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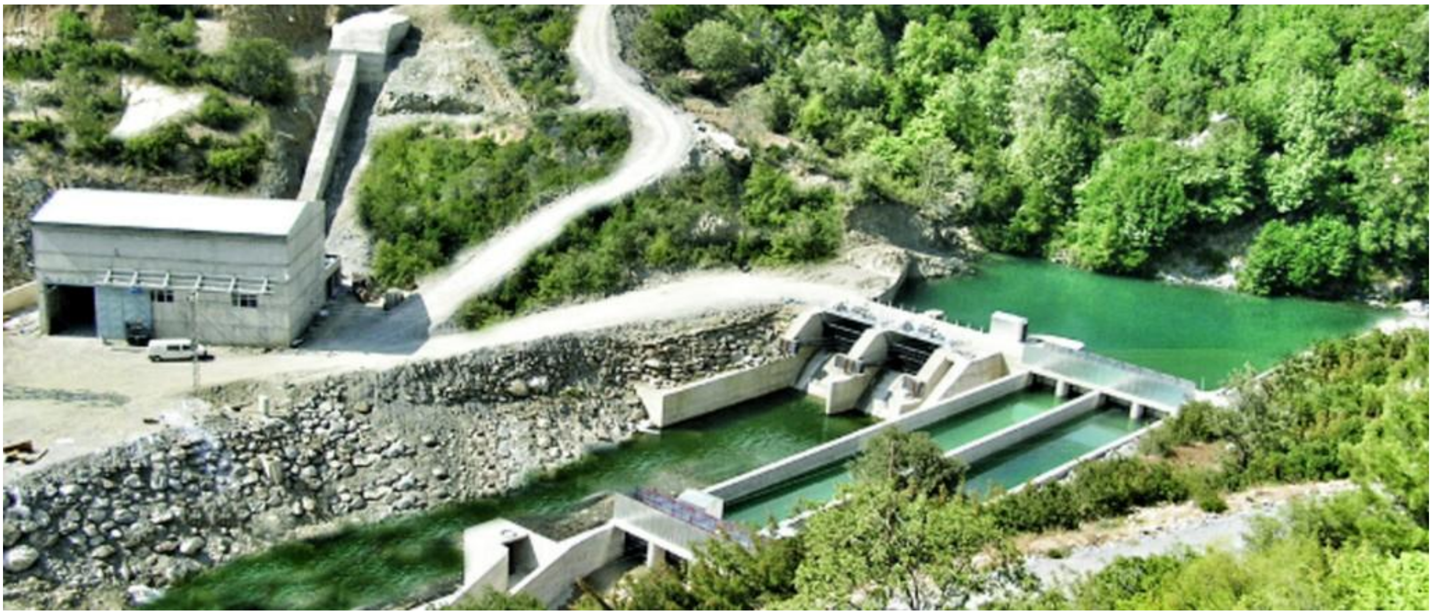
Capacity Factor Investigation of HEPP's in Turkey

Dursun Yıldz

Hydropolitics Association

2019



Capacity Factor Investigation of HEPPs in Turkey

July 2019

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Title : Capacity Factor Investigation of HEPP's in Turkey

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ABOUT THE REPORT

As Hydropolitics Association (HPA), we are in favor of environmentally friendly, planned and most efficient development of our country's domestic and renewable hydroelectric energy resource. To this end, we continue our work to date.

In this report;

- We have determined the current situation,
- We have made statistical analysis based on information,
- We have made some suggestions for today's situation and the future.

Hydroenergy resources are the domestic and renewable energy sources of our country.Therefore we need to;

- Increase the production efficiency of those in operation,
- Develop our water potential, which is still waiting to be developed, in a more planned, efficient and environmentally sensitive manner,
- Ensure environment-sensitive hydroenergy production maximization at the sub basin and basin scale
- Contrubite environmentally sensitive hydroenergy production today and in the future

For this purpose; We want to draw attention to the hydroenergy planning and operation need at the basin scale, as well as the importance of engineering hydrology and the pressures that climate change will create on water-energy relationship and sectoral water allocation,

We hope our report will be useful

Sincerely yours

Dursun Yıldız

President

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1. Data used in the study and some results obtained

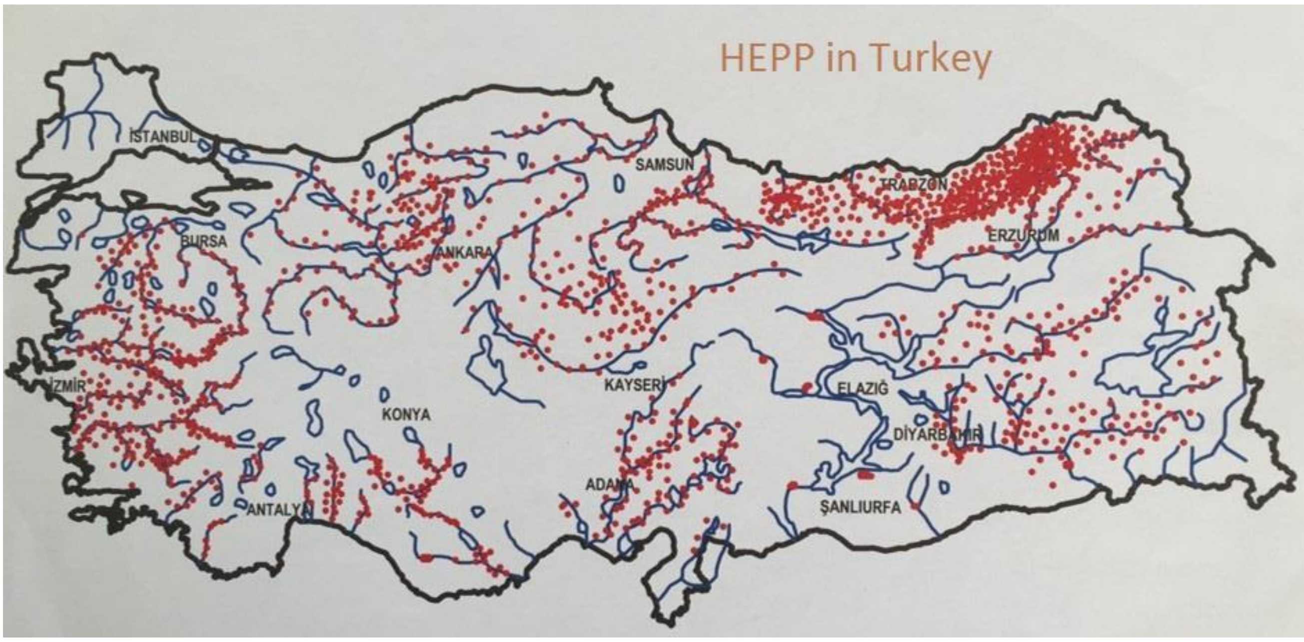
In this report, the following criteria are used in the calculations for capacity utilization of HEPPs and the results obtained are summarized below.

1. All data used (Installed Capacity, Planned Production Amount, Annual Electric Energy Produced) are obtained from YEKDEM Final Lists published annually by YEKDEM (Renewable Energy Resources Support Mechanism).
2. Only River and Channell Power Plants and Reservoir's HEPPs, which are among the energy facilities in the YEKDEM lists, were evaluated.
3. In the YEKDEM lists, in 2013, 2014 and 2015 only statistical data of 44, 14 and 41 HEPPs are included. Therefore, in this study, lists after the year of 2016, which include more HEPP statistical data, were used.
4. In the study, the installed power, planned and actual production data of 259 river and channell type HEPPs[1] and 41 Reservoir HEPPs[2], which have been produced continuously from 2015 in 2016, 2017 and 2018, are used.
5. Although there are 463 HEPP data in the 2014 final YEKDEM list, only 259 of them have continuous production data for the past 4 years. Only 41 of the reservoirs HEPP have continuous production data for the last 3 years.
6. According to EMRA(Energy Market Regulation Agency) data, as of the end of 2018, the total installed capacity of the HEPP without storage in Turkey is 7748 MW and the number of HEPPs is 510. In this case, our investigation covers 60% of the installed capacity and 59 % in terms of their total electricity production.
7. In this study ,the average installed capacity of 259 river and channel type HEPP's is 17 MW.
8. In thşs study, the maximum installed capacity for the river and channel type HEPP's is 142 MW and the minimum is 0.63 MW.
9. 64% of the river and channel type hydroelectric power plants studied are located in the Eastern Black Sea, Tigris and Euphrates, Ceyhan, Yeşilirmak and Coruh River Basins, respectively.
10. In the 4 years (2015-2018) considered in this research, in 2017, when production was high, only 33 river and channel type HEPPs (Total 590 MW) produced more electricty production than planned.
11. 26 (394 MW) of the 259 river and channel type HEPPs examined in this research were very close to their planned production value in 2017.
12. Among the river and channel-type HEPPs, 200 of them were produced at various rates below the energy they plan to produce.

[1] River and Channell Type HEPP's: Micro,Mini,Small HEPP's without reservoirs on river and channells.

[2] Reservoir Type HEPP : HEPP with dams and reseroirs. Generally Large Dams

13. The weighted average of the calculated 4-year capacity factors of 259 river and channel type HEPPs is determined as of 29%.
14. The four-year average capacity factor of the 41 reservoir type HEPP is determined as of 27%.
15. Both the Capacity Factor values given above are well below the regional and national average values in the literature.
16. In 2015, which is a period of low rainfall, river and channel-type power plants as well as reservoir type HEPPs have reached only half of their planned electricity production.



2. ELECTRICITY SECTOR IN TURKEY

The first electricity production in Turkey has started in Tarsus with a mini HEPP as of 60 kW. After 1930, electrical energy was also used outside lighting and large industrial corporations producing their own electricity started to develop. Karabük, Demirçelik, Sümerbank and İzmit Seka, which have established their own power plants to meet their needs, can be counted in this scope. Developments in the world with privatization in the 1980s, Turkey has also affected. As a result of these developments, on 4 December 1984, the Law No. 3096 and the "Law on the Assignment of Electricity Generation, Transmission, Distribution and Trade of Non-TEK Organizations" were made. It is not possible to say that this issue has been fully implemented in 14 years. On 12.08.1993 and with the decision of the Council of Ministers numbered 93/4789, TEK was structured as two separate Joint Stock Companies: TEAŞ and TEDAŞ. Since 1995, TEDAŞ has been transformed into 7 Subsidiaries and Distribution Companies. In the meantime, in 1989, AKTAŞ Elektrik A.Ş. and Kayseri and Vicinity Electricity Inc. It has signed a contract according to the Law no. Later, a new restructuring has been made in the field of electricity generation, transmission, distribution and trade and new companies have been established. Presently, Electricity Generation Inc. (EGC), Turkey Electricity Transmission Company (TEIAS), Turkey Electricity Distribution Company (TEDAŞ) and Turkey Electricity Trading Inc. (TETAŞ) companies provide these services.

2.1 Historical Development of Hydropower in Turkey (3).

The first hydroelectric production started in 1902 with a small scale hydroelectric power plant in Tarsus. The first large-scale power plant was built in 1913 in Istanbul. In 1933, the lighting and electricity network operating with hydroelectric energy was established for the first time in Ödemiş. In 1935, several state institutions were established for electricity generation. The total installed capacity of 29.66 MW of installed when the Republic of Turkey and the annual production of 45 GWh was in order this year. Electricity was only available in Istanbul, Adapazarı and Tarsus. In 1932 EIE was established to conduct investigations. and research to develop the potential of the hydraulic potential of water resources and other sources of energy. Important projects in this process; Seyhan, Sarıyer, Hirfanlı, Kesikköprü, Demirköprü and Kemer Dams and Hydroelectric Power Plants.

