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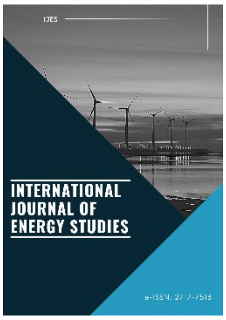

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Parameters affecting energy production in hydroelectric power plants: A case study in Şırnak

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Highlights

- Discussing the parameters affecting energy production with the help of Hydroelectric Power Plants (HEPP), which is a renewable energy source.
- The effect of meteorological data on energy production was examined.
- It has been proven that there is a direct proportion between capacity factor and energy production.

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ABSTRACT

Energy demand is increasing due to population growth and industrial development. As fossil resources become insufficient to meet energy demand, the focus is shifting to renewable energy. Hydroelectric power plants using renewable hydraulic energy are preferred to help close this energy gap. In this study, data were collected from turbines, energy production, pressure, water used in energy production, generator voltage, grid voltage, frequency and head measurements at Zagros Energy Production Inc. located in Silopi district of Şırnak province and Elbi Electric Production Manufacturing Construction Industry and Trade Inc. located in Uludere district, and various parameters affecting electricity production in hydroelectric power plants were analyzed. In addition, average monthly atmospheric pressure (hPa), average temperature (°C), average relative humidity (%) and average precipitation (kg/m²) data for the years 2020-2023 from the Automatic Meteorological Observation Stations closest to the hydroelectric power plants were obtained from the Şırnak Governorship Meteorology Directorate. The study also calculated the capacity factors, efficiencies and the effect of various parameters on energy production, including the actual energy produced in Zagros and Elbi HEPPs in 2022, monthly average temperature, actual pressure, precipitation levels, relative humidity and flow rates through the turbines. When the energy production and efficiency were examined as a result of the research at Zagros Hydroelectric Power Plant (HEPP) and Elbi HEPP, the findings obtained show that higher energy production in a hydroelectric power plant does not necessarily mean higher efficiency. In terms of capacity factor, the highest value was recorded in December at Zagros HEPP with 89.38%, while the lowest value was recorded in April with 68.61%. The highest capacity factor was recorded in May at Elbi HEPP with 67.76%, while the lowest value was recorded in August with 0.2%. The analysis shows that there is a direct correlation between capacity factor and energy production.

Keywords: Hydroelectric power plant, Capacity factor, Energy efficiency, Energy production, Elbi HEPP, Zagros HEPP.

1. INTRODUCTION

From the beginning of human existence until now, humans have needed different types of energy to meet their primary needs. The increase in the world population and the development of technology have led to an increase in the energy consumed and, thus, an increase in the demand for energy [1, 2].

Energy is the indispensable and most crucialpart of economic and social development, and studies continue to obtain clean and cheap energy that can be obtained more efficiently[3, 4]. Although the energy produced from fossil fuels meets this need and can be stored to meet the need for energy since fossil fuels are inedible and produce gases such as carbon dioxide and methane that are harmful to the ozone layer during use, their use is beginning to be reduced and replaced by renewable energy sources [5, 6]. As energy demands have increased in societies, studies continue to obtain reliable, uninterrupted, clean, low-cost, quality energy from natural, renewable sources such as wind, sun and water to meet this demand [7, 8]. Geothermal energy, solar energy, hydrogen energy, hydroelectric energy, wave energy, biomass energy and wind energy are examples of renewable energy sources [9-14].

Our country's energy needs have increased due to increased daily use andindustrialisation[15]. Although we are a country with a high potential for renewable energy sources, a significant part of our energy needs are imported. To reduce this import, the trend towards environmentally friendly sectors that require less investment has become widespread.Reducing foreign dependency on energy and using renewable water resources for sustainable development is important[16].Hydroelectric energy is the most commonly preferred form of energy production in terms of renewable energy sources.Hydroelectric energy ranks first among renewable energy sources. It is a renewable energy source with high potential. Our country's water resources are hydroelectric, making it possible to make energy investments[17]. The critical reasons why hydroelectric energy sources are preferred are that they do not use any substances that will harm the environment, that their energy is obtained entirely by using water, and that it is renewable [18].Hydroelectric power plants are the world's most used power plants for energy production [6]. It was thought that it would be helpful to work on hydroelectric power plants, considering the potential of our country's geographical structure in closing the energy deficit [19].

In this study, the parameters affecting energy production were examined by comparing the data obtained from Zagros HEPP, Elbi HEPP and Şırnak Meteorology Provincial Directorate in Şırnak province using the data for 2022.

2. MATERIAL METHOD

2.1. Information on Silopi Dam- Zagros Hydroelectric Power Plant and How it Works

Silopi Dam was built as a foothill power plant type within the Uludere district of Şırnak province and is located on the right bank of the Hezil Stream with a tailwater elevation of 585.50 m (Figure 1.).Zagros Energy Production Joint Stock Company operates it. The water taken from the right bank of the Silopi Dam, built on the Hezil Stream, through a 220.00 m long and 1.00 m diameter penstock, is turned into turbines to produce energy in the Zagros HEPP, which is built at a tailwater elevation of 585.50 m and an installed power of 2.400 MWm I am running a few minutes late; my previous meeting is running over. 2.340 MWe. The generated energy is transmitted through switchboards arranged at the transformer's output with a power of 2.80 MVA (6.3/34.5 kV). An approximately 12.0 km long 3/0 AWG energy transmission line was constructed and connected to the Uludere (Bağlıca) Transformer Center.

Figure 1. Silopi Dam

Synchronous generators, electrical machines that produce electricity, are one of the most essential parts of hydroelectric power plants and are called alternators[20, 21]. Horizontal shaft synchronous type generators used in Zagros HEPP are used (Table 1). 6200 V comes from the generator and passes to the generator output cell. The unit enters 6200 V from the power transformer primary and receives 31150 V output from the power transformer secondary. 31150

V coming out of the power transformer passes to the unit input feeder and enters the domestic supply feeder, and the required energy is used for domestic needs. The energy produced is transmitted through the switchboards at the exit of the transformer. It delivers the power it makes to the villages, towns and neighbourhoods on the feeder 9 (f9) line taken from the Uludere (Bağlıca) Transformer Center.The data in Table 1 and Table 2 are provided by Zagros company.

Table 1. Zagros Hes turbine and synchronous generator information

Type	**Francis**
Total	1
Capacity (MWe)	2.340
Turbine Efficiency	0.93
Generator Efficiency	0.975
Frequency (Hz)	50
Output Voltage (kV)	6.3

Table 2 shows the operating study values according to the feasibility report of Zagros HEPP.

Table 2. Monthly feasibility production values - Zagros Hes

Month	**Production According to Feasibility (MWh)**
January	1713
February	1515
March	1541
April	1686
May	1547
June	1713
July	1658
August	1713
September	1658
October	1713
November	1713
December	1658

2.2. Information on Uludere Dam-Elbi Hydroelectric Power Plant and its Working Method

Uludere HEPP was built as a skirt power plant type just below the Uludere Dam located on the Robozik Stream in the Uludere district of Şırnak province. The waters are taken from the right bank of the Uludere Dam built on the Robozik Stream with a penstock of 65.00 m in length and 1.60 m in diameter at a tailwater elevation of 853.00 m. It contains two Francis turbines with a power of 1,750 MWm, and energy is produced by turbines at Uludere HEPP, which was established with an installed power of 3,500 MWm / 3,430 MWe. It is operated by Elbi Electric Production Manufacturing Construction Industry and Trade Ltd. Co. The energy produced at Elbi HEPP is transmitted through switchboards arranged at the transformer's output with a total power of 4.20 MVA (6.3/34.5 kV). An approximately 4.0 km long 3/0 AWG energy transmission line was constructed and connected to the Uludere (Bağlıca) Transformer Center.

Elbi HEPP meets the water required for energy production from the Uludere dam. The dam basin's water accumulated at the necessary elevation values is directed to the power plant building through the penstock (Figure 2.). After production in the Elbi HEPP building, the energy produced is delivered to the villages, towns and neighbourhoods on the feeder 5 (f5) line taken from the substation.

Figure 2. Uludere Dam-Elbi HEPP

Horizontal shaft synchronous type generators are used in Elbi HEPP (Table 3.). 690 V comes out of the generator and passes to the generator output cell. The unit enters 690 V from the power transformer primary and receives 31150 V output from the power transformer secondary. 31150 V coming out of the power transformer passes to the unit input feeder and enters the domestic supply feeder, and the required energy is used for domestic needs. The energy produced is transmitted through the switchboards at the exit of the transformer. It delivers the energy it produces to the villages, towns and neighbourhoods on the feeder 5 (f5) line taken from the Uludere (Bağlıca) Transformer Center.The data in Table 3 and Table 4 were provided by Elbi company.

Table 3. Elbi HEPP turbine and synchronous generator information

Type	Francis
Total	2
Capacity (MWe)	2 x1.750
Turbine Efficiency	0.925
Generator Efficiency	0.98
Frequency (Hz)	50
Output Voltage (kV)	6.3

Table 4 shows the operational study values according to the feasibility report of Elbi HEPP.

Table 4. Monthly feasibility production values - Elbi HEPP

Month	**Production According to Feasibility (MWh)**
January	360,7
February	329
March	316
April	292
May	263
June	1409
July	1672
August	2574
September	980
October	400
November	391
December	363

2.3. Şırnak General Directorate of Meteorology Data-Zagros HEPP

The data of the monthly average actual pressure (hPa), average temperature (°C), average relative humidity (%) and average rainfall amount (kg/m²) graphs in the atmosphere between 2021 and 2022 in the research findings section are from Şırnak Governorship Meteorology General Directorate. It was taken from the monthly data prepared by the Directorate of Automatic Meteorology Observation Stations (OMGİ) numbered 19721 in Silopi Görümlü Town, closest to Zagros HEPP, and numbered 17950 in Cizre.

Table 5 shows monthly average actual pressure values in the atmosphere for 2021-2022. Table 6 gives monthly average temperature change, and Table 7 shows monthly relative humidity values in the atmosphere. Table 8 details the monthly average rainfall, the most important factor affecting the amount of energy production.

