar power plants with 91.53% in 2021, followed by natural gas with 6.14% and biomass with 1.18% (Table 4, Figure 6).

**Table 4.** Changes in Unlicensed Installed Capacity by Energy Sources between 2020 and 2021 [13]

Fuel/Source Type	2020		2021		Change (%)
	Installed Capacity (MWe)	Ratio (%)	Installed Capacity (MWe)	Ratio (%)	
Solar	6,257.61	91.71	6,907.78	91.53	10.39
Natural Gas	402.67	5.90	463.05	6.14	14.99
Biomass	83.71	1.23	89,11	1.18	6.45
Wind	70.83	1.04	73.08	0.97	3.17
Hydraulic	8.65	0.13	13.98	0.19	61.64
<b>Total</b>	<b>6,823.47</b>	<b>100.00</b>	<b>7,546.99</b>	<b>100.00</b>	<b>10.60</b>



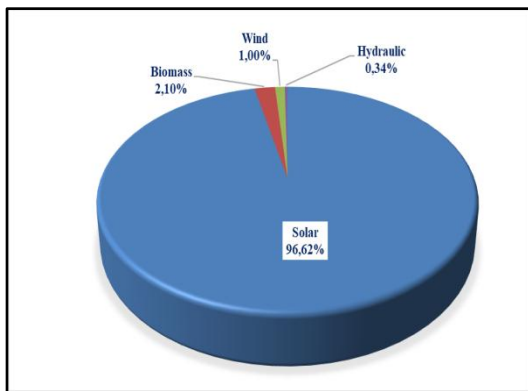
**Figure 6.** Breakdown of Unlicensed Installed Capacity by Sources in 2021 [13-16]

In 2021, the amount of unlicensed generation increased by 6.27% compared to 2020. While the amount of energy supplied to the grid within the scope of unlicensed electricity generation was 11,245.48 GWh in 2020, it increased by 6.27% to 11,950.26 GWh in 2021. Of this 96.62% was produced from the sun, 2.10% from biomass, and 1.29% from wind and hydraulics. In 2021, the share of hydraulic and solar energy in unlicensed electricity generation increased by 26.03% and 6.66%, respectively, while the share of biomass and wind decreased by 8.26% and 0.44%, respectively (Table 5, Figure 7).

Therefore, it can be predicted that renewable energy generation will take an important place in unlicensed electricity generation in the future.

**Table 5.**Changes in Unlicensed Electricity Generation by Energy Sources between 2020 and 2021[13]

Fuel/Source Type	2020		2021		Change (%)
	The amount of extra energy supplied to the system (GWh)	Ratio (%)	The amount of extra energy supplied to the system (GWh)	Ratio (%)	
Solar	10,825.50	96.27	11,546.36	96.62	6.66
Biomass	273.45	2.43	250.86	2.10	-8.26
Wind	119.47	1.06	118.94	1.00	-0.44
Hydraulic	2,707	0.24	34.11	0.29	26.03
<b>Total</b>	<b>11,245.48</b>	<b>100.00</b>	<b>11,950.26</b>	<b>100.00</b>	<b>6.27</b>



**Figure 7.** Breakdown of Unlicensed Electricity Generation by Resources in 2021

**3. HYDROPOWER POTENTIAL IN TURKEY: DATA OF 2021**

The theoretical hydroelectric potential in Turkey is calculated as 433 billion kWh/year, and the technically evaluable potential is calculated as 216 billion kWh/year. The technical hydropower potential of Turkey corresponds to 1.5% of the world's technical hydropower potential and 18% of the European technical hydropower potential. The USA has developed 86% of its technical hydropower potential, Japan 78%, Norway 72%, Canada 56%, and Turkey 50% [12,13].

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 32.9 % hydraulic installed capacity will be about 32 GW in 2023 according to MENR's Strategic Plan 2019-2023[17].In cooperation with the public - private sector 743 Hydroelectric Power Plants have completed and commissioned with an installed capacity of 31.647 MW and an energy generation potential of approximately 109 Billion kWh in cooperation with the Public-Private sector as of 31.12.2021(Table 6).

**Table 6.** Hydropower Potential of Turkey [6]

Potential	Number	Total Installed Capacity (MW)	Generation (GWh/Year)	Ratio (%)
In operation	743	31,647	108,932	68.8
Under construction	26	1,141	4,090	2.6
Project	469	15,143	45,379	28.6
<b>Total</b>	<b>1,238</b>	<b>47,931</b>	<b>158,401</b>	<b>100</b>

From 743 facilities, 68 facilities with an installed capacity of 13,766 MW and an energy generation potential of 49 Billion kWh were established by DSI; 646 facilities with an installed capacity of 17,881 MW and an energy generation potential of 60 Billion kWh have been built and put into operation by the private sector (Table 7).