As of 1940, there are 28 hydroelectric power plants that account for 3.2% of total energy production. Etibank and İller Bank aimed to construct small hydroelectric power plants and electrify villages and towns. When the total installed capacity reached 408 MW in 1950, the share of hydroelectric power plants with a total installed capacity of 18 MW was only 4.4%. However, after the establishment of DSI in 1954, hydroelectric capacity has reached 412 MW (equivalent to 34% of total installed capacity), which is responsible for 44% of total energy production within 10 years.

The period between 1950 and 1969 was the construction period of hydroelectric power plants by DSI, Iller Bank, Etibank and Sumerbank. This period is characterized by the fact that DSI and state institutions work together, that the interconnected system has not been introduced yet , and that it is a period in which İller Bank established thermal power plants for municipalities primarily for lighting purposes, where possible, small hydroelectric power plants, and if not diesel or coal power plants.

In 1970, Turkey Electricity Authority (TEK) established and period is over for İller Bank Eti Bank and municipalities to set up and produce electricity.State Hydraulic Works 8DSİ) has played the most important role to develop hydroenergy resources in Turkey .

In the period of 1970-1990, the interconnected system was spread to the whole country by the General Directorate of TEK and all villages were supplied with electricity. In this process, hydroelectric power plants were built by DSI and Privileged Companies. Law No. 3096, which provides electricity to the private sector with the Build-Operate-Transfer model called BOT, was enacted in 1984 and the BOT model HEPP period started with the HEPPs commissioned in 1991. During the period between 1991 and 2003, DSI started to build dams and hydroelectric power plants within the framework of bilateral cooperation between governments and ve Karkamış Dam and Hydroelectric Power Plant ye was commissioned in 1999. At the beginning of 2001, the Energy Market Regulatory Authority "was established and a new era for the generation, transmission and distribution of electricity including hydropower has started. For 2003-2005 and beyond, the Free (Competitive) Market Period, together with the Water Use Regulation enacted in 2003 as a result of the expectations and persistence of the private sector and the Law No. 5346 on the Use of Renewable Energy Resources With the right to water use agreement, the private sector has the freedom to produce and sell electricity from HEPPs.
Next in the process, Renewable Energy Sources for Electricity Amending the Law on the Use Purpose Production Act January 8, 2011 the Official Gazette published the entry into force and the Energy Market published by the Regulatory Authority for Electricity Market with regulations relating to unlicensed electricity production, opened the road for the construction and operation of HEPP by the private sector.

2.2.Private Sector has involved to Energy Production Market

In Turkey, the topographic structure and the precipitation intensity are suitable to develope large and small hydroelectric power potential. The development of small hydropower plants in Turkey began in 1902. From this date, the country's many regions of government departments, a large number of private sector and local municipalities have built small hydroelectric however, present as a result of the rapid increase in the energy consumption area, to ensure maximum energy to Turkey's economy and meet the growing energy demand priority in order scale HEPP projects.

The average annual increase in small HEPP capacity during the last thirty years is around 5% -10%. Prior to the entry into force of the "Electricity Market Law Mart in March 2001, all projects related to water, such as drinking water supply, irrigation, energy, flood protection and drainage, were carried out at all levels from the initial survey stage to operation. The responsibility of DSI was in its field. After the construction was completed, the operation of the power plant was transferred to the Electricity Generation Company (EÜAŞ), which is an expert company with the transfer protocol.

With the "Electricity Market License Regulation" on 4 August 2002 and the "Water Use Agreement Regulation 26 on 26 June 2003, all HEPP projects developed by DSI and EIE in various levels until 2003 , has been opened for private sector application for investment. Apart from these projects developed by the public sector, HEPP projects can be developed by legal entities and proposed to DSİ upon request of investment. Such projects are also published on the DSI website and open to the proposals of other investors for a month. After this stage, a series of conditions and rules are applied to those who attempt to obtain a license from EMRA.

Especially in the period of 1950-1990, as required by the country's policy, Priority has been given to multi-purpose, large and efficient projects and a significant portion of these has been implemented. Domestic private sector companies preferred mostly small scale projects in the 90s.

In recent years, a significant increase in the dependence on foreign energy sources like natural gas that jeopardizes the reliability of the supply, as well as an orientation towards domestic and renewables resources has begun due to the current account deficit problem. With the Renewable Energy Incentive Law 53 (Law No. 5346 on the Use of Renewable Energy Resources for the Purpose of Generating Energy) enacted in 2005, private sector interest in renewable energy resources has increased and the share of HEPPs as installed power has also increased (5).

2.3.HEPP Projects Completed to date within the Scope of Law No. 2.3.4628

As of today, HEPP projects, which are carried out under license by the private sector within the framework of the Electricity Market Law No. 4628, have a share of 9.32 % of the total installed power (4).

However, with the "Water Use Right Agreement" in our country, planning, project Environmental Investigation Report, construction supervision and operation process of HEPPs were problematic.

Following the Electricity Market Law No. 4628, many laws and regulations related to the design, construction and operation of hydroelectric power plants have been enacted and are still enacted today. Some of the HEPPs commissioned since 2005 have some deficiencies in terms of technical inspections, measurements and engineering hydrology calculations. In addition, some problems were experienced in the calculation and control of the water that natural life needs in the rivers and surrounding areas where HEPPs were established.

In order to ensure social, economic and ecological sustainability (continuity of natural life) along the river, the regulation on the release of life water from HEPPs was added to the related regulation after the construction of many HEPPs. This sometimes means that in a project designed without taking into account the "water for ecology " the capacity factor and realized value in production falls below. In some cases, the amount left under the name of life water is insufficient for the continuation of the ecological system (5).

Table 1. HEPP's Licences Situation (5)

Stage	Number of HEPP	Installeed Capacity MWe	Sahare in Total %
LICENCED			
In operation	584	27 131	56,25
Under Construction	167	7 222	14,97
Cancelled	65	1615	3,35
Licences Revoked	461	12 625	25,43
TOTAL	1227	48 223	100
PRE- LICENCED			
In use	122	4145	77,88
In evaluation	17	133	2,5
Cancelled	103	1044	19,62
TOTAL	242	5322	100

When Table 1 is examined, it is seen that there are approximately 13 500 MW HEPP projects since 2005, whose generation license and pre-license have been terminated. Considering the 7748 MW Akarsu HEPP capacity currently in operation, it is seen that the generation license and pre-license of the power plant project, which has nearly twice the installed capacity, has been terminated. Examining the reasons why these projects are terminated and associate license and licenses may help to better understand some of the issues related to Licensed HEPP projects.

Some of the deficiencies in water resources and energy production planning that should have to be done at the basin scale have been effective for current situation . (5).

2.4 The HEPPs Registered with YEKDEM

Renewable energy resources support mechanism (YEKDEM) has been established with the aim of making the installation of power plants based on renewable resources more attractive and reducing the dependence on foreign sources. In essence, it is considered to be an application to guarantee purchase of small electricity generation facilities based on renewable resources at encouraged USD prices. However, it became an application that many power plants producing renewable energy based electricity were also utilized.
While the number of HEPPs benefiting from YEKDEM was 4 in 2011, the number of power plants that will benefit in 2019; It reached 463, 41 of which are Large HEPP with reservoir.

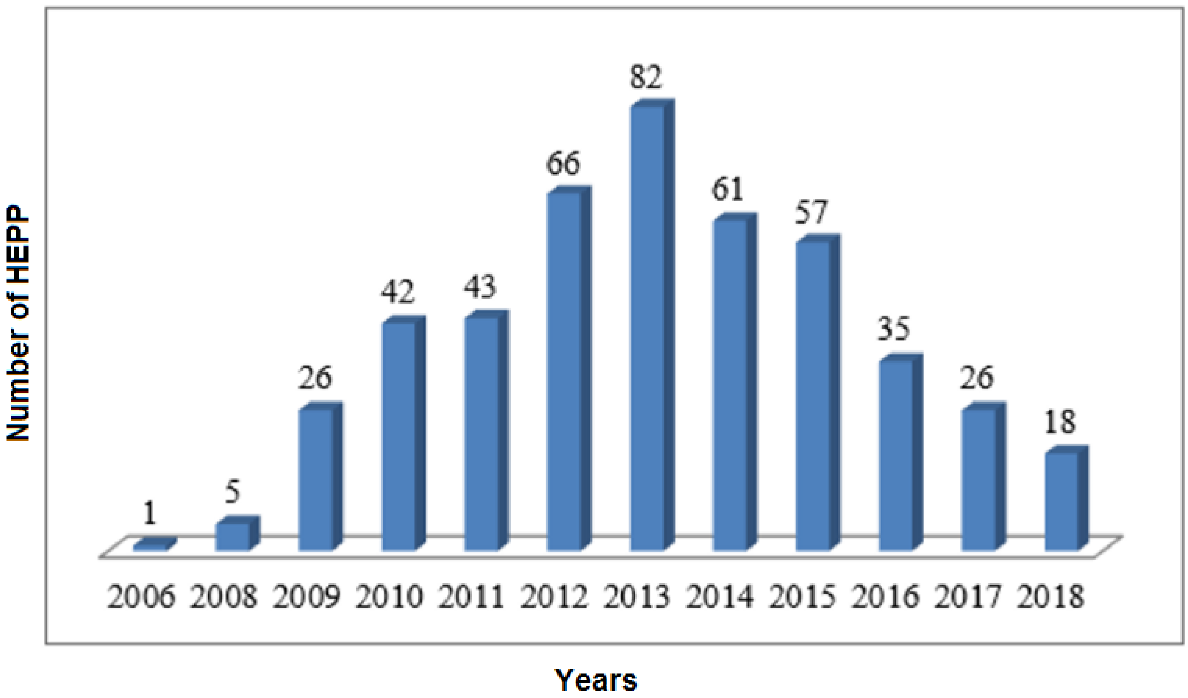


Figure 1. HEPP number in operation by years

82 of 463 HEPPs in the YEKDEM list in 2019 were put into service in 2013. While the number of

HEPPs commissioned until 2013 increased steadily, it decreased gradually after this year (Figure 1).

3. DATA USED IN THE INVESTIGATION

3.1. River and Channel Type HEPPs

In the research, the production data of River and Channel type HEPPs and Reservoir Type HEPPs that have been registered with YEKDEM have been used in the last 4 years. However, since not all of the power plants are continuously registered with YEKDEM every year, only 259 of them have been continuously registered in the last 4 years and their production values have been used and examined in the research study
Therefore we used 259 River and Channel power plants and 41 Reservoir Type HEPPs for this study.

As mentioned earlier, this research was started to calculate the realization rates and capacity utilization factors of river and Channel type HEPPs in the last four years, but the capacity factors of Reservoir Type HEPPs are also examined.