Table 5. Monthly average actual pressure (hPa)-Silopi

Year/Month	1	2	3	4	5	6	7	8	9	10	11	12
2021	972.3	971.2	966.7	966.5	960.8	959.6	954.5	957.4	960.9	967.5	970.8	971.5
2022	970.3	969.2	967.9	964.5	963.0	958.1	954.2	956.4	960.8	967.1	970.5	972.7

Table 6. Monthly average temperature (°C)-Silopi

Year/Month	1	2	3	4	5	6	7	8	9	10	11	12
2021	8.1	9.5	11.1	19.4	25.9	29.4	33.5	32.8	27.3	21.3	15.2	8.9
2022	4.2	9.7	7.4	19.0	20.7	29.7	33.1	33.3	29.5	23.0	14.3	10.5

Table 7. Monthly average relative humidity (%)-Silopi

Year/Month	1	2	3	4	5	6	7	8	9	10	11	12
2021	50.6	54.7	55.5	34.7	23.4	17.7	17.8	18.6	22.6	30.1	43.7	56.7
2022	74.2	54.8	65.9	34.5	43.9	22.9	17.0	18.5	19.8	33.6	52.2	61.1

Table 8. Average monthly rainfall (kg/m^2)-Silopi

Year/Month	1	2	3	4	5	6	7	8	9	10	11	12
2021	191.0	50.9	105.1	5.8	2.5	0.0	0.0	0.5	0.0	5.3	0.6	26.3
2022	50.7	24.0	44.5	17.7	60.5	0.5	0.0	0.0	0.0	31.1	111.5	24.7

2.4. Şırnak General Directorate of Meteorology Data-Elbi Hes

The data of the monthly average actual pressure (hPa), average temperature (°C), average relative humidity (%) and average rainfall amount (kg/m^2) graphs in the atmosphere between 2021 and 2022 in the research findings section are from Şırnak Governorship Meteorology General Directorate. It was taken from the monthly data prepared by the Directorate of Automatic Meteorological Observation Stations (OMGİ) no. 18175 in Uludere Town, closest to Elbi HEPP, and no. 18344 in Silopi.

Table 9 shows monthly average actual pressure values in the atmosphere for 2021-2022. Table 10 gives monthly average temperature change, and Table 11 shows monthly relative humidity values in the atmosphere. Table 12 details the monthly average rainfall, the most crucial factor affecting the amount of energy production.

Table 9. Monthly average actual pressure (hPa)- Uludere

Year/Month	1	2	3	4	5	6	7	8	9	10	11	12
2021	885.2	884.3	880.7	872.4	878.9	878.4	874.9	877.5	879.1	884.1	885.6	884.4
2022	882.0	882.6	880.6	880.6	879.8	877.3	874.8	876.5	879.8	884.3	885.1	886.1

Table 10. Monthly average temperature (°C)-Uludere

Year/Month	1	2	3	4	5	6	7	8	9	10	11	12
2021	3.2	5.2	8.0	16.2	21.5	25.3	29.0	27.8	22.8	16.3	10.3	4.4
2022	0.6	5.1	4.2	15.2	16.3	24.8	27.6	28.4	24.4	18.1	9.6	6.0

Table 11. Monthly average relative humidity (%)-Uludere

Year/Month	1	2	3	4	5	6	7	8	9	10	11	12
2021	67.5	66.5	69.1	40.9	35.3	21.3	22.8	24.3	27.4	43.6	55.0	78.4
2022	70.5	69.5	29.1	39.7	52.5	31.4	21.9	24.4	26.5	42.5	61.3	67.6

Table 12. Average monthly rainfall (kg/m^2)-Uludere

Year/Month	1	2	3	4	5	6	7	8	9	10	11	12
2021	276.7	69.5	186.0	11.6	33.9	0.0	0.5	2.0	0.0	22.6	21.7	136.5
2022	148.2	54.6	234.3	35.3	108.9	7.1	0.3	2.2	0.0	66.6	114.3	40.6

2.5. HEPP Production Efficiency

Since losses are constant in hydroelectric power plants, they affect efficiency. Efficiency is calculated based on these losses. Hydraulic power loss occurs until the water reaches the turbine inlet. Losses can occur during mechanical transformation in many parts, such as the shaft shaft, transformer and salt installation. These losses need to be considered separately. Many methods have been developed in hydroelectric power plants to calculate efficiency. Flow measurement is done with these methods. Thanks to the data monitoring systems installed in power plants, net head value and generator output power data are obtained, and efficiency is monitored instantly[9, 22].

The most critical parameters for efficiency calculation in hydroelectric power plants are the flow rate and head values, which directly impact the power to be obtained from the power plant. When making this calculation, hydraulic power must first be calculated. For this purpose, the hydraulic power equation shown in 2.1 is used [23, 24].

$$P_a = \mu \rho Q g h \tag{2.1}$$

P_a = Actual Production Amount (W), μ = Efficiency, ρ= Density of water (kg/m^3) Q= Flow rate of the water coming to the turbine (m^3/sn), g= Gravity acceleration (m/s^2), h= net head ((m).

Table 13 and Table 15 show the average values of the variable parameter flow rate according to months. These values were obtained from Zagros and Elbi power plants using Supervisory Control and Data Acquisition (SCADA).

Here, Table 13 and Table 15 were used to calculate productivity by month. Additionally, the p, g, and h values were taken as constants in the theoretical calculation.

Table 13. Monthly change of average flow in 2022 - Zagros HEPP

p=1 kg/m3, g= 9,81 m/s2, h=58,46 m	
Month	**Flow (m3/sn)**
January	3,3
February	5,3
March	4,05
April	4,07
May	4,1
June	4,04
July	4,02
August	4
September	3,79
October	3,93
November	3,98
December	4,02

Table 14the monthly efficiency values are calculated using equation (2.1) for the average flow rate values according to the actual production. (ZAGROS).

Table 14. Monthly efficiency value-Zagros HEPP

Monthly	Actual Production (MWh)	Efficiency %
January	1388	73,34
February	1245	40,96
March	1368	58,89
April	1156	49,52
May	1228	52,22
June	1383	59,69
July	1413	61,28
August	1502	65,47
September	1415	65,1
October	1261	55,94
November	1256	55,02
December	1506	65,32

Table 15. Monthly change of average flow in 2022 - Elbi HEPP

p=1 kg/m^3, g= 9,81 m/s^2, h=40,60 m	
Month	**Flow (m^3/sn)**
January	1,77
February	1,39
March	2,91
April	5,36
May	3,9
June	2,1
July	1,02
August	0,14
September	1,33
October	1,52
November	1,33
December	1,6

Table 16the monthly efficiency values calculated using equation (2.1) for the average flow rate values according to the actual production (ELBI) are shown.

Table 16. Monthly efficiency value -Elbi HEPP

Monthly	**Actual Production (MWh)**	**Efficiency %**
January	464	65,81
February	185	33,41
March	538	46,41
April	1260	59,02
May	1550	99,7
June	826	98,7
July	142	34,95
August	5	8,96
September	209	39,45
October	601	99,2
November	146	27,56
December	635	99,6

2.6. Capacity Factor

Capacity factor: It expresses how efficiently a hydroelectric power plant operates and how much capacity it uses in a certain period. A high capacity factor proves that the hydroelectric power plant operates efficiently.

Capacity factor is the division of the power produced by a power plant at certain time intervals into the power that each hour can produce at total capacity within the specified time interval [25]. The capacity factor is one of the most critical parameters in the efficiency of power plants. The energy source used in power plants, operating conditions, seasonal changes, power plant type, meteorological situation, etc., varies. Apart from these, production may fall below the maximum level due to low demand and system failures. Available power output is vitalfor a safe system [26, 27].

2.6.1. Calculation of capacity factor

The HEPP capacity factor is found by dividing the amount of energy produced by the HEPP in a period of time by the amount of energy produced by the HEPP at total capacity [28].

$$\% \, CF=(MW*Hour)/((Day)*(Hour\backslash Day)*MW) \quad (2.2)$$

3. RESEARCH FINDINGS

In this section, the feasibility report of Zagros Hydroelectric Power Plant and Elbi Hydroelectric Power Plant was examined. Production efficiency and capacity factor calculations were made using the energy and flow rates produced monthly in 2022. Graphs were created by comparing the production realized in 2022 with the monthly average actual pressure, monthly average temperature, monthly average relative humidity, and monthly average rainfall amount, and the effects of these parameters were examined.

3.1. Production According to Zagros HEPP Feasibility Report

Figure 3. Shows the monthly feasibility production amounts prepared using Table 2, according to the data in the feasibility reports made during the establishment of Zagros HEPP. In terms of production, the rainfall period varies throughout the year. The rainy period lasts for 7.5 months, from October 7 to May 24, with the most rainy days occurring in March. The dry season starts on May 24 and lasts for 4.5 months until October 7, with the least rainy days in August [29].

According to the feasibility report, the production values are the maximum value of 1713 MWh in January, June, August, October and November, and the minimum value is 1515 MWh in February.

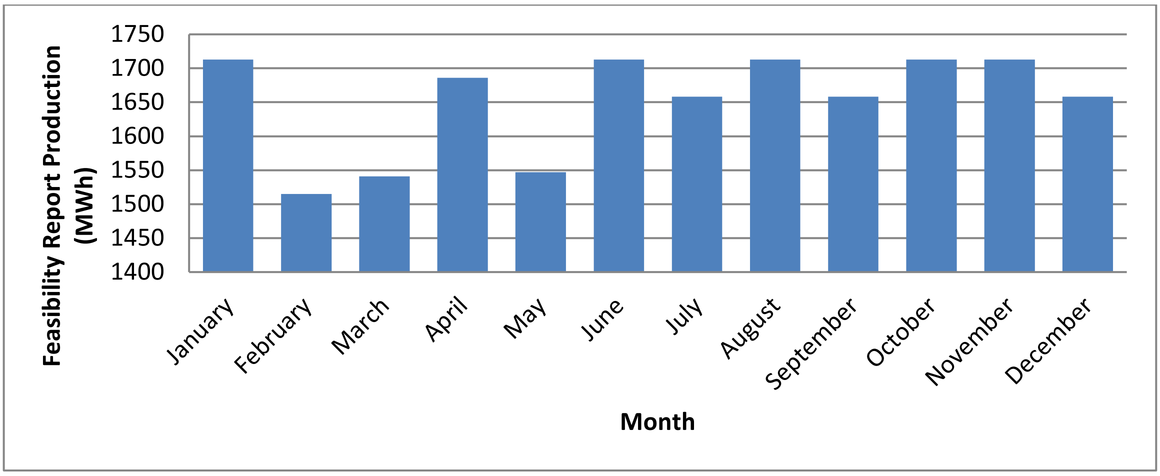

Figure 3. Zagros HEPP feasibility report monthly distribution chart

3.2. Production According to Elbi HEPP Feasibility Report

Figure 4 shows the monthly feasibility production amounts prepared using Table 4, according to the data in the feasibility reports made during the establishment of Elbi HEPP. In terms of production, the rainfall period varies throughout the year. The rainy period lasts for 7.8 months, from October 3 to May 28, with the most rainy days occurring in April. The dry season starts on May 28 and lasts for 4.2 months until October 3, and the least rainy days occur in August [30].