The construction of those built by the Public from these facilities is carried out by DSI and the operation is transferred to EUAS, while those built by the private sector, except for the EMRA license, are other (water use right agreement, project, construction, acceptance of water structures, etc.) operations are performed by DSI.

Turkey is very rich in hydroelectric, geothermal, solar and wind energy sources and has a very high potential to develop these resources. Accordingly, development of renewable energy sector in Turkey is highly encouraged. At the end of December 2021, share of renewable energy in total installed capacity exceeded 50%.

Electricity demand, which is one of the most important indicators of economic growth, has experienced great fluctuations on a global scale due

to the measures implemented to prevent the Covid-19 pandemic. The effect of the slowdown in economic activity of the measures taken in this context was also seen in the electricity demand as of the end of the year. Turkey has been among the least affected countries by the epidemic with an increase of 7.89 % in electricity demand in December 2021.

The structural arrangements made in recent years to encourage the use of renewable energy sources instead of imported sources in electricity generation have continued to show their results despite the developments experienced and resulting from the Covid-19 pandemic in the markets. In this context, the share of renewable energy sources, which was 51.4% in the total installed electricity capacity in 2020, including unlicensed ones, increased to 53.34% in 2021. In addition, despite the pandemic conditions, two new products put into service in the electricity market of our country in 2021, namely the Term Electricity Market (VEP), the Renewable Energy Resource Guarantee (YEK-G) System and the Organized YEK-G Market [13].

**Table 7.** Hydroelectric Potential Development of Turkey as of 31 December 2021 [6]

Stage of Project	Operator (Public/Private)	Number	Installed Capacity (MW)	Generation Potential (GWh/year)	Ratio (%)
In Operation	DSI (Public)	68	13,766	48,952	27.2
	Private	675	17,881	59,980	33.3
	Total	743	31,647	108,932	60.5
Under Construction	DSI (Public)	2	700	2,569	1.4
	Private	24	441	1,521	0.9
	Total	26	1,141	4,090	2.3
Inspection and Project	Private	160	5,853	16,799	9.4
	Private (declared in Table)	7	247	778	0.4
	DSI (Prelicense-Planned)	33	1,398	4,122	2.3
	Total	200	7,498	21,699	12.1
<b>Total potential (Operation-construction-inspection-project)</b>		969	40,286	134,721	74.9
<b>Possible projects over 10 MW</b>		269	7,645	23,680	13.2
<b>Potential to be developed by 2023</b>		1,238	47,931	158,401	88.1
<b>SHP projects to be developed</b>		625	2,646	8,728	4.8
<b>Potential to be developed after 2023</b>		--	4,423	12,871	7.1
<b>POTENTIAL GENERAL</b>		1,863	55,000	180,000	100.0

#### 4. CONCLUSION AND RECOMMENDATIONS

Though hydraulic installed capacity will be about 32 GW in 2023 according to Strategic Plan 2019-2023 of Ministry of Energy and Natural Resources, this prediction seems to have come true from today. The share of hydroelectric installed capacity and power generation has increased around 1 % from last year in 2021. However, this increase is insufficient compared to increase in other energy sources.

Especially with the widespread distribution of natural gas in recent years, the use of natural gas in both homes and industry has increased, and “Natural Gas Cycle Power Plants” have been established to meet the increasing energy needs. As a result, the share of energy produced from hydropower has decreased in recent years, and the share of thermal energy generation has increased. The European Union has adopted on supporting green energy (hydropower, wind, solar and biomass) in its energy policies. In this case, the energy policies in force in Turkey and the related it has become mandatory to decouple the differences between the legal legislation and the legislation of the European Union. In this context, it is very important to use the renewable energy potential, which is the natural resources of a country, to the maximum extent, and this should be a state policy. As a result, it is necessary to increase the share of hydroelectric energy in the total energy generation in Turkey by improving the hydroelectric potential and

making it available for the benefit of the country's economy.

Turkey consists of 25 hydrological basins, and the water that forms the basis of these basins is a vital and socially important resource. In terms of water resources, the precipitation regime of our country, which is located in a semi-arid region of the world, varies greatly according to the seasons and regions, and it is observed that water needs in some basins have exceeded the potential of resources. Therefore Turkey is vulnerable to climate change and it causes additional stress to water availability in Turkey. This situation may significantly jeopardize the use of both water resources and hydraulic energy in the future. Therefore, in addition to diversifying energy, it is necessary to take the path of benefiting from water resources by providing maximum efficiency. Moreover dam and canal type HEPP projects abandoned by the investor for various reasons should be re-evaluated and their construction should be started after they are made efficient. Some hydro 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. On the other hand, the necessary security measures should be taken at the border dams to ensure that the investor companies start working and the facilities should be completed and put into service as soon as possible.

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