Table 1. Number of Installed Power and Power Plants in 2018 Source: TEİAŞ

Resource Type	**Installed Capacity MW**	**Share (%)**	**Number of Powe Plant**
FUEL OIL+DIESEL	294	0,3	11
COAL+ LIGNITE +ASPHALITE COAL	10 203,5	11,6	31
IMPORT COAL	8794	10	11
NATURAL GAS+LNG	22 683	25,9	253
WASTE +PIROLITIC OIL	622,5	0,7	99
MULTI -FUEL TYPE (Solid+Liquid)	697,1	0,8	22
MULTI-FUEL TYPE (Liquid+Natural Gas)	3361,2	3,8	47
GEOTHERMAL	1163,6	1,3	41
HYDRO ENERGY DAMS	20503,5	23,4	117
HYDROENERGY RIVER TYPE	7602	8,7	510
WIND	6685	7,6	167
SOLAR	31,9	0	4
THERMAL (No licence)	263,8	0,3	90
WIND (No licence)	57,3	0,1	68
HYDROENERGY (No Licence)	7,4	0,0	10
SOLAR (No Licence)	4761	5,4	5503
Total	**87 736,8**	**100**	**6984**

✓ Table 2. In 2017-2018, licensed **installed capacity** according to resource type (4)

Resource Type	**2017 (MW)**	**Share (%)**	**2018 (MW)**	**Share (%)**	**Change 2017-2018 (%)**
NATURAL GAS	26.311,80	32,28	25.731,93	30,93	-2,20
HYDRO DAM	19.746,05	24,23	20.534,80	24,69	3,99
LIGNITE	9.267,12	11,37	9.597,12	11,54	3,56
IMPORT COAL	8.936,35	10,96	8.938,85	10,75	0,03
RUN OF RIVER	7.509,98	9,21	7.748,90	9,32	3,18
WIND	6.482,12	7,95	6.942,27	8,35	7,10
GEOTHERMAL	1.063,73	1,31	1.282,52	1,54	20,57
FUEL OIL	702,77	0,86	709,21	0,85	0,92
HARD COAL	616,15	0,76	616,15	0,74	0,00
BIOMASS	439,72	0,54	590,92	0,71	34,39
ASPHALTITE COAL	405,00	0,50	405,00	0,49	0,00
SOLAR	17,90	0,02	81,66	0,10	356,19
NAPHTA	4,74	0,01	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
Total	**81.506,42**	**100,00**	**83.187,05**	**100,00**	**2,06**

✓ **Table 3.** In 2017-2018, licensed **electricity generation** according to resource type. **(4)**

Resource Type	2017 (GWh)	Share (%)	2018 (GWh)	Share (%)	2017-2018 (%)
NATURAL GAS	108.837,19	37,20	91.227,14	30,88	-16,18
IMPORT COAL	51.172,22	17,49	62.949,64	21,31	23,02
HYDRO DAM	41.269,59	14,10	40.961,45	13,86	-0,75
LIGNITE	40.581,02	13,87	45.055,29	15,25	11,03
WIND	17.859,86	6,10	19.891,37	6,73	11,37
RUN OF RIVER	17.124,40	5,85	18.975,98	6,42	10,81
GEOTHERMAL	5.969,48	2,04	7.611,58	2,58	27,51
HARD COAL	3.453,87	1,18	3.005,55	1,02	-12,98
ASPHALITE COAL	2.394,64	0,82	2.328,50	0,79	-2,76
BIOMASS	1.939,72	0,66	2.410,00	0,82	24,24
DIESEL	1.008,83	0,34	0,98	0,00	-99,90
FUEL OİL	957,86	0,33	957,98	0,32	0,01
SOLAR	24,56	0,01	65,56	0,02	166,97
LNG	2,20	0,00	1,12	0,00	-48,83
Total	**292.595,42**	**100,00**	**295.442,15**	**100,00**	**0,97**

According to TEIAS and EMRA data given in Tables 1, 2 and 3, as of the end of 2018, the installed capacity of River and Channel HEPP in our country is 7748 MW and the number of HEPP is 510.

In this case, our investigation covers 60% of the total installed capacity of all River and Channel HEPPs in operation. This ratio was 59% in terms of electricity produced.

3.2. Reservoir Type HEPPs

In this study, besides the 259 River and Channel type HEPP registered to YEKDEM, the efficiency of 41 HEPP the same tables obtained from YEKDEM were examined.

3.3 Hydroenergy Potential in Turkey

According to the General Directorate of State Hydraulic Works Annual Action Report 2018 (15), in Turkey, in operation by the end of 2018, 644 units total installed capacity of 28 423 MW and average annual production is 99.1 billion kWh, the value of total development potential of approximately 55% corresponds to. Turkey HEPP Potential is given in the table below. According to this table there are currently 55 HEPPs under construction and the construction of 554 HEPPs has not yet started. These data suggest that studies should be carried out to develop our hydroenergy potential in a more efficient and environmentally sensitive manner.

HEPP	Number of HEPP	Total Installed Capacity (MW)	Annual Mean Production (GWh/year)	Share in Total (%)
In operation	**644**	**28 243**	**99 051**	**62**
Under construction	**55**	**4370**	**13 427**	**8**
Planned	**554**	**15 387**	**46 907**	**29**
TOTAL	**1253**	**48 180**	**159 385**	**100**

(*) It is included the projects developed by Private Sector (Table 3) .Source : State Hydraulic Works

4. RESULTS OBTAINED FROM THE INVESTIGATION

4.1.Ratio of Actual Electricity Generation to Planned Production

At the beginning of the study, we firstly calculated the ratios of planned and actual electricty generation for 259 River and Channel Type HEPPs in the last 4 years The obtained results are given in Table 4.

Table 4. Realization rates of planned production in river and Channel power plants in the last 4 years

Years	Number of HEPP	Total Installed Capacity MW	Total Planned Energy Generation kWh	Total Generated Energy kWh	Energy Generation Realization Ratio %
2015	259	4490	16.550.761.799	7.531.244.000	% 45
2016	259	4490	16.550.761.799	12.274.556.000	%74
2017	259	4490	16.550.761.799	12.275.536.000	%74
2018	259	4490	16.550.761.799	11.302.221.883	%68

The total annual energy generation planned for the licenses of 259 HEPPs, is 16,550,761,799 kWh,

But actual production was 7,531,244,000 KWh in 2015, 12,274,556,000 KWh in 2016, 12,275,536,000 KWh in 2017 and 11,302.221.883 KWh in 2018. In this case, since 2015, 45%, 74%, 74% and 68% of the energy planned and declared to EMRA has been generated. These results show that an average of 35% less energy was produced in 259 HEPPs than planned in the last 4 years. Table 5 shows the changes in the last four years of planned and produced energy in 2015, 2016, 2017 and 2018 according to percentiles.

Table 5. Change of planned and produced energies in HEPPs examined in percentiles over the last four years

Year of Generation	of planned HEPPs producing up to 25%		of planned % 26-% 50 producing		of planned %51-%75 producing		of planned %76-%95 producing		of planned and over producing	
	MW	Number	MW	Number	MW	Number	MW	Number	MW	Number

2015	782,59	54	1829,68	90	1273,96	81	498,30	28	97,92	6
2016	216,90	13	471,75	21	1415,40	99	1724,10	81	649,30	45
2017	78,06	10	626,95	44	1761,90	92	1176,72	65	845,59	48
2018	88,25	8	801,96	57	2084,10	115	1361,60	65	280,05	14

In this table, it is seen that 58% of 259 River and Channel Type HEPPs with a total installed capacity of 4482.45 MW were able to generate only half of the planned energy in 2015. Figure 2 shows that the average rate of last 4 years is around 60%. emerges.

This table also shows that only 6 of the total investigated HEPPs in 2015, 45 in 2016, 48 in 2017 and 14 in 2018 are close to and above their planned energy production.

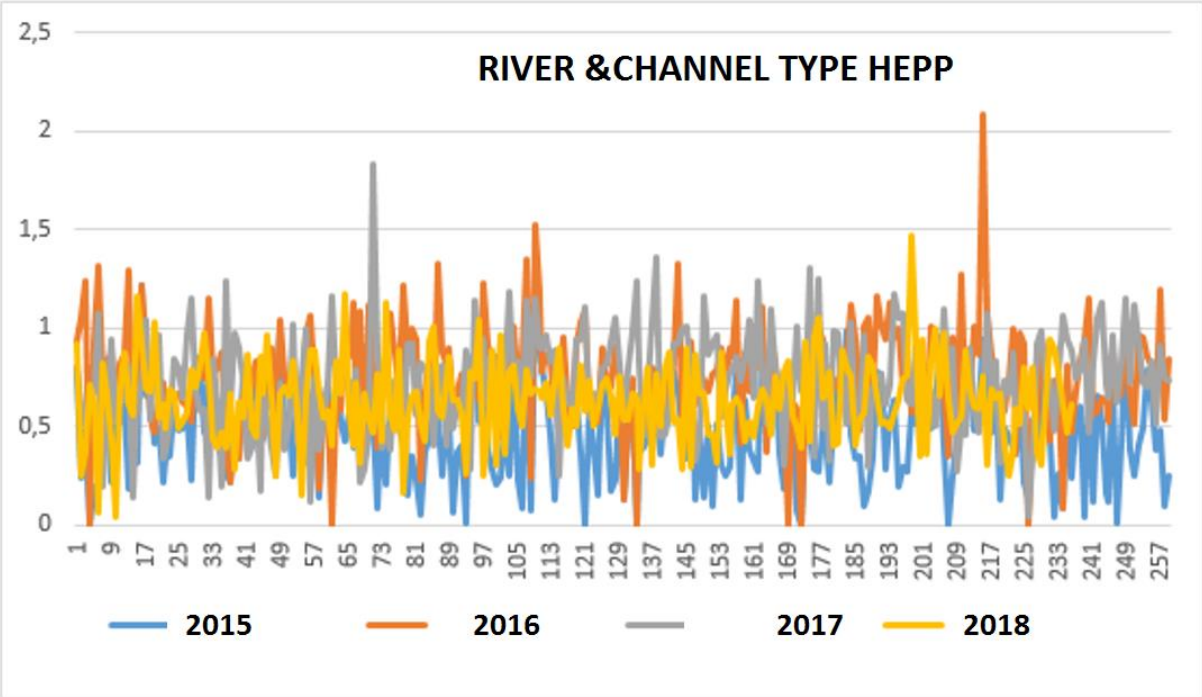


Figure 2. Variation of the realization rate of the planned energy to be produced in the HEPPs examined by years.

4. 2. Capacity Factors of the HEPPs

The net capacity factor (KF) of the power plant is the ratio of the total energy produced by the power plant in a certain period to the power it can produce at full capacity : - KF = Generation (MWh / year) / {8760 h / year * P (MW)} –

Capacity Factor in HEPPs : world average is 44%, US 38% average (Figure 3), the average is 37% in Turkey for many years (14). However, this rate is more than the DS in Turkey for many years the production of large dams made by the General Directorate hes been evaluated as determined by the average. Therefore, it is considered that this ratio does not cover Capacity Factors of more than 500 river and channel type HEPPs built in the last 10 years and reservoir.