According to the feasibility report, the production values are the maximum value of 1672 MWh in July and the minimum value of 263 MWh in May.

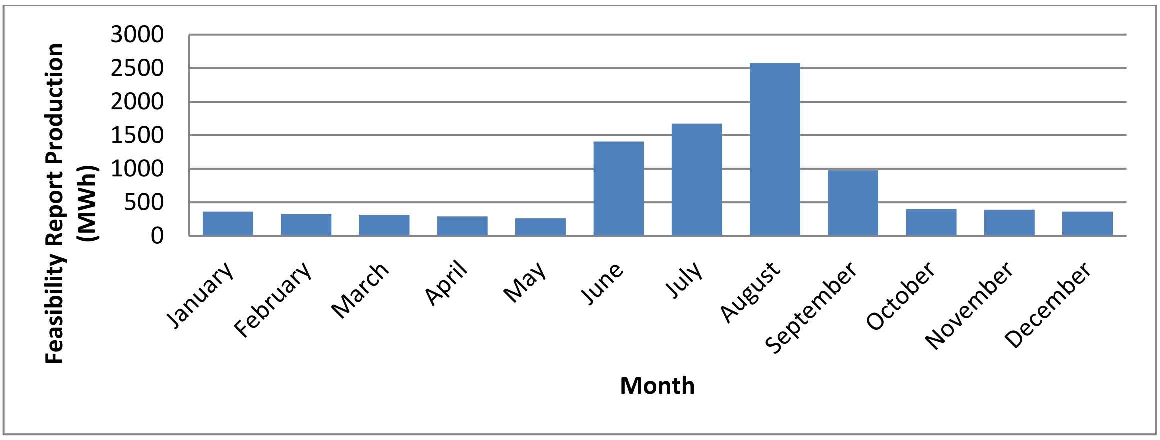

Figure 4. Elbi HEPP feasibility report monthly distribution chart

3.3. Zagros HEPP 2022 Actual Production

When we look at Figure 5, produced using Table 14, it is seen that December is compatible with feasibility and the production in 2022 is the highest production of the power plant with 1506 MWh in December. Although the lowest production is in February in the feasibility report, the production in 2022 was realized in April with 1156 MWh.

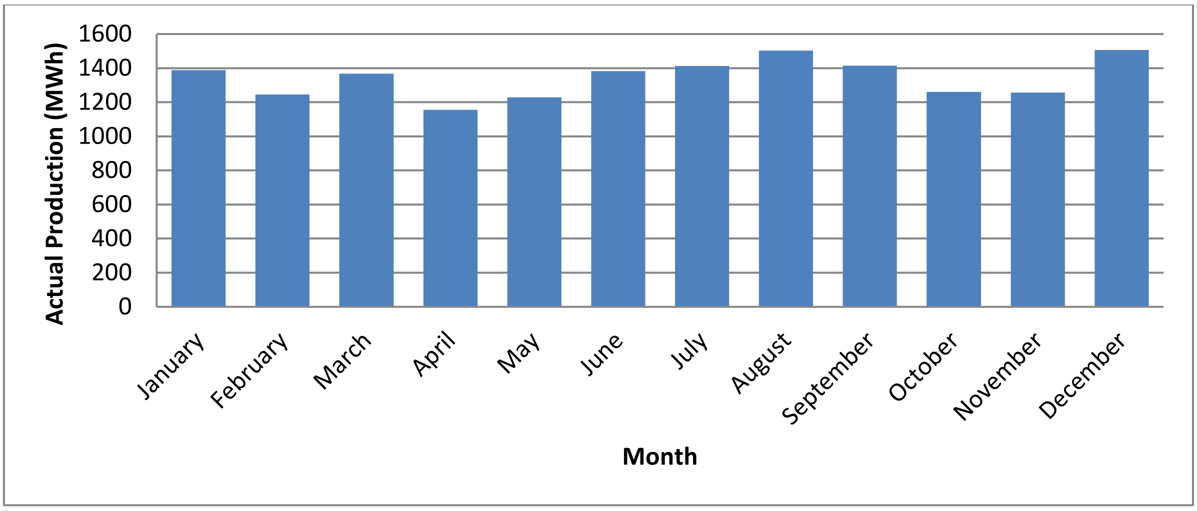

Figure 5. Distribution chart of actual production by months

3.4. Elbi HEPP 2022 Actual Production

Looking at Figure 6 produced using Table 16, it can be seen that although January is partially compatible with feasibility, the production in 2022 was achieved by the power plant with 1550 MWh in May. Although the lowest production was in April in the feasibility report, the production in 2022 was realized in August with 5 MWh.

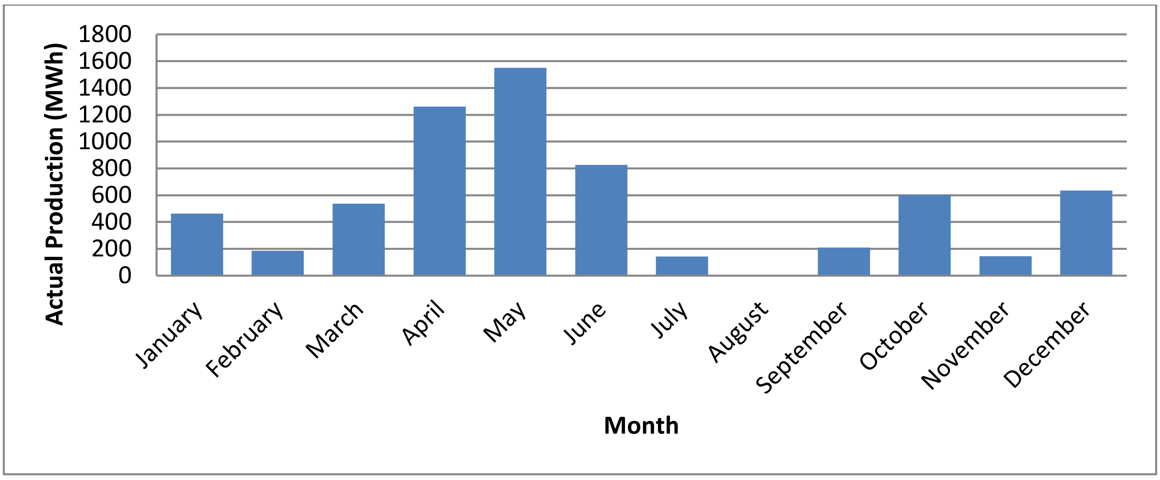

Figure 6. Distribution chart of actual production by months

3.5. Zagros Hes Relation between Actual Production and Average Actual Pressure

Figure 7 graphs a-b show monthly energy production and monthly average actual pressure data received from Şırnak Governorship General Directorate of Meteorology, respectively. According to these data, when the actual production of Zagros HEPP in 2022 is compared, it is seen that the actual pressure was at the lowest levels in July, namely 954.2 hPa, and the production realized in this month increased and reached 1413 MWh. As the average actual pressure increases towards December, there is a decrease in the production amount in October and November, and it is seen that it is 1261 MWh and 1256 MWh, respectively.

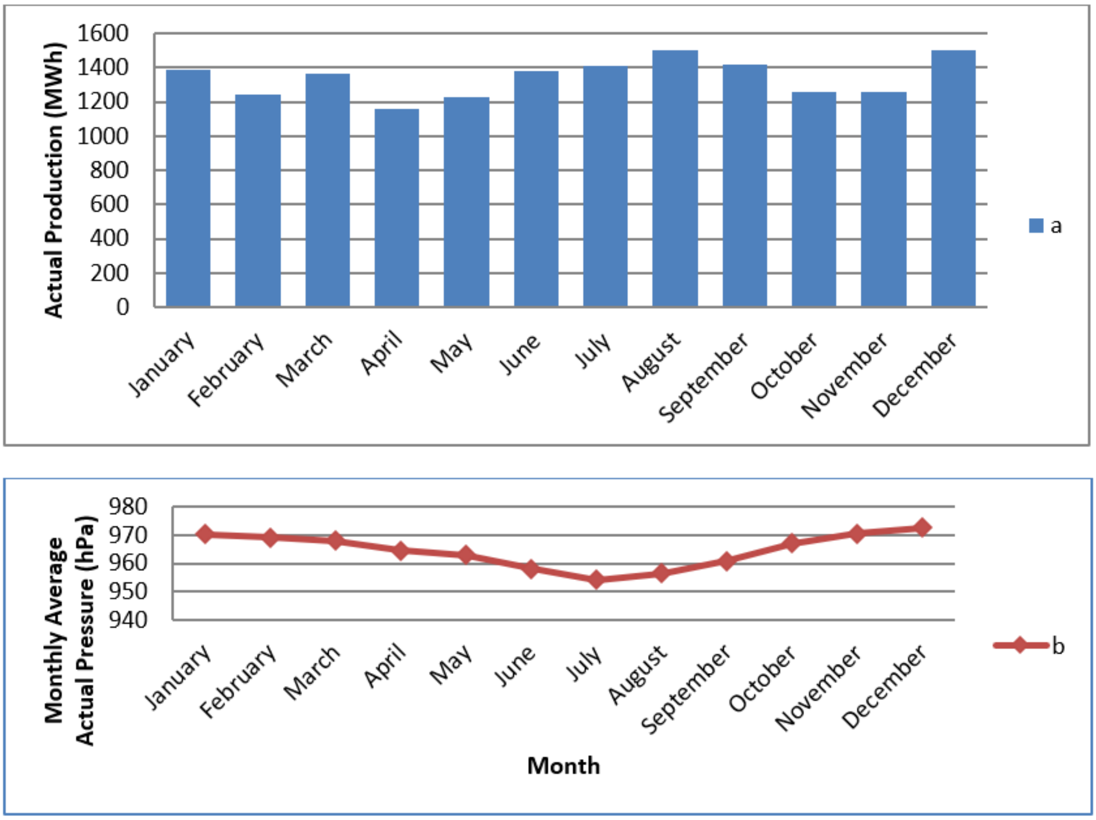

Figure 7. a) Actual energy production chart in 2022 b) Average current pressure chart in 2022

Figure 8 shows the effect of the monthly change of the average actual pressure values in 2022 on production. When this effect is examined, it is seen that the average actual pressure was at its lowest in July, 954.2 hPa, and in this month, the production increased and 1413 MWh was produced, and towards December, the average actual pressure increased by 972.7 hPa, affecting and decreasing the energy production. In July, there was an increase in energy production with the decrease in average actual pressure. Although there has been a decrease in the average actual pressure since February and the increase in energy production due to other impact parameters (temperature, amount of precipitation, etc.), the increase in energy production appears in the monthly production graph of the average actual pressure.