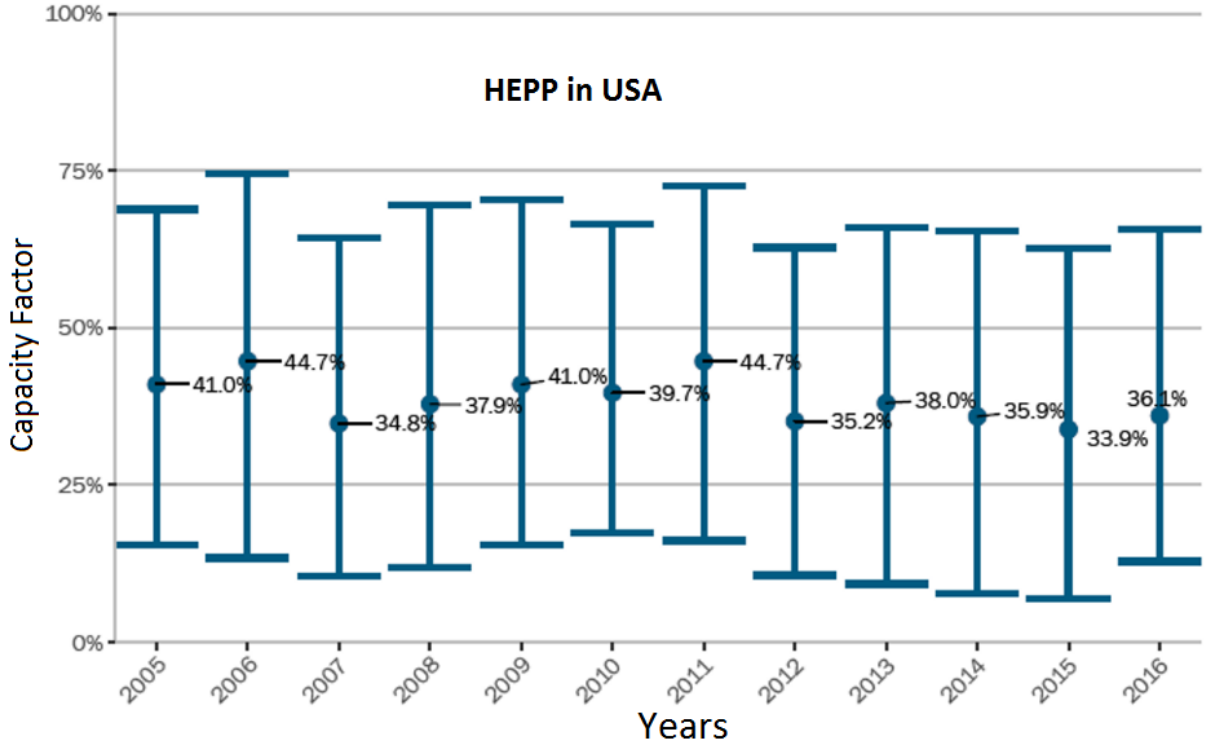


Figure 3. Capacity Factors of Hydroelectric Power Plants in the USA[3] (12)

4.2.1. Capacity Factor of River and Channel Type HEPPs

Table 6 shows the change in the capacity factor calculated in 259 river and Channel type HEPPs, and the annual weighted average of the capacity factors.

Table 6. Change of Capacity Factor of River and Channel Type HEPPs examined by years

Year	Capacity Factor **0- %15**		Capacity Factor **%16-25**		Capacity Factor **%26- 36**		Capacity Factor **>%37**		Capacity Factor Annual Weighted Avarage
	MW	Number	MW	Number	MW	Sayı	MW	Sayı	%
2015	1421,32	90	1938,58	88	953,60	63	168,94	18	20,51
2016	457,40	21	1049,43	66	1820,68	89	1149,95	83	35,23
2017	386,13	30	1180,32	59	1732,36	105	1190,42	65	32,26
2018	387.55	28	1859,58	103	1769,67	85	668,47	44	28,65

The total average weighted capacity factor of the River and Channel Type HEPPs for the last 4 years was approximately 29% (Figure 4).

[3] As of 2018, there are 2241 HEPPs in the USA with a total capacity of 80 000 MW. (12)

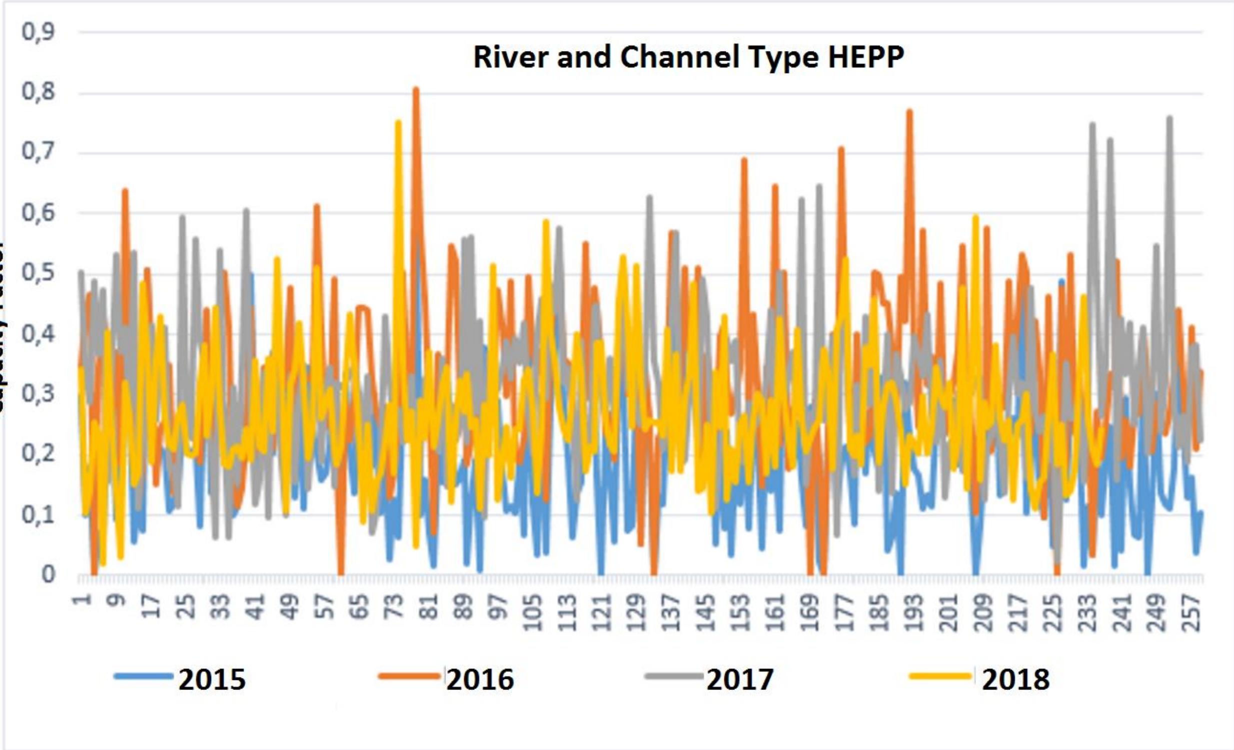


Figure 4. Variation of capacity factors of river and channel type HEPPs by years

Since river and channel power plants has no reservoirs , energy production is directly related to the change in precipitation on a daily basis. Therefore, the production is directly affected during the drier periods. This situation arises between the year of 2015 and 2016,2017,2018 energy produced. In this study, it was observed that the production of reservoir type HEPPs also decreased by almost the same rate in the dry year of 2015. However, due to the storage characteristics of these HEPPs, they had the opportunity to shift their production to peak hours.It is highly probable that Reservoir Type HEPPs have generated peak energy more than before since last four years.

In general, the difference between the planned and produced energies of the HEPPs in the Aegean and Mediterranean regions of Turkey was larger than the HEPPs in other regions.HEPP In other words,in these regions HEPP generated less energy from planned one comparing with other regions.

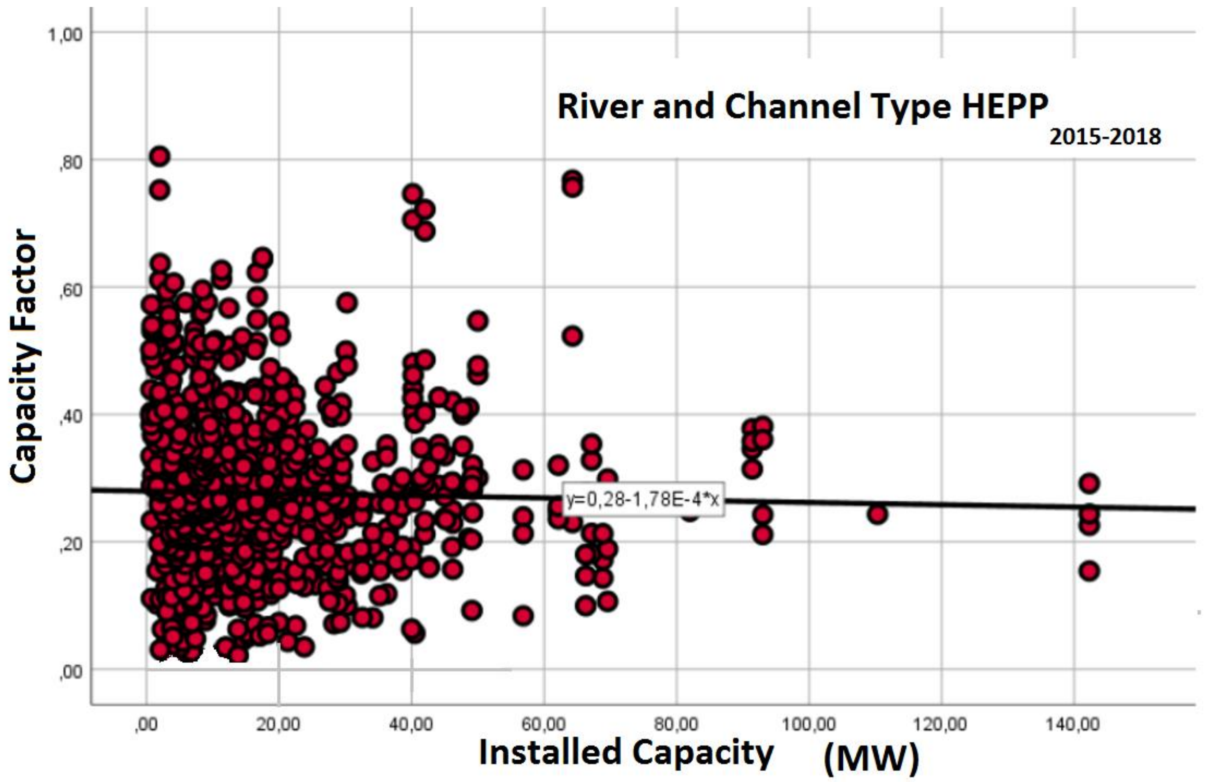


Figure 5. Variation of calculated capacity factors of river and channel type power plants in the last 4 years

The variation of capacity factors of 259 river and channel type HEPPs used in the study with installed power in the last 4 years is given in Figure 5. As seen in this figure, the weighted average values of the capacity factors of the HEPPs examined fall as the installed capacity increases.

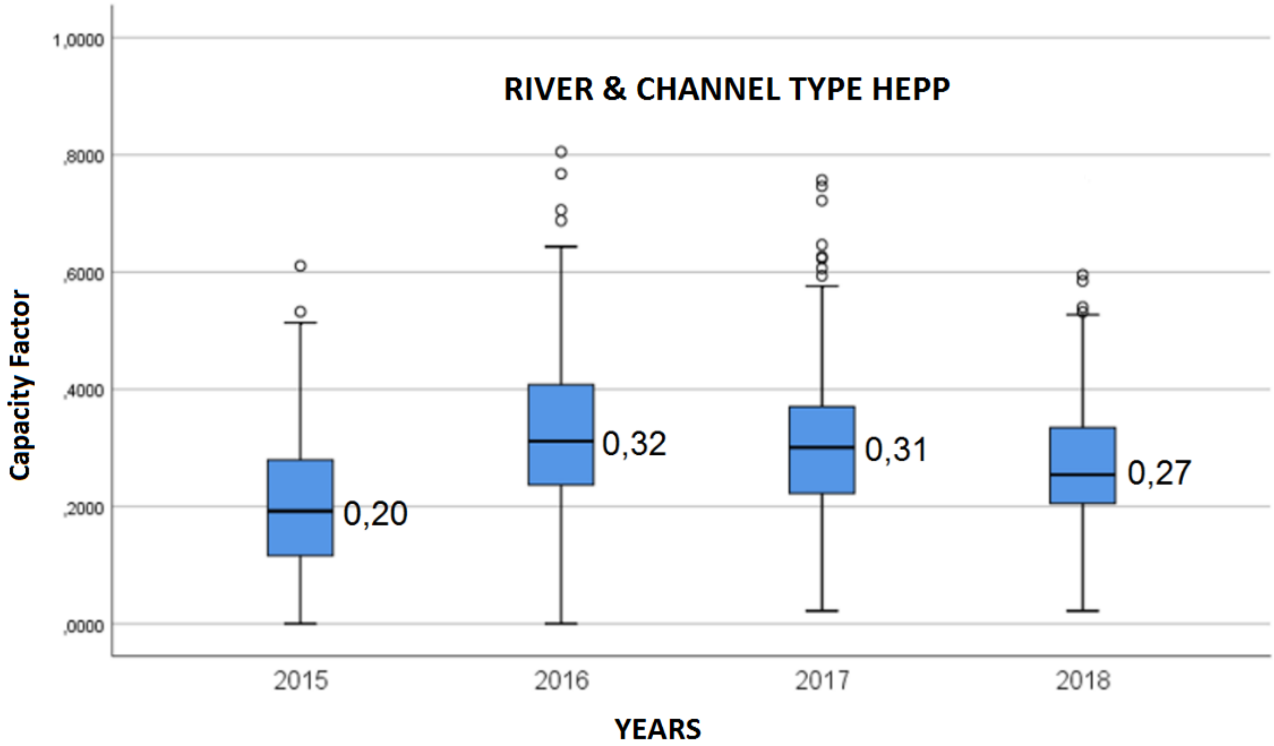


Figure 6. Median values of capacity factors of 259 river and channel type power plants and their variation by years.

In this study, the median values of the capacity factors of 259 River and Canal Type power plants examined and the changes according to years are given in Figure 6. The average annual value of the weighted capacity factor of 259 River Channel Type HEPPs was 27.5%.

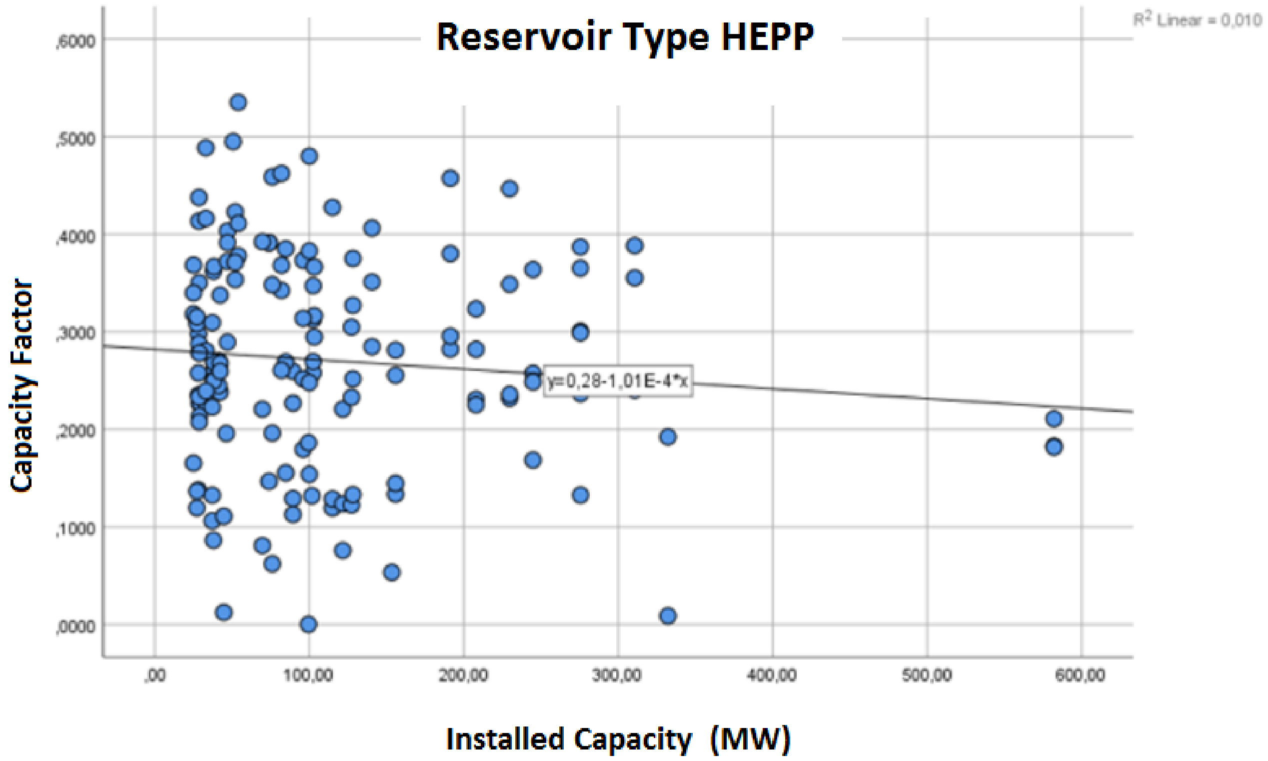
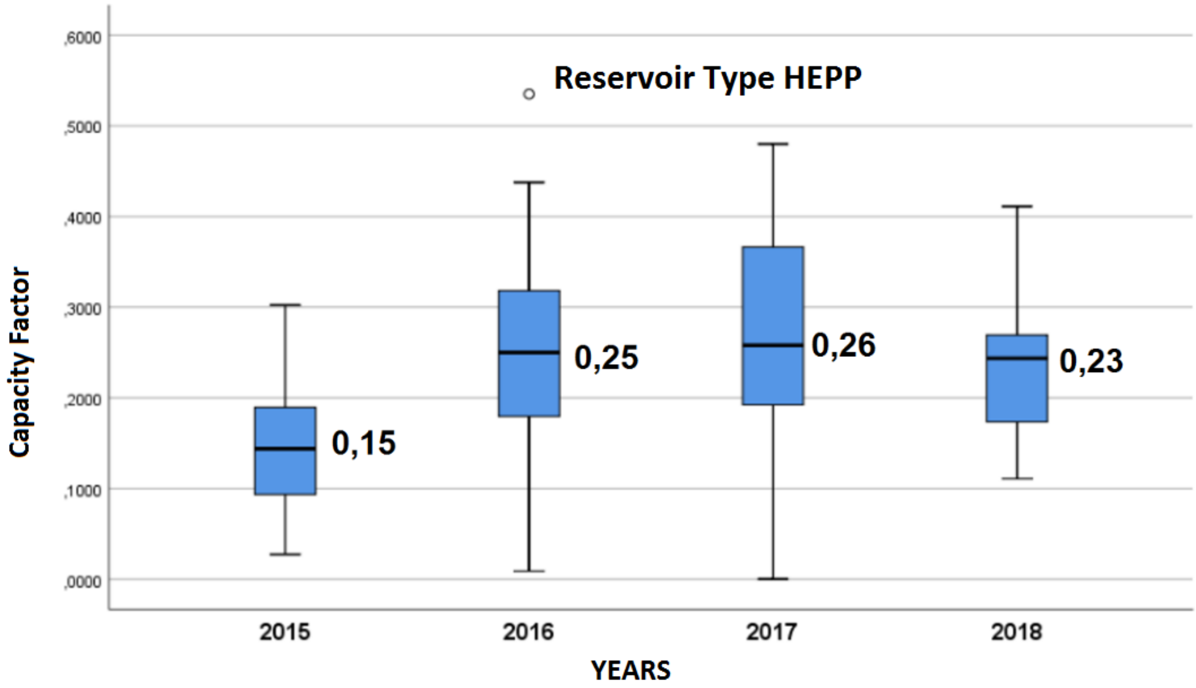


Figure 7. Variation of capacity factors of the reservoir type HEPPs operating in the last 4 years with the installed power

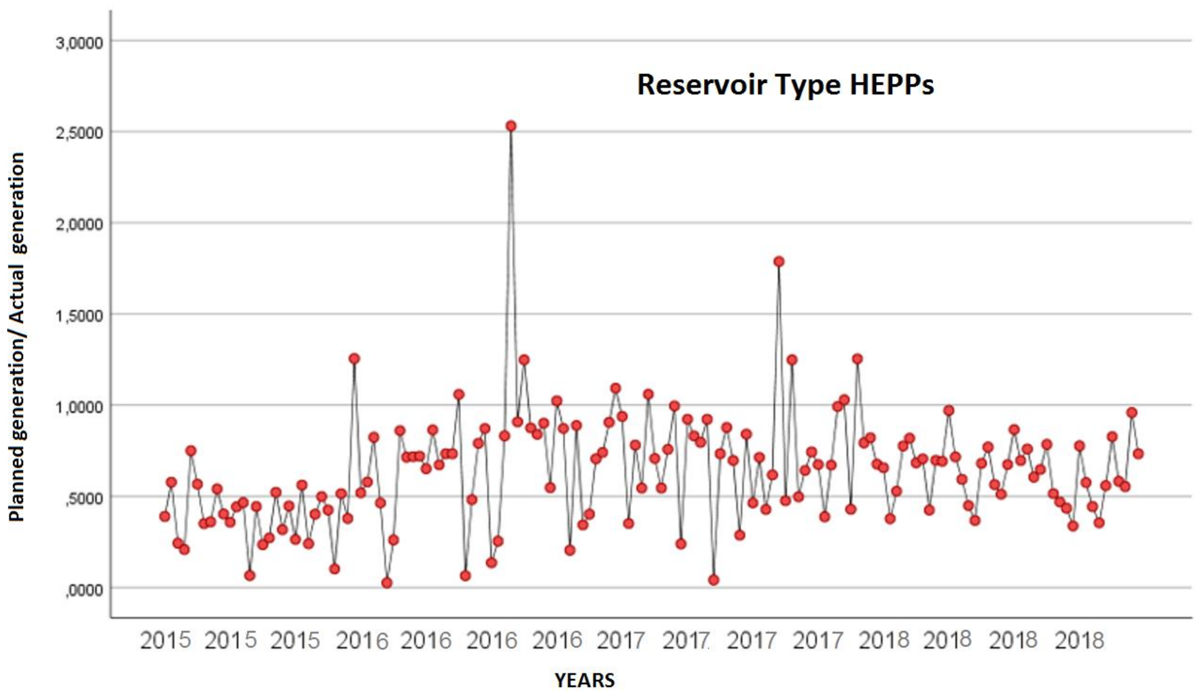
4.2.2. Capacity Factor of Reservoir Type HEPPs

This study mainly focuses on the production efficiency of river and channel type HEPPs. However, the production efficiency and capacity factors of 41 Reservoir Type HEPPs with 4950 MW installed capacity, which are registered to YEKDEM and have continuous production data in the last four years, were also examined.