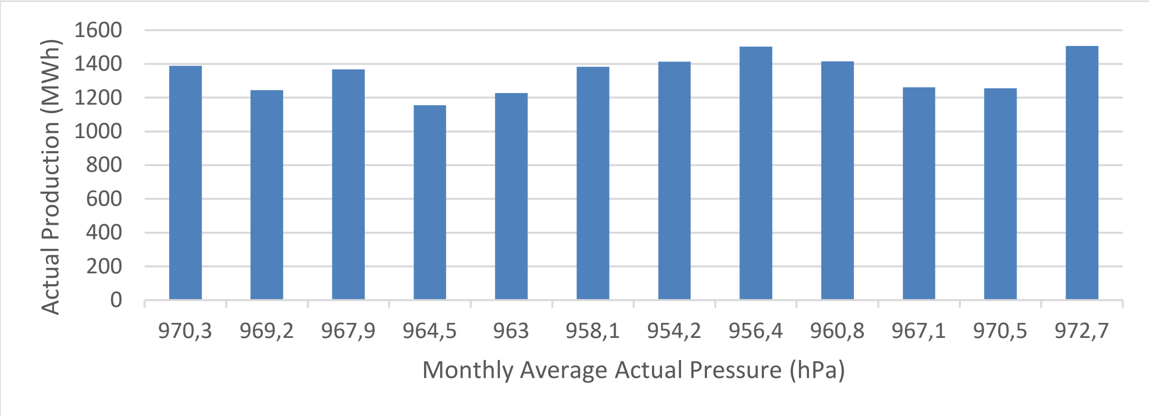

Figure 8. Monthly actual production graph of average actual pressure

3.6. The Relationship between Elbi Hes Actual Production and Average Actual Pressure

Figure 9 graphs a-b show monthly energy production and monthly average actual pressure data received from Şırnak Governorship General Directorate of Meteorology, respectively. According to these data, when the production of Elbi HEPP in 2022 is compared, it is seen that the actual pressure started to decrease in April and was at its lowest level in July, namely 874.8 hPa, whereas the production in May reached its maximum and reached 1550 MWh. As the average actual pressure begins to rise in August, there is a decrease in the production amount, and the lowest production is observed to be 5 MWh in August.

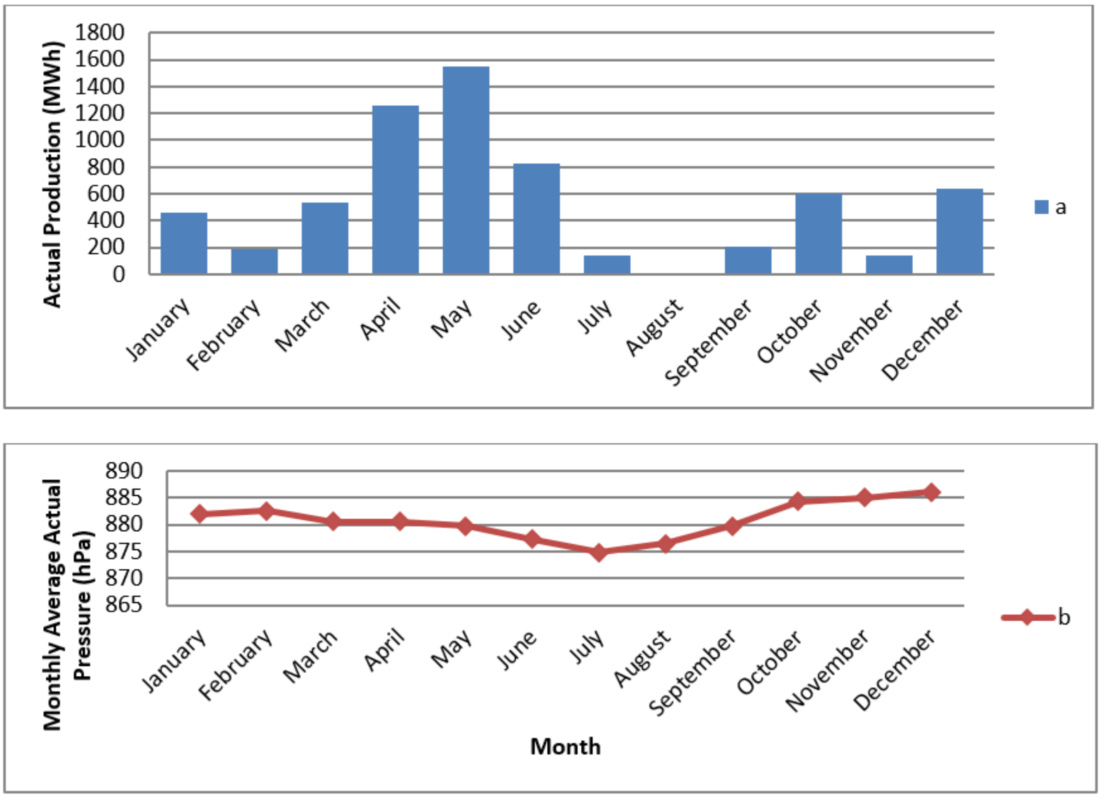

Figure 9. a) Actual energy production chart in 2022 b) Average current pressure chart in 2022

Figure 10 shows the effect of the monthly change of the average actual pressure values in 2022 on production. When this effect is examined, it is seen that the average actual pressure was lowest in July, 874.8 hPa, and the highest production of this year was made in May, and towards December, the average actual pressure increased by 884.4 hPa, affecting energy production and decreasing it. In July, there was a partial increase in energy production with the decrease in average actual pressure. There has been a decrease in the average actual pressure since March, and the change in energy production due to other impact parameters (temperature, amount of precipitation, etc.) appears in the monthly production graph of the average actual pressure.

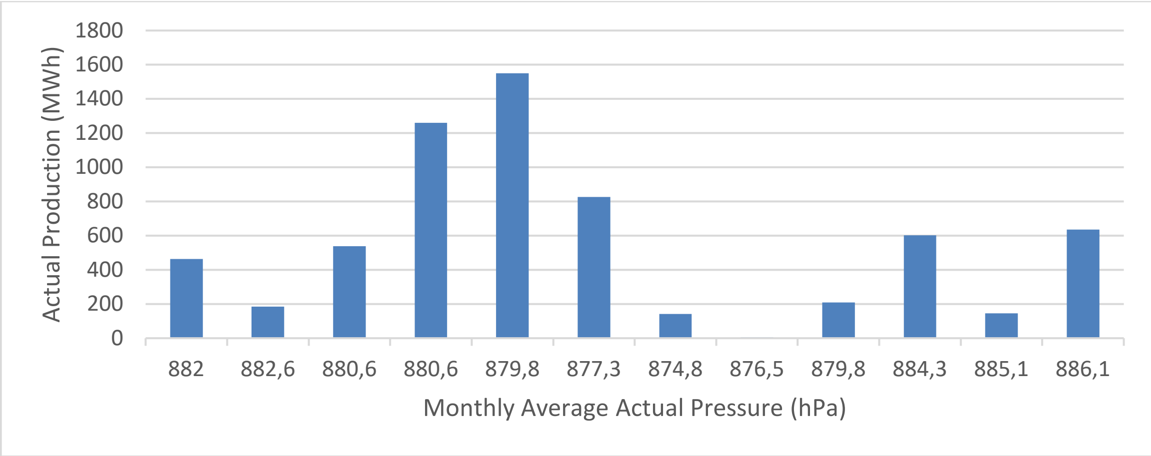

Figure 10. Monthly actual production graph of average actual pressure

3.7. Zagros Hes Actual Production and Average Temperature

The monthly change in electricity produced and the monthly average temperature change in 2022 are shown in Figure 11 a-b graphs, respectively. When the monthly temperature chart is examined, the production was 1388 MWh and above due to low temperatures and snow and rain in December, January and February. As the temperature increased in the higher regions in March-April, the snow began to melt and affected energy production. Although the increase in temperature levels and low precipitation affected the amount of water in June, energy production decreased in some months and increased in others.

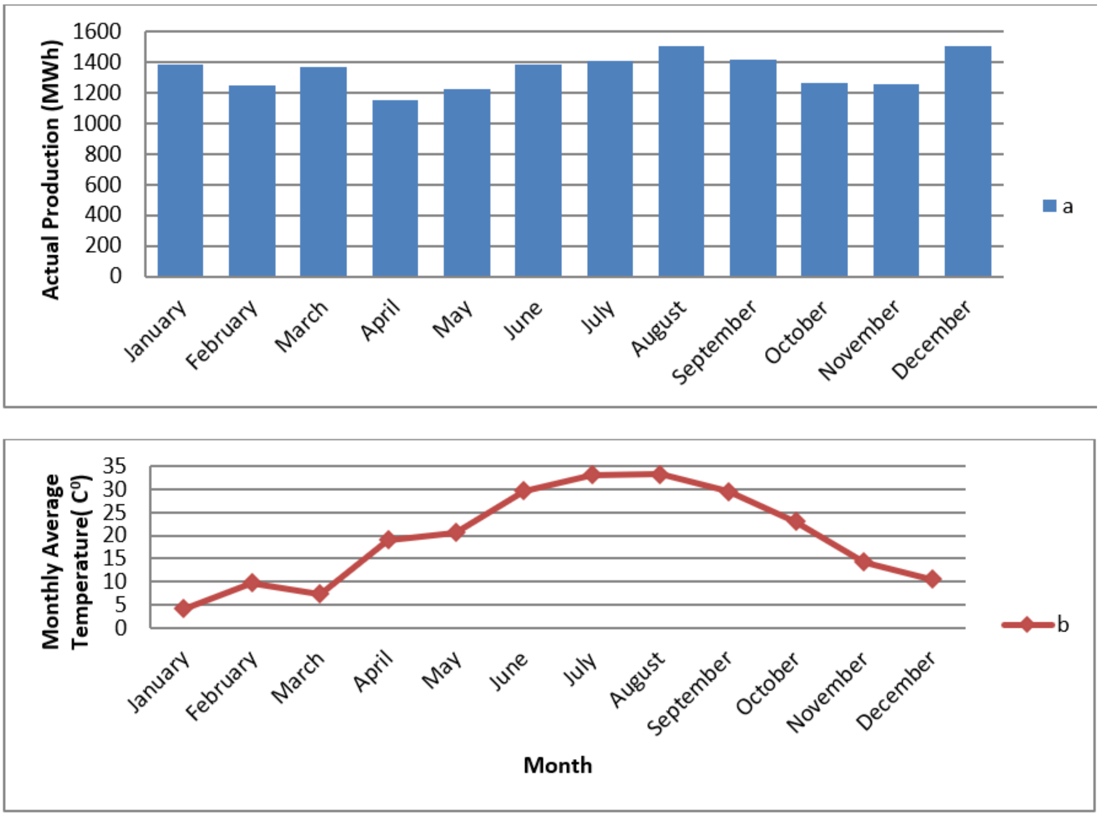

Figure 11. a) Energy production chart in 2022 b) Average temperature chart in 2022

Figure 12 shows the production amounts in response to monthly average temperature values. Here, it is seen that the lowest temperature was experienced in January with 4.2 °C, and as the temperature increased from January onwards, there was a decrease in energy production. 1368 MWh was produced in March due to the low rainfall and the majority of the snow melting in the higher areas at the end of March-April. The highest average temperature was August with 33.3 °C and 1415 MWh was produced this month.