As can be seen in Figure 7, the capacity factor of the Reservoir Type HEPPs, especially those with an installed capacity of up to 100 MW, has varied over a wide band such as 0-55 %. The range of this variation decreased as the installed power increased and decreased between 15-40%.
The 4-year average value of the capacity factor of 41 Reservoir Type HEPPs has been calculated as of 23%.

4.2.3.Realization Rate of Planned Production in Reservoir Type HEPPs



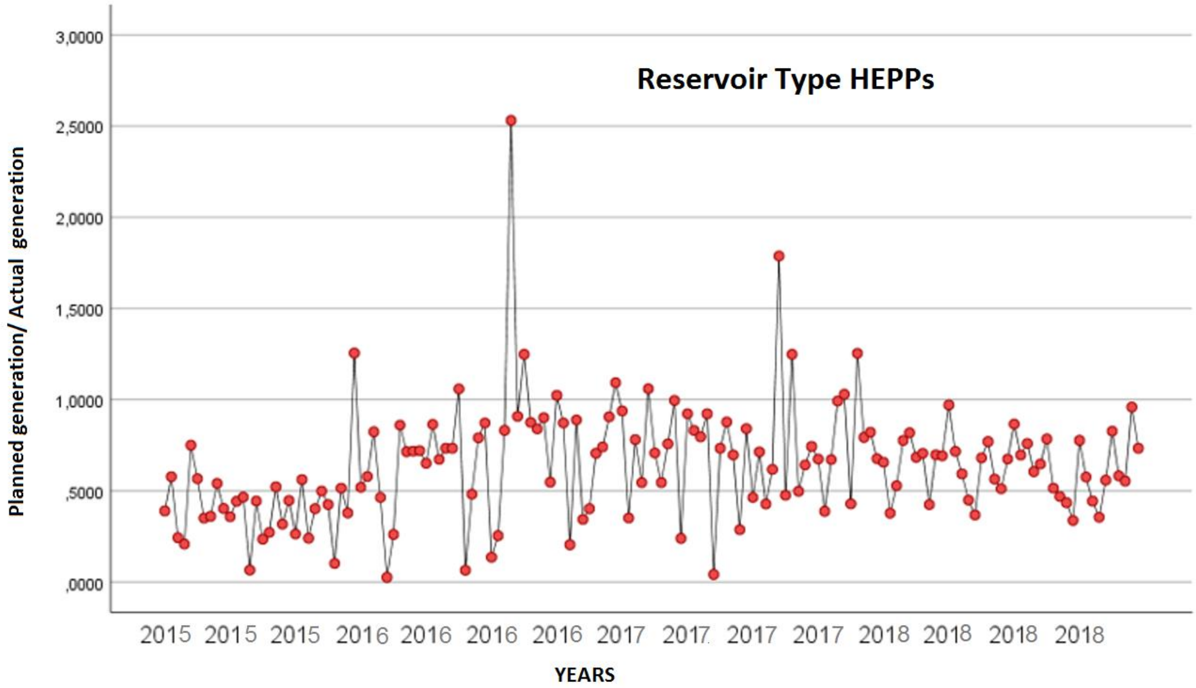


Figure 9. Realization rate of planned production in YEKDEM registered reservoir type HEPP by years

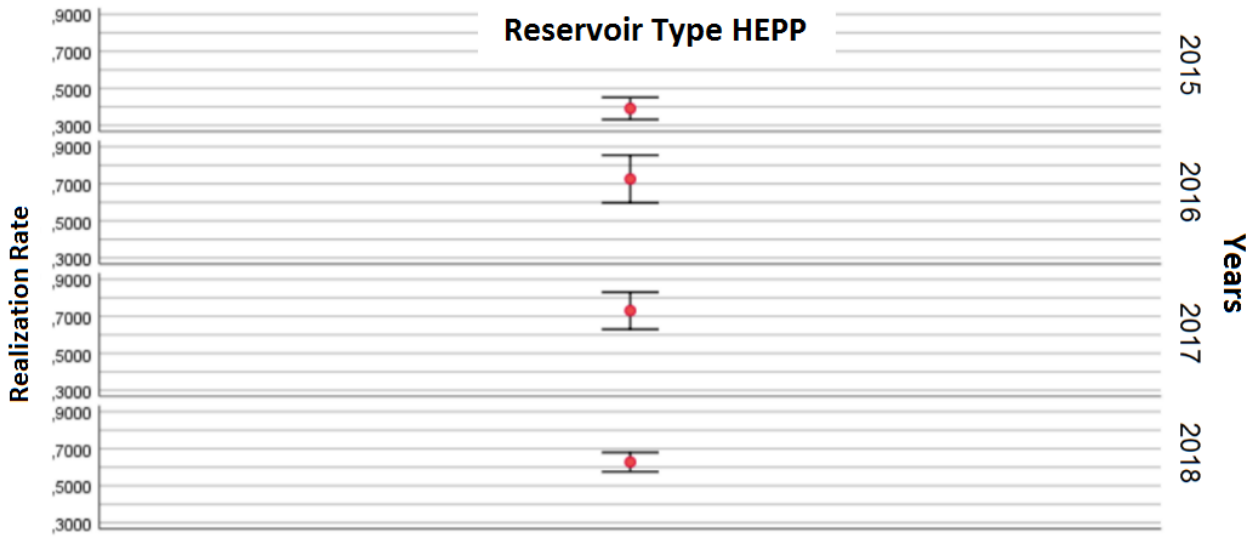


Figure 10. Average realization rates of the planned production fort he reservoir type HEPP by years

The realization rate of the planned production in YEKDEM registered reservoir type HEPP by years is given in Figure 9 and Figure 10. When these figures are analyzed, in 2015, which is a low rainy year, almost all of the reservoir type HEPPs' production remained below 50% of the planned. In 2016,2017,2018 this rate was around 70% on average. (Figure 9-10).

4.2.4. About Assessment by Capacity Factor

Capacity factors of hydroelectric power plants should be handled differently from other renewable energy plants. The flow values in a river basin and Project discharge can be quite variable and may also vary from basin to basin. Therefore, the installed capacity determination of HEPPs can be handled with a very flexible approach during the project design phase. Thus, for example, when large installed power selection and low capacity factor are accepted, peak energy demands are met and supply security in the network is ensured. On the other hand, HEPPs operating with small installed power and large capacity factor may not be able to provide peak energy need and therefore supply continuity.

In other words,weighted average capacity factors are around 27 % for small and large hydropower projects, with most projects in the range of 5% to 65 % (Figure 4). Given the design flexibility for hydropower, depending on inflows and site characteristics, this wide range is to be expected and uniquely to hydropower, low capacity factors are often a design choice to meet peak demands, not a handicap to project economics. Therefore, the range of capacity factors of HEPPs can be quite wide. For example, the capacity factors obtained from the 142 HEPP projects in operation worldwide and given in Figure 11 vary between 23% and 95% (9). In our study, this issue was taken into consideration and the realization ratio of the produced energy / planned energy, which is another parameter showing the production efficiency of HEPPs, was also taken into consideration.

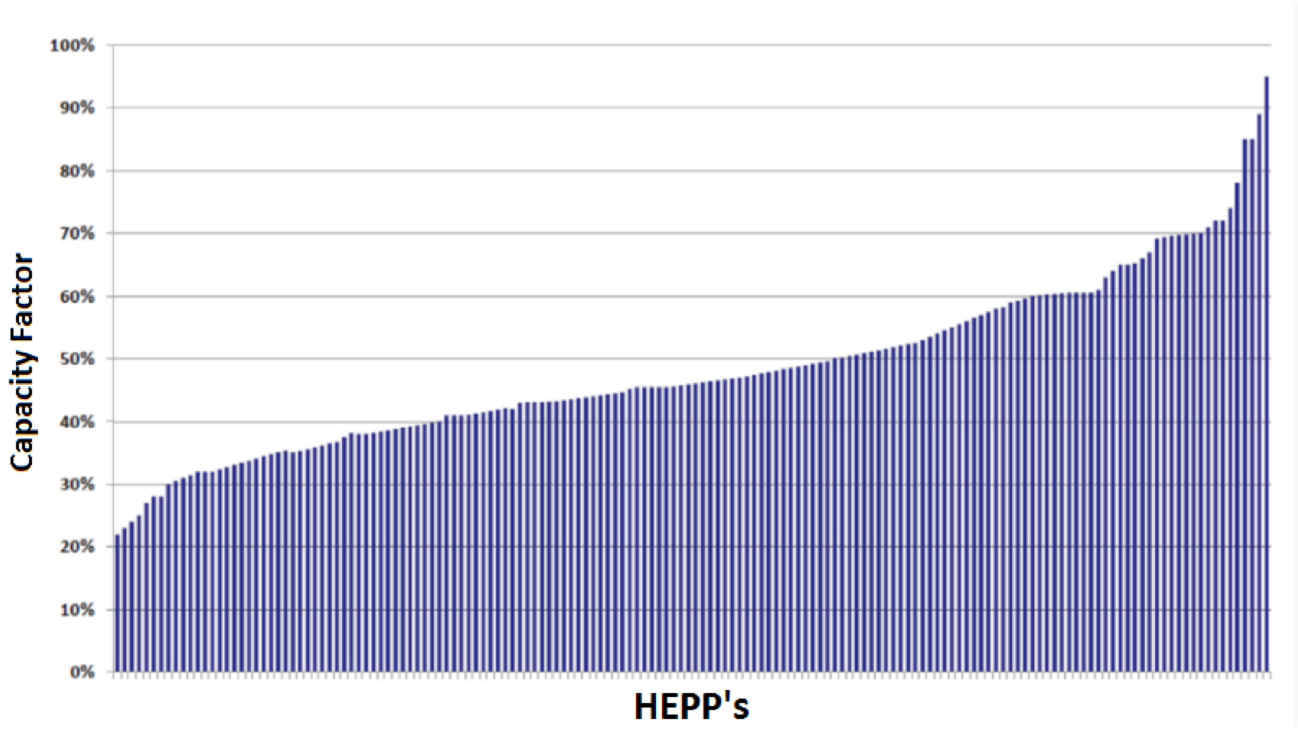


Figure 11. Capacity Factors of some HEPPs in the world (9).

Although the capacity factor range can be quite wide , the weighted average capacity factors are expected to be higher than a certain value as of %45,%50.

As it is in Turkey , capacity factors for new small and large hydropower projects are 29% and 27% respectively,we need to reevaluate the design choice as well as engineering hydrology of the HEPP projects.

4.2.5. Hydropower Production and Capacity Factors in 2018 in Turkey

In 2018 Market Development Report of EMRA (4), total installed capacity of Reservoir Type HEPPs and River and Channel HEPPs is given as 20 534 +7748 = 28 282 MW. In the same report, the electricity generation in 2018 is given as 40.961 billion kWh for Reservoir HEPPs and 18.975 billion KWh for River and Channel HEPPs. In this case, 68% of the hydro power generation (59.936 billion kWh) produced in 2018 by dam-operated hydroelectric power plants (20 534 MW) and 32% (7748 MW). of it generated by River and Channel HEPP.
In other words annual working hours of River ,Channel HEPP has been as of 2450 hours while Reservoir Type HEPPs is 2000 hours. In 2018, average capacity factor of all of the River & Channel HEPP’s has been 23% while reservoir type HEPP’s 28% through Turkey.

These results are consistent with the results obtained with the HEPPs registered with YEKDEM in 2018 in this study. In this study, the weighted capacity factor of River and Channel Type HEPPs for 2018 was 27% and 23% of Reservoir HEPPs. (Figure 6 and Figure 8).

In this case, the results we obtained from this study showed that it represents majority of Dams’ capacity factor in Turkey. Furthermore, it also shows that the capacity factors of Reservoir Type HEPPs and the reason for the decrease of annual working hours to 2000 hours need to furher study

5. THE EFFECT OF CLIMATE CHANGE ON WATER RESOURCES PROJECTIONS

Several studies have been conducted on the impact of climate change on water resources in Turkey . The most comprehensive of these was carried out by the General Directorate of Water Management as a project. The aim of the “Impact of Climate Change on Water Resources Project , carried out by the General Directorate of Water Management, is to determine the impact of climate change on surface waters and groundwater on the basis of River Basin.

It also aims determination of adaptation activities. covering the whole 25 river basins in the 2015-2040-2070-2100 projection period using three different global climate models for climate change projections, two different representations of the concentration route (RCP4.5 and RCP8.5).

This is the most reliable state organisation owned study to determine climate change effects on water resources. The Final Report was published in 2016 (13).

In the Final Report, it says that “ *Due to the unique characteristics of each basin, the distribution of accessible water in the basin and therefore the needs of the sectors vary from basin to basin. The intersectoral distribution is expected to change in the future with the effect of climate change.*

Therefore;Vulnerability Analysis based on the sectors that need water resources in the basins in order to ensure sustainable water use is of great benefit. "

Within the scope of the aforementioned project, the impacts of climate change projections produced on 25 river basins for the 2015-2040 projection period by using three different global climate models on water resources with two different representative concentration routes (RCP4.5 and RCP8.5) were determined.
In this context, the percentage differences of basin-based gross water potential in 2040 compared to 2015 are given in the Table 7.

Table 7. Percentage differences of basin-based gross water potential in 2040 compared to 2015 (13)

River Basins	HadGEM2-ES RCP4.5	HadGEM2-ES RCP8.5	MPI-ESM-MR RCP4.5	MPI-ESM-MR RCP8.5	CNRM-CM5.1 RCP4.5	CNRM-CM5.1 RCP8.5
	2015-2040	2015-2040	2015-2040	2015-2040	2015-2040	2015-2040
Akarçay	-60	-62	-12	-12	-5	-19
Antalya	-38	-51	-40	-39	-30	-38
Aras	6	5	47	43	46	49
Asi	-35	-43	-26	-14	2	-22
Batı Akdeniz	-20	-39	-34	-31	-17	-30
Batı Karadeniz	-50	-46	-20	-19	-22	-27
Burdur	-75	-79	-10	-14	23	-18
Büyük Menderes	-56	-59	-43	-39	-23	-43
Ceyhan	-59	-60	-34	-35	-25	-36
Çoruh	-20	-18	18	18	15	19
Doğu Akdeniz	-28	-39	-33	-32	-22	-29
Doğu Karadeniz	-59	-59	-38	-38	-43	-40
Meriç-Ergene	-40	-54	-9	0	18	-14
Fırat-Dicle	-51	-49	-21	-15	-17	-24
Gediz	-58	-64	-54	-48	-42	-57
Kızılırmak	-51	-47	-13	-8	-22	-25
Konya Kapalı	-58	-61	-44	-41	-38	-45
Küçük Menderes	-43	-59	-54	-53	-33	-48
Kuzey Ege	-26	-45	-21	-16	4	-14
Marmara	-41	-46	-29	-27	-23	-33
Sakarya	-69	-72	-27	-22	-23	-33
Seyhan	-15	-14	-12	-10	-3	-22
Susurluk	-42	-50	-29	-27	-29	-35
Van Gölü	-3	-1	22	40	52	45
Yeşilırmak	-30	-27	14	16	0	1
Türkiye	**-43,8**	**-46,5**	**-22,7**	**-19,4**	**-17,5**	**-25,1**

As shown in Table 7, three different climatic scenarios pointed out a decrease in the gross water potential at various rate in 2040 compared to 2015 in almost all of the basins. Gross water reduction potential ranged from 46.5% to 17.5 %.
According to various scenarios mentioned in theproject final report (13) , a thematic climate projection maps showing the percentage differences of basin-based gross water potentials in 2040 compared to 2015 are given in Figure 12.

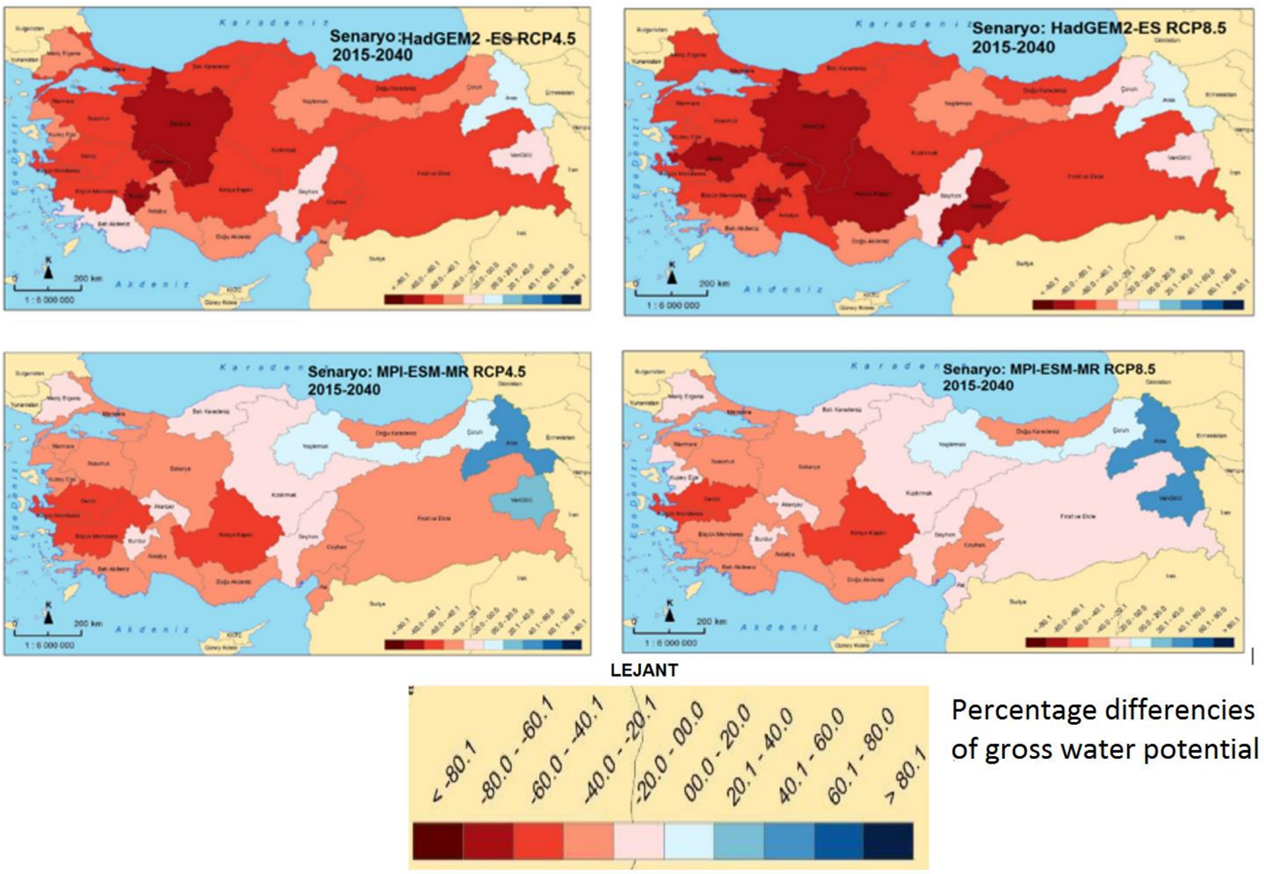


Figure 12. Thematic climate projection maps showing the percentage difference of basin-based gross water potential in 2040 compared to 2015 according to various scenarios. (13).

6. COMPARISON OF THE RESULTS WITH SOME WORLD SAMPLES

The Renewable Energy Agency's annual reports (6,7,8) include the weighted average capacity factor values of small and large HEPPs in the world. (Figure 13..and Figure 14). As shown in Figure 13,, this has increased in recent years as of 48% on average in last sixth years. Developing technology was also effective in this increase. The average capacity factor is around 50% in Norway, which has around 1700 large and small hydroelectric power plants and supplies 98% of its electricity from hydroelectric power. (10). The Norwegian Energy Agency's data show that the average capacity factor of 432 HEPPs with an installed capacity up to 1 MW is 55%, while 368 HEPPs between 1-10MW and 253 HEPPs with an installed capacity of 10-100 MW and those with more than is 46% (10).

According to some other literature, the weighted average capacity factors of HEPPs constructed between 2010 and 2018 in the world ranged from 44% to 51% (8) (Figure 13). According to the data of the International Renewable Energy Agency, the weighted average value of the capacity factor varied by region and country. While this ratio varies between 21% and 62% in Large Reservoir Type HEPPs, the weighted average capacity factor is between 43% and 68% in HEPPs with an installed capacity of less than 10 MW. The lowest value was found in China with 43% between 2010 and 2013 and the highest value in South America (excluding Brazil) with 68% between 2014-2018 (8). These values are clearly seen in Figure 14. The data obtained from this study is marked on the same way as Turkey value remained at very low level.