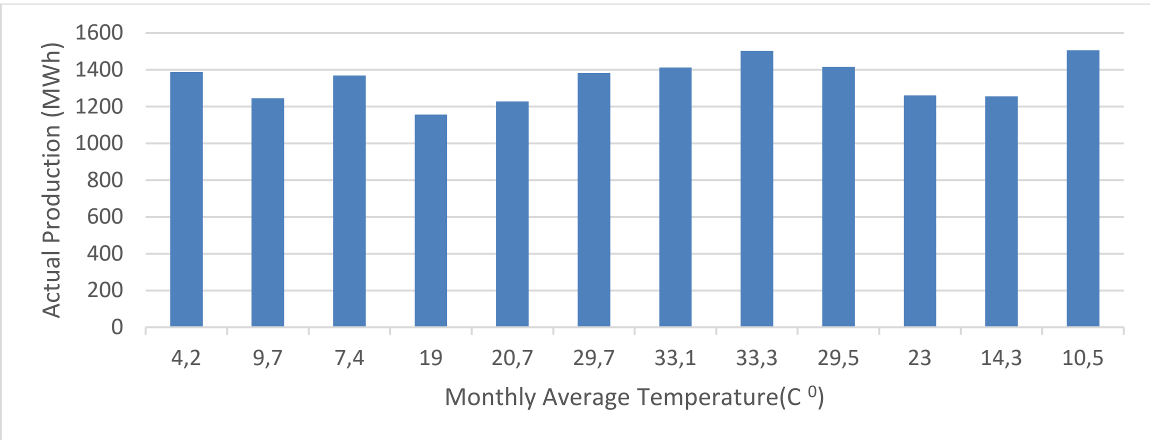

Figure 12. Zagros HEPP monthly average temperature and actual production graph

3.8. Elbi Hes Actual Production and Average Temperature

The monthly change in electricity produced and the monthly average temperature change in 2022 are shown in Figure 13 a-b graphs, respectively. When the monthly temperature chart is examined, the production was 635 MWh due to low temperatures and snow and rain in December, January and February. As the temperature increased in the higher regions in March-April, the snow began to melt and had a positive impact on energy production. As of June, there is a decrease in energy production due to the increase in temperature levels and low rainfall. With the decrease in temperatures in September, the amount of energy production started to increase again.

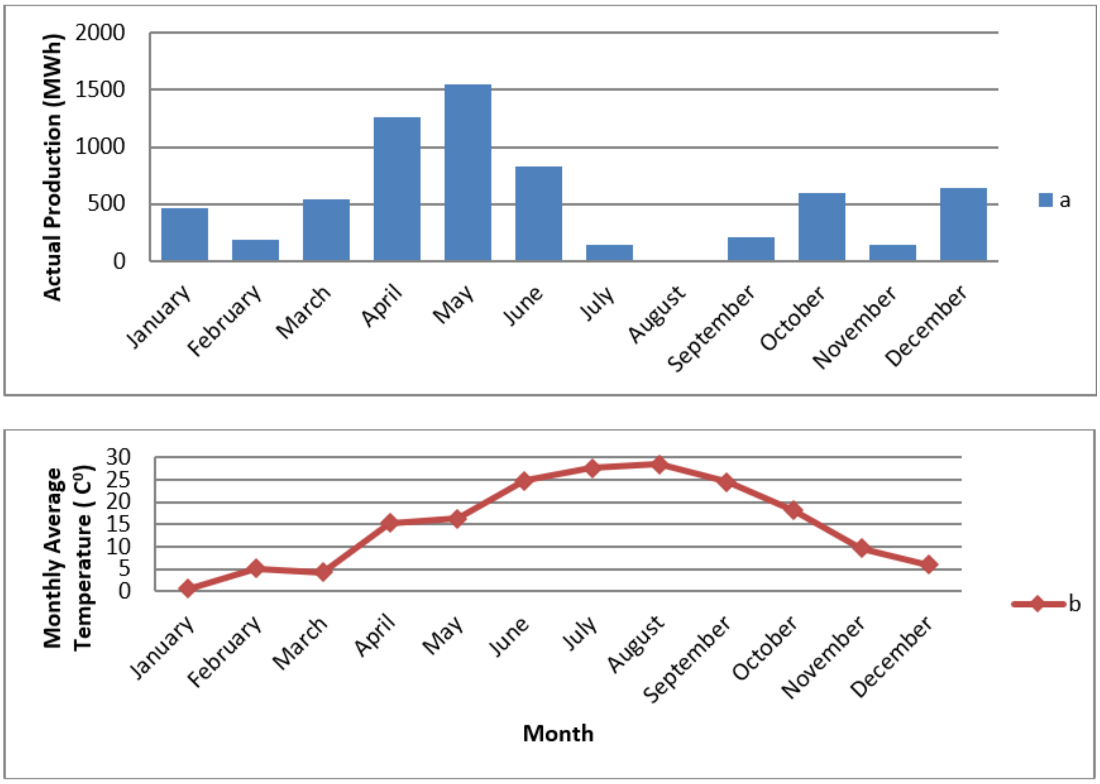

Figure 13. a) Energy production chart in 2022 b) Average temperature chart in 2022

Figure 14 shows the production amounts in response to monthly average temperature values. Here, it is seen that the lowest temperature was experienced in January with 0.6 °C, and as the temperature decreased from January, there was an increase in energy production. An increase in production was observed in April, as the temperature increased by 15.2 °C and the effect of snow melting in high places. 1260 MWh was produced in April due to the low rainfall and the majority of the snow melting in the higher areas at the end of March-April. The highest average temperature was August with 28.4 °C and 5 MWh was produced this month.

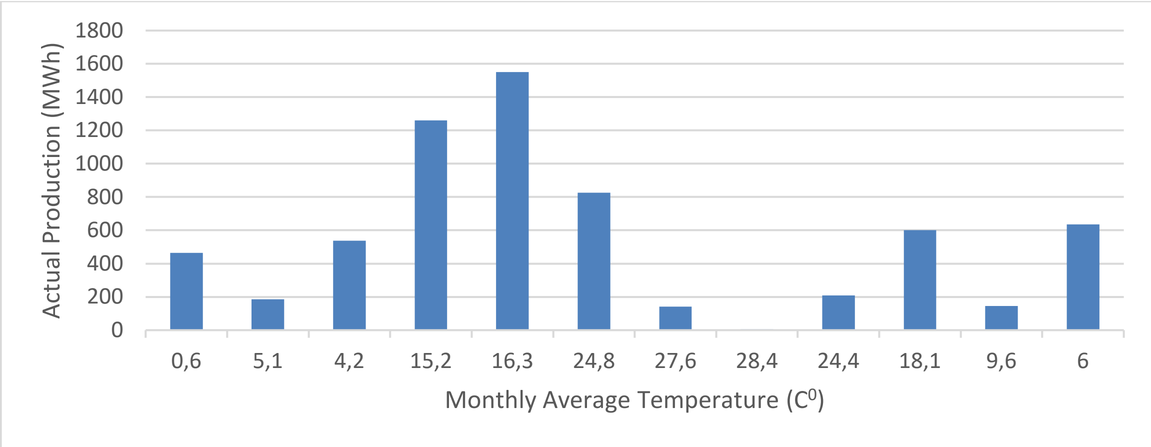

Figure 14. Elbi HEPP monthly average temperature and actual production graph

3.9. Zagros Hes Actual Production and Average Relative Humidity

Another factor affecting the electricity production of power plants is average relative humidity. Figure 15 a-b graphsshow the monthly production and monthly average relative humidity. When we look at the change in monthly average relative humidity with the production at Zagros HEPP in 2022, it is seen that the relative humidity in the environment was 61.1% in December, which is the month with the highest energy production, and the average relative humidity was 34.5% in April, when the lowest energy production was made.

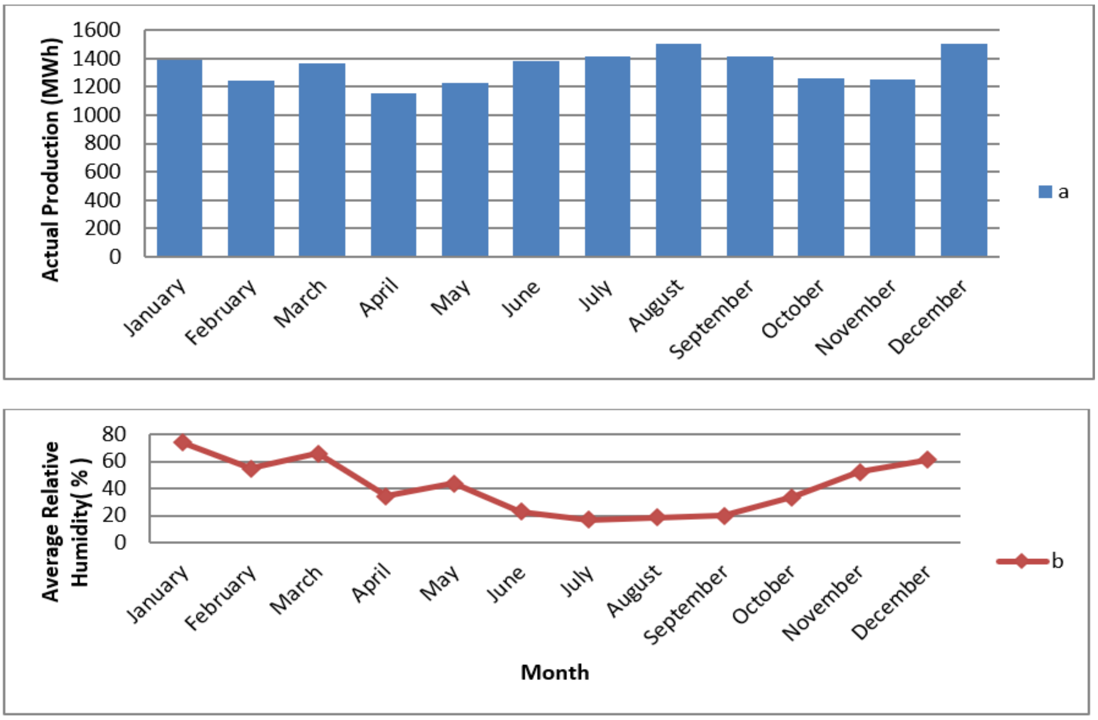

Figure 15. a) Actual energy production chart for 2022 b) Average relative humidity chart for 2022

Figure 16 shows the production in response to the monthly average relative humidity. The monthly average relative humidity was lowest in July, at 17.0%, and energy production was 1413 MWh in that month. The highest average relative humidity is seen to be 74.2% in January for 2022, and 1388 MWh of energy was produced this month. The average relative humidity remained at 61.1% in December, when production was highest with 1506 MWh of energy production.