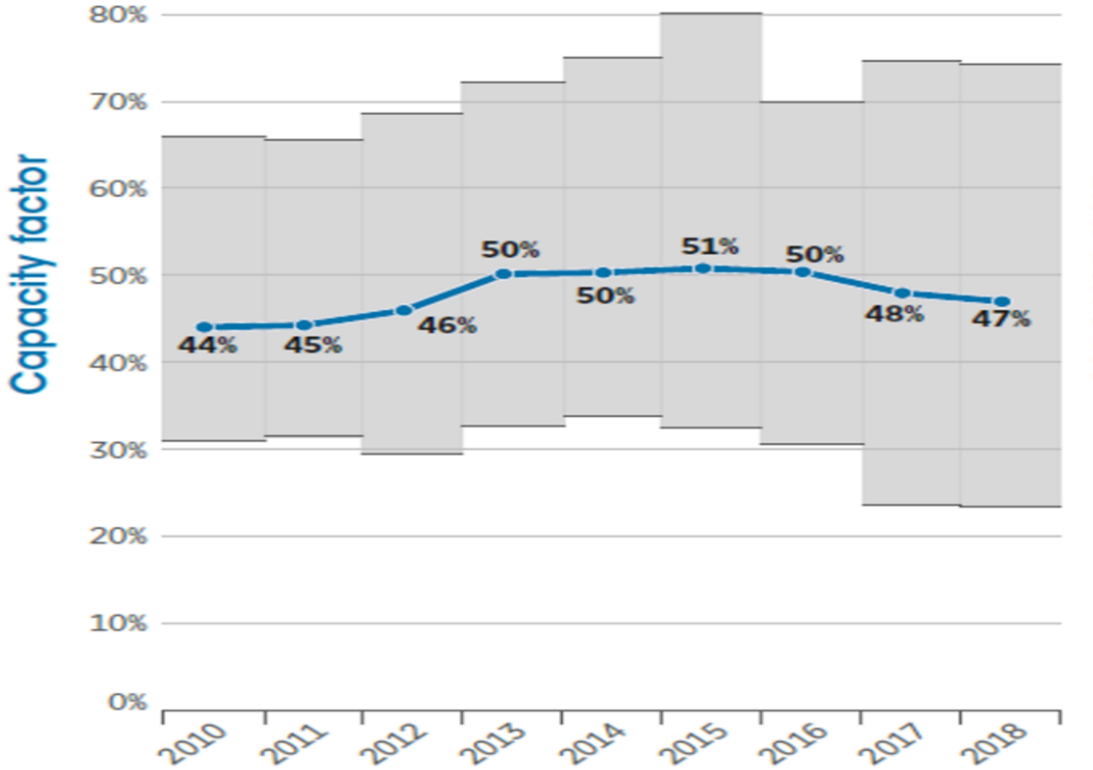
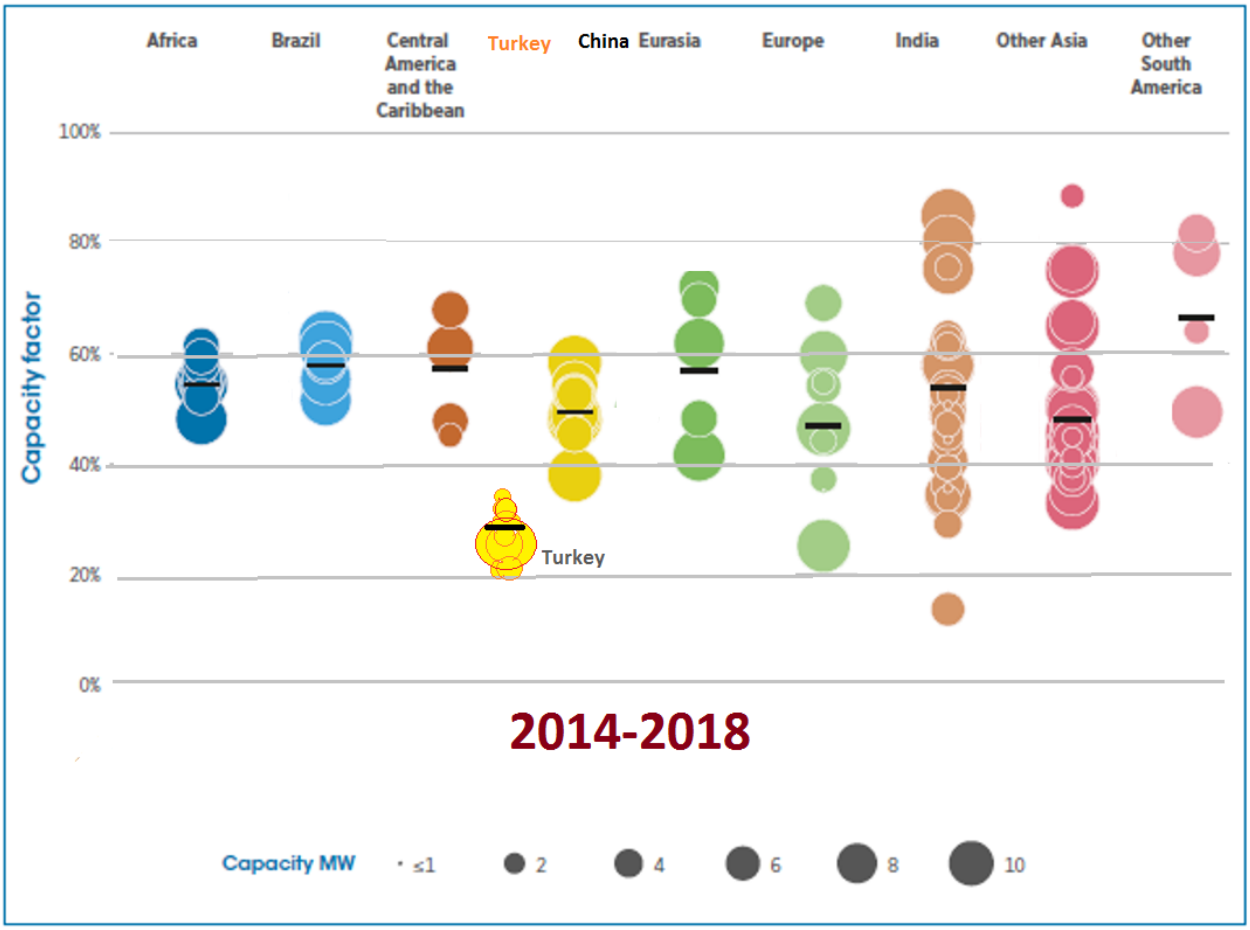


Figure 13. Weighted average capacity factors of some HEPPs in the world between .2010-2018 (8).



Note: Small hydropower projects in this figure are all those with capacity less than or equal to 10 MW.

Şekil 14.2014-2018 yılları arasında 10 MW'dan küçük HES'lerin kapasite faktörlerinin ağırlıklı ortalama değerlerinin bölge ve ülkelere göre değişimi (8). (Türkiye'nin değeri tarafımızdan işlenmiştir.)

Figure 14.Change in the weighted average capacity factors of HEPPs less than 10 MW by region and country (8). (Turkey's value is processed by us.)

7. CONCLUSIONS, EVALUATIONS AND RECOMMENDATIONS

Turkey has irregular flow and about half of the run off flows in the rivers during   5-month rainy period. İn addition to this effect of climate change, causes some arid periods to increase and temporal shift.

In particular, the energy production efficiency of non-storage River and Channel HEPPs is highly sensitive to project hydrology and hydrometeorological changes. This was also determined in this study. Over the last 10 years, more than 500 River and Channel type HEPPs have been built in Turkey. Feed back of these HEPPs will increase our knowledge and experience in both project consultancy and operation rules..

These studies will allow to determine the current status of river basins, their sensitivity to climate change impacts to be taken into consideration in planning, designing and operating new HEPPs.

The HEPP's which are not planned within the basin-scale planning approach and lack of detailed engineering hydrology may have low energy production efficiency and capacity utilization rates, as well as disrupt the ecological balance.

Existing projects need to be re-evaluated in this respect and updates to the operational program This will increase the sustainability of the project benefits.

In new HEPP projects, taking into consideration the above mentioned issues together with the optimization of production between successive HEPPs will reduce various uncertainties and risks, prevent economic losses and protect ecological balance.

1.The weighted average capacity factor of 259 river and channel type hydro power plants is obtained as of 29% for the last 4 years.operation.

2.In the same study, the average capacity factor is obtained as of 27 % for 41 Reservoir's HEPPs in the last 4 years.

3.The annual average working hours of the river and channel type HEPP is obtained as of 2450 , the capacity factor is 28%, while reservoir type HEPP of 2000 hours and average capacity factor is 23%.

4.The realization rate of the planned production in these river and channel type HEPPs has been 60% on average in the last 4 years.

5.Reservoir type HEPPs examined in this study have realized an average of 75% of their planned production in the last 3 years.

6.Approximately 50 river and channel type hydroelectric power plants with a total installed capacity of 750 MW have achieved half of their planned production in the last 4 years.

7.The weighted production efficiency values (Weighted Average Capacity Factors as of 25 %) of the investigated river channel type and reservoir type HEPPs, has been 50% lower than the world average.

8.It has been observed that the realization rates of the planned annual production are lower especially in the Mediterranean and Aegean regions.

9.Recently, the purchase guarantee (Feed-in Tariff) given to the production in thermal power plants encouraged the supply of base energy needs with these power plants and the production of the large dam hydroelectric power plants in peak hours. It is considered that the decrease in the production realization rate and capacity factor in the reservoir type HEPPs may be caused by this reason.

10.Recent procurement guarantee for production in thermal power plants has encouraged companies that have both hydraulic and thermal power plants to meet their base energy needs with natural gas, domestic coal power plants and to generate peak energy with reservoir type HEPPs.It is considered that the decrease in the production realization rate and capacity factor in the resrvoir's HEPPs may be caused by this reason.

11.In the river and channel type HEPP projects carried out in the last 10 years, the problems have started from planning stage and turned into operational inefficiencies. Hydrological Factors and Operational Factors are the most effective factors in the low realization rate of production in our HEPPs.

These observed reasons are listed below;

- Failure to comply adequately with the hydrological principles during the planning phase and insufficient engineering hydrology studies,
- Failure to determine the flow regime as comprehensive as possible with sufficient flow measurements in the project section,
- The fact that the change in the flow rate during the year and over the years has not been examined properly,
- The temporal variation of the current has not been evaluated within the whole river basin where the plant is located.
- There was no synchronous operation planning in successive HEPPs while they were planning
- A Basin Scale Energy generation optimization plan has not been developed.
- The impact of climate change on water resources is not taken into account adequately in the Feasibility Reports.

12.In Turkey, disruptions in planning, management and supervision prevent the activities to be sustainable.

13.All development activities on a basin scale need to be considered within the scope of a Regional Plan in which the basin is located. Noncompliance with the Regional Plan and Environmental Plan has been effective on the problems experienced today.

RECOMMENDATIONS ;

1. In the dry period of 2015, the realization rates in the annual generation of reservoir type HEPPs as well as River and Channel type HEPPs remained below 50%. This situation seems to be caused by the conflict of sectoral needs, necessitates.Therefore more realistic approach to sectoral water allocation is strongly needed in the coming period.

2. It would be useful to examine the differences in capacity factor and production realization rate of HEPPs by region. HEPPs, whose production realization rate is continuously low, should be re-examined by considering the future climate change effect in that region and alternative proposals should be developed.

3. Operation and Energy Optimization Planning study need to be prepared on the Basin Scale, it will be useful to consider the Report of the Effects of Climate Change on Water Resources prepared by the General Directorate of Water Management.

4. Due to the low average production efficiency of HEPPs, it would be beneficial to control the amount of water that should be released for natural life especially from HEPP’s in the Mediterranean and Aegean regions.

5. “Operation and Energy Optimization Plans need to be prepared for the existing power plants in order to evaluate the real energy potential of our basins by taking into account natural life and ecology.

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EVALUATION of OBTAINED RESULTS IN THE HPA ROUNDTABLE MEETING

The resuts obtained from this study is analysed and evaluated in a experts round table meeting in the Hydropolitics Association .

At the Round Table Conference held by the SPD on July 6, 2019
Final Decleration prepared by the Contributions of Speakers and Participants

Incentives for the development of our country's HEPP Potential and guarantees for a period of payment at fixed prices (feed-in tariff) have caused a rapid increase in the number of River and Channel type and Reservoir Type HEPPs in the last 10 years.

However, despite this increase in the installed capacity and the number of HEPPs, energy production from both river and channel type and reservoir type HEPPs did not increase as planned. The realization rates and capacity factors of the planned production in these energy facilities in the last 4 years have been very low.

In this roundtable meeting the causes of these low realization rates in the power generation and lower capacity factors of HEPPs were discussed, it was evaluated that our HEPPs were not able to operated efficiently.


HYDROPOLITICS ASSOCIATION
HYDROPOLITICS ASSOCIATION
YILLAR
HES SAYISI
KURULU GÜÇ MW
2015 144 2611 %58
2016 34 687 %16
2017 54 704 %16
2018 65 890 %20
İncelenen TOPLAM 259 4490 MW


HYDROPOLITICS ASSOCIATION
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HPA

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