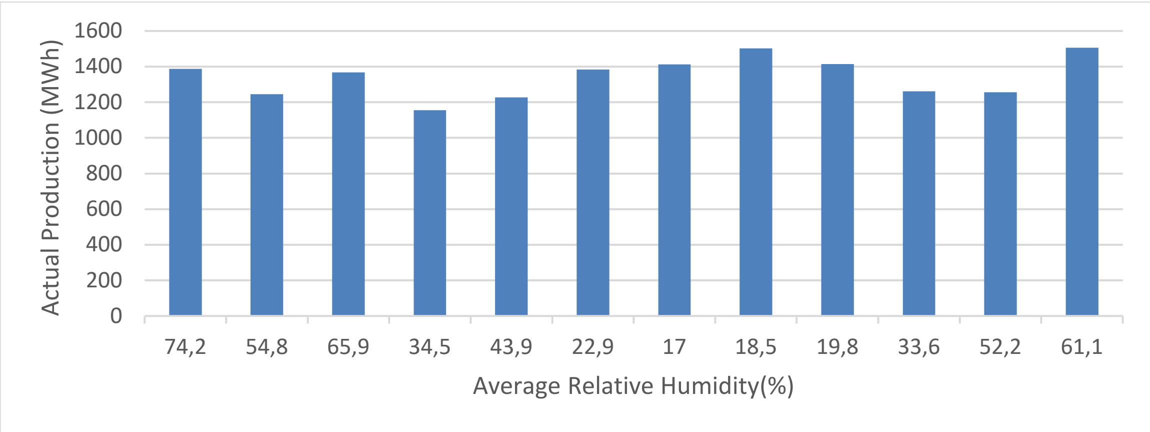

Figure 16. Monthly average relative humidity and actual production chart

3.10. Elbi HEPP Actual Production and Average Relative Humidity

Another factor affecting the electricity production of power plants is average relative humidity. Figure 17 charts a-b show the monthly production and monthly average relative humidity. When we look at the change in monthly average relative humidity with the production realized in Elbi HEPP in 2022, it is seen that the relative humidity in the environment was 52.5% in May, the month in which the highest energy production was made, and the average relative humidity was 21.4% in August, when the lowest energy production was made.

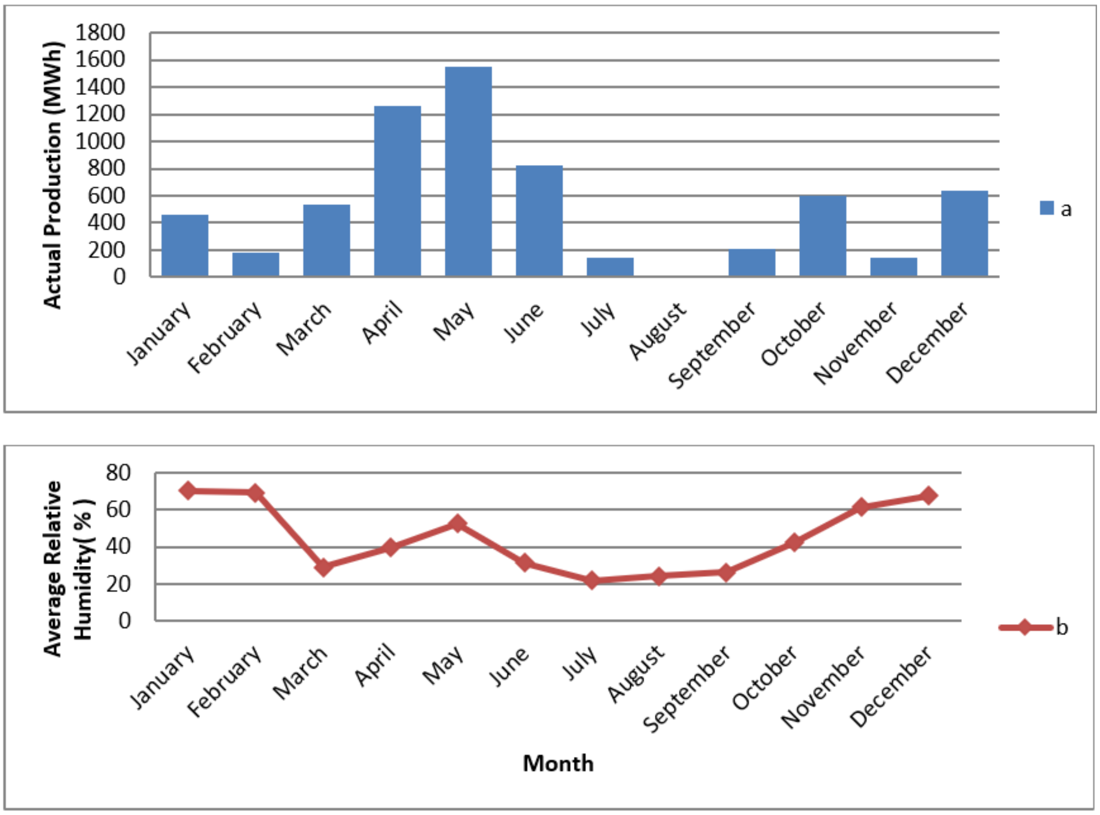

Figure 17. a) Actual energy production chart for 2022 b) Average relative humidity chart for 2022

Figure 18 shows the production in response to monthly average relative humidity. The monthly average relative humidity was 21.9% in March and July, and energy production was 538 MWh and 142 MWh, respectively, in that month. The highest average relative humidity is seen to be 70.5% in January for 2022, and 464 MWh of energy was produced this month. With 5 MWh energy production, the average relative humidity remained at 24.4% in August, when production was lowest.

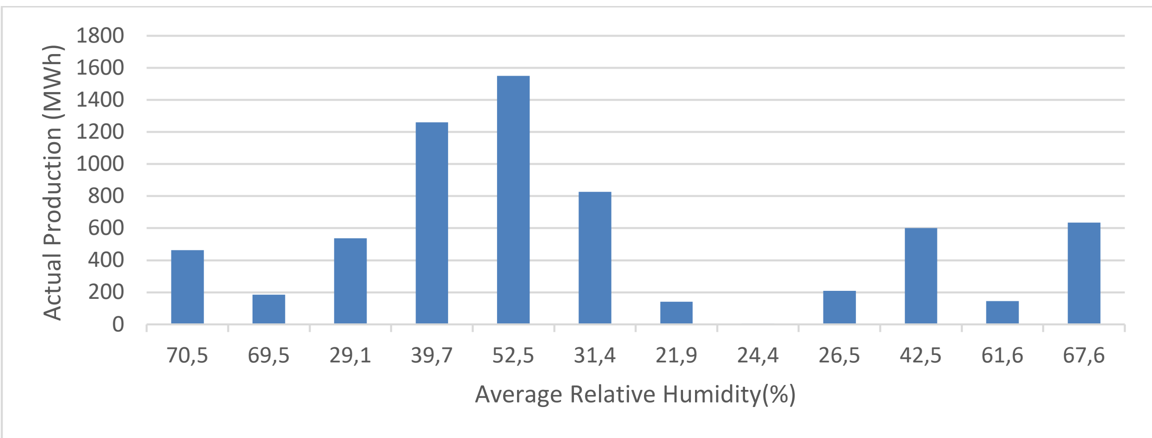

Figure 18. Monthly average relative humidity and actual production chart

3.11. Zagros HEPP Production and Average Precipitation Amount

The effect of the monthly average rainfall amount prepared with the data from Table 8 on the actual production can be seen in Figure 19, a-b graphs, and the average rainfall amount in December 2022, when the maximum energy production is made, is 24.7 kg/m^2. The average rainfall in April, which is the minimum production of 2022, is 17.7 kg/m^2.

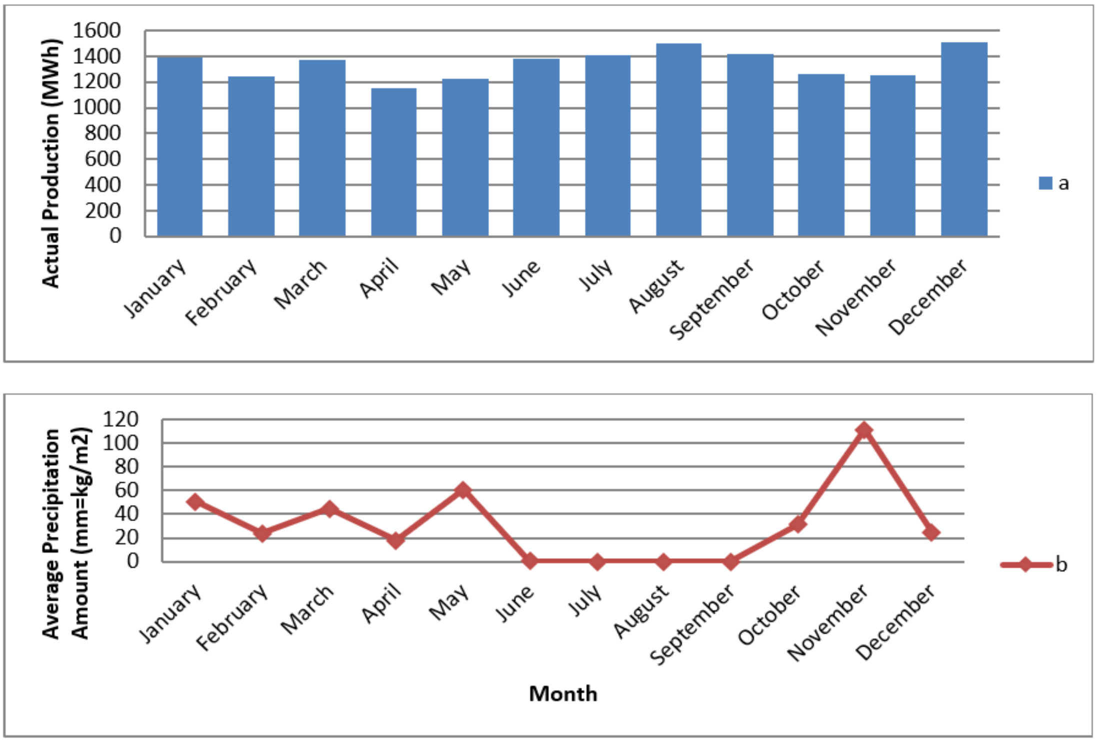

Figure 19. a) Energy production chart in 2022 b) Average rainfall chart in 2022

Figure 20 shows the change in production according to monthly rainfall. The highest average rainfall amount was 111.5 kg/m^2 in November, and energy production was 1256 MWh. The lowest average rainfall occurred in July, August and September and was 0.0 kg/m^2. In these months, 1413 MWh, 1502 MWh and 1415 MWh energy were produced respectively.

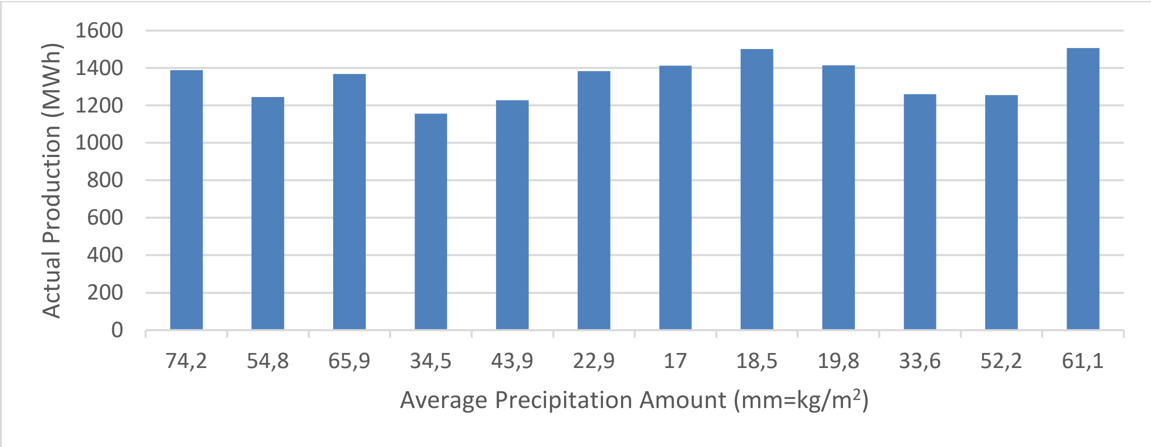

Figure 20. Monthly average rainfall amount and actual production graph

3.12. Elbi HEPP Production and Average Precipitation Amount

The effect of the monthly average rainfall amount prepared with the data from Table 12 on the actual production can be seen in Figure 21 a-b graphs, and the average rainfall amount in May 2022, when the maximum energy production is made, is 108.9 kg/m^2. The average rainfall in August, which is the minimum production of 2022, is 2.2 kg/m^2.

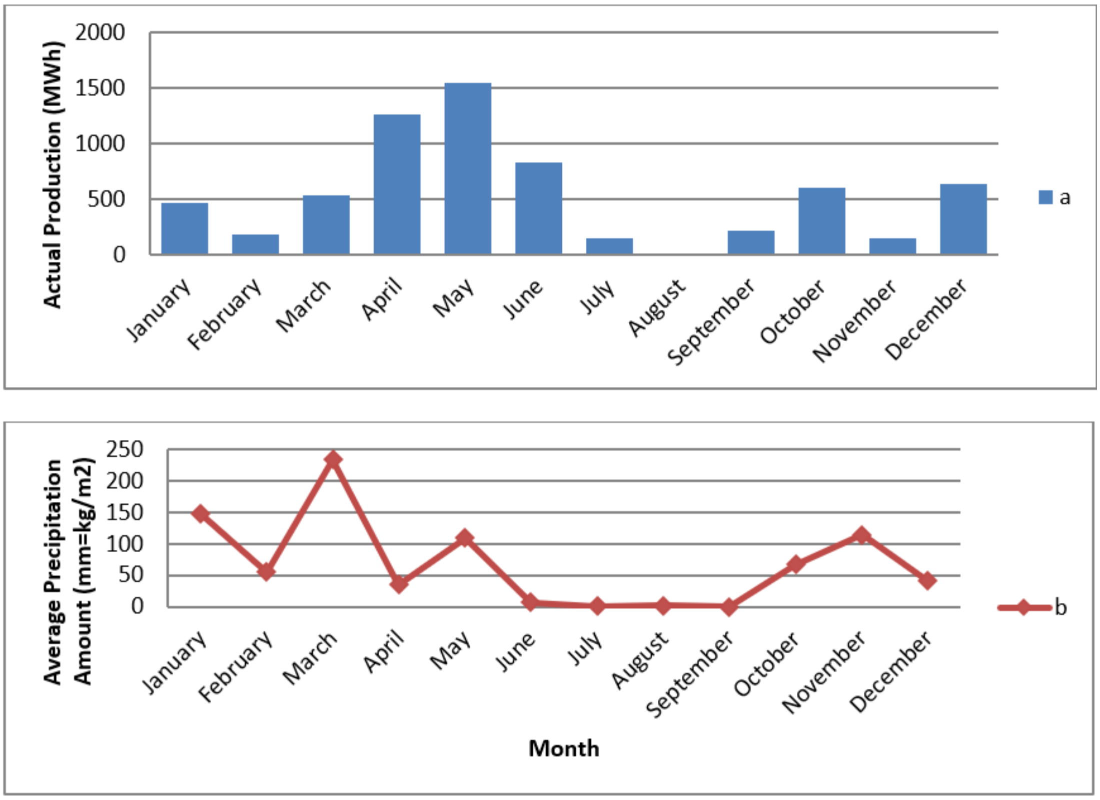

Figure 21. a) Energy production chart in 2022 b) Average rainfall chart in 2022

Figure 22 shows the change in production according to monthly rainfall. The highest average rainfall amount was 234.3 kg/m^2 in March, and energy production was 538 MWh. The lowest average rainfall occurred in September and was 0.0 kg/m^2. 209 MWh of energy was produced this mont.

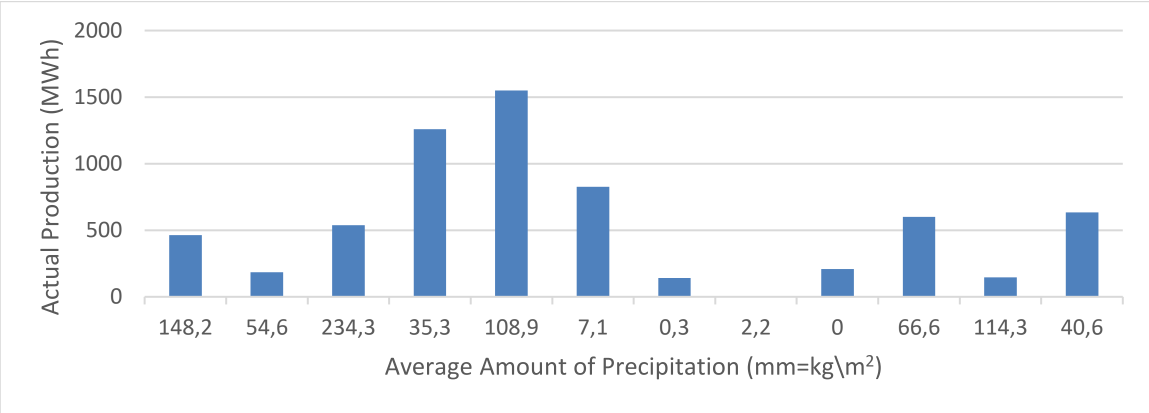

Figure 22. Monthly average rainfall amount and actual production graph

3.13. Zagros HEPP Production Efficiency

According to the data in Table 13 and Table 14, Zagros HEPP production efficiency for 2022 was calculated and shown in Figure 23.

Productivity, which was 73.34% in January, decreased to 40.96%, 58.89% and 49.52%, 52.22% in February, March, April and May, respectively, and reached 61.28% in July. Looking at Figure 23, it is seen that the productivity is at the level of 65.10% in September 2022. As the temperatures started to increase in April, May and June, productivity decreases were observed, and as the precipitation started to increase, it started to increase, reaching 65.32% in December.

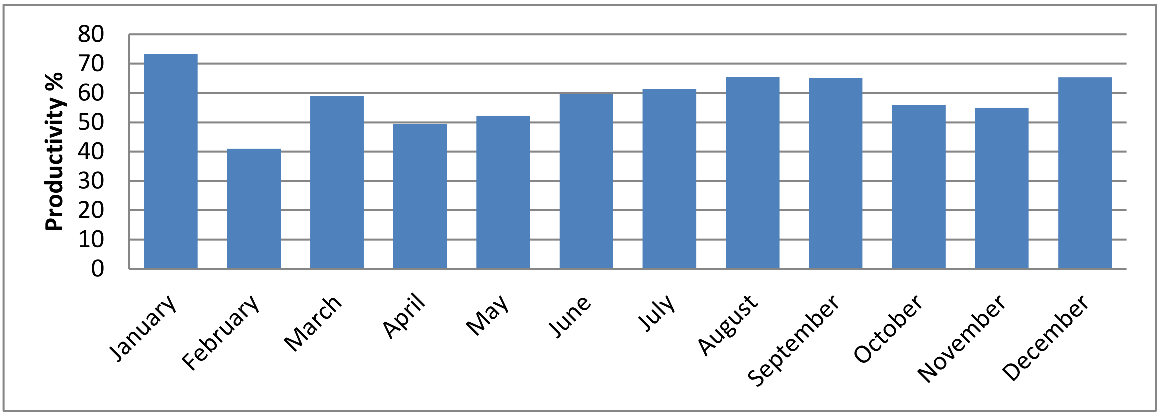

Figure 23. Zagros hydroelectric power plant efficiency chart for 2022

3.14. Elbi HEPP Production Efficiency

According to the data in Table 15 and Table 16, Elbi HEPP 2022 production efficiency was calculated and shown in Figure 24.

Productivity, which was 65.81% in January, decreased to 33.41% and 46.41% in February and March, respectively, and reached 99.7% in May. Looking at Figure 58, a decrease in productivity is observed as temperatures begin to increase in July and August in 2022, and as precipitation begins to increase, it starts to rise, reaching 99.6% in December.

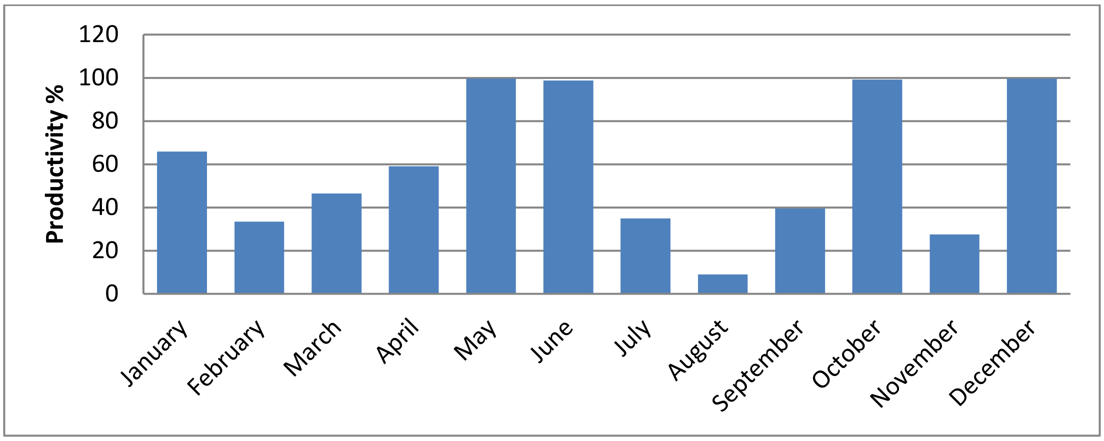

Figure 24. Elbi hydroelectric power plant efficiency chart for 2022

3.15. Zagros HEPP Capacity Factor

Figure 25 shows the capacity factor values of Zagros HEPP in 2022, calculated according to Equation 4.2. The capacity factor is theoretically calculated as the maximum amount of energy that Zagros Hes can produce monthly with a single unit operating 24 hours a day. Zagros HEPP, with an installed capacity of 2,340 MWe, achieved maximum production in December with 89.38% capacity. With the highest rainfall in November, production was realized at 74.54% capacity. Production at the lowest capacity was realized in April and May, with values of 68.61% and 72.88%, respectively.

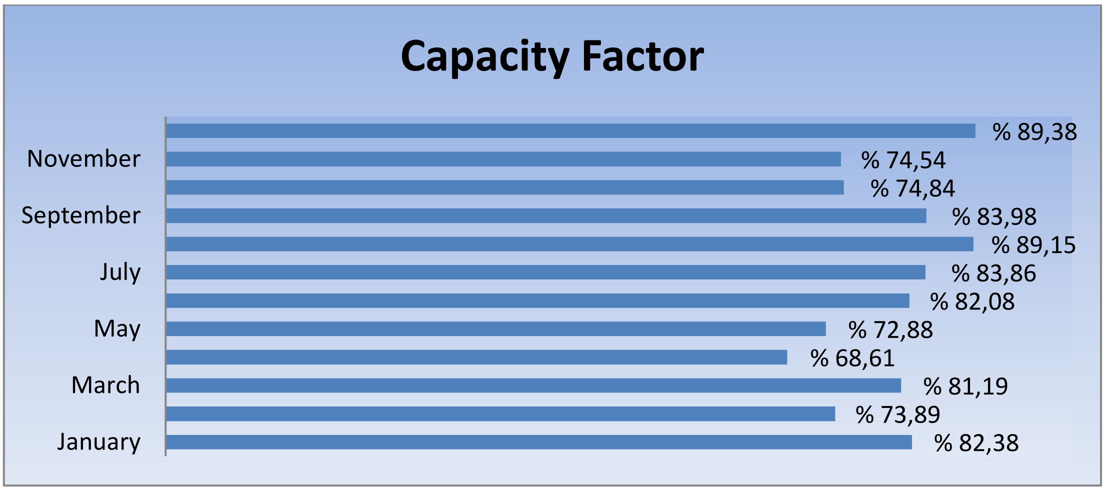

Figure 25. Zagros HEPP monthly capacity factor values for 2022

3.16. Elbi HEPP Capacity Factor

Figure 26 shows the capacity factor values of Elbi HEPP in 2022, calculated according to Equation 4.2. The capacity factor is theoretically calculated as the maximum amount of energy that Elbi HEPP can produce monthly with its two units operating 24 hours a day. Elbi HEPP, with an installed capacity of 3,430 MWe, achieved maximum production in May with a capacity of 62.76%. In March, when the highest amount of rainfall occurred, energy was produced with 21.78% capacity. In July, August and September, when the lowest rainfall amounts were experienced, production was realized with 5.74%, 0.2% and 8.46% capacity, respectively.

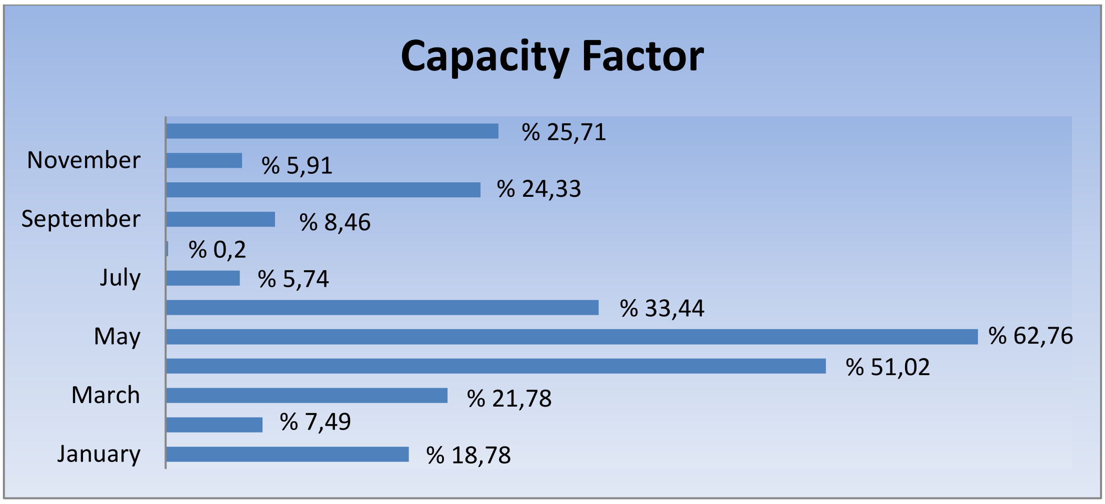

Figure 26. Elbi HEPP monthly capacity factor values for 2022

4. CONCLUSIONS

The parameters mentioned in the study are effective, the lowest energy production in Zagros HEPP was in April with 1156 MWh, the highest in December with 1506 MWh, the lowest energy production in Elbi HEPP in August with 5 MWh, and the highest in August with 1550 MWh. It was realized in MWh in May. When we examined the energy production efficiency, it was calculated that the highest production of Zagros Hes in 2022 was in January, not December. It is calculated that the lowest production at Elbi Hes in 2022 will be in February and March, not in August. Accordingly, it has been concluded that excessive energy production in the hydroelectric power plant does not create much efficiency. It was understood that the productivity and actual production occurred in the form of small fluctuations and that other parameters, which are the subject of this study, should also be taken into account. The highest value of the capacity factor in Zagros Hes was in December with 89.38%, the lowest was in April with 68.61%, and the highest value of the capacity factor in Elbi Hes was in May with 67.76% and the lowest was 0.2%. It was obtained from the calculations that it was in August. However, it has been proven that there is a direct proportion between capacity factor and energy production. The examinations carried out are given below;

• Although the energy production of Zagros HEPP and Elbi HEPP may vary in some months during the year, it has been observed that it is compatible with the feasibility report.
• It has been determined that there is an increase in the production in Zagros HEPP and Elbi HEPP in the months when the average actual pressure in 2022 is low, and there is a decrease in the production in the months when the actual pressure begins to increase, and therefore there is an inverse proportion between the average actual pressure and the actual production in the hydroelectric power plant.
• When the monthly average temperature values and actual production values in Zagros HEPP and Elbi HEPP in 2022 are examined, it is seen that the production increased due to the increase in the amount of snow, rain and low temperature in the winter months, and that the production increased due to the melting of the majority of the snow in the spring, and in the summer months. It has been found that the actual production decreases due to the increase in the average temperature, therefore there is an inverse proportion between the average temperature and the actual production in the hydroelectric power plant.
• When the monthly average relative humidity values and actual production values in Zagros HEPP and Elbi HEPP in 2022 were examined, it was observed that the effect of average relative

humidity was less effective compared to other parameters. It has been determined that when the average relative humidity in the atmosphere is high, there is an increase in the actual production, and when the average relative humidity decreases, the actual production decreases. A change in direct proportion was observed between the average relative humidity and the actual production.

• When the monthly average precipitation values and actual production values in Zagros HEPP and Elbi HEPP in 2022 are examined, although the actual production fluctuates from place to place, an increase in the production in the months when the precipitation is high and a decrease in the production in the months when the precipitation is low or the temperature is not observed and the temperature increases. It has been observed that the amount of rainfall, which is expected to affect production the most, partially showed the expected effect, but did not meet the expected effect in some months.

• In Zagros Hes, the highest efficiency was in January with 73.34% and the lowest efficiency was in February with 40.96. Although the highest production was in December with 1506 MWh, when the efficiency values were examined, there were no similar increases and decreases. When the reason for the months of February and April, when productivity is lowest, is examined in general, it is seen that the amount of precipitation has decreased compared to the previous months and similarly the temperature values have increased compared to the previous months. Although the decrease in productivity at a rate of 32.38% in the transition from January to February was observed to be due to the decrease in the amount of precipitation, the decrease in the average relative humidity, and the increase in the amount of temperature, it was observed that the increase in the amount of flow in these months was not linked to the decrease in efficiency. The average flow rate from March to August was calculated to be 4.04 m^3/sec, and it was understood that the productivity and production occurred in small fluctuations in these months and that other parameters, which are the subject of this thesis, should also be taken into account.

• In Elbi HEPP, the highest efficiency values were in May and December with 99.7% and 99.6%, respectively, and the lowest efficiency was in August with 8.96%. It was observed that the highest production occurred in May with 1550 MWh. When the general reason for the decrease in August, when productivity was at its lowest, was examined, it was seen that the amount of precipitation decreased with the previous and following months, and similarly, temperature values increased in the previous and following months. The 26.05% decrease in productivity in the transition from July to August was observed to be due to the decrease in the amount of precipitation, the decrease in the average relative humidity, and the increase in the temperature. However, the increase in the flow rate in these months was also seen to be linked to the decrease in efficiency. The average flow rate from July to November was calculated to be 1 m^3/sec, and the fact that productivity and actual production occurred in the form of small fluctuations in these months showed that other parameters, which are the subject of this thesis, should also be taken into account.

• When we look at the monthly capacity factor changes of Zagros and Elbi hydroelectric power plants in 2022, it is seen that the capacity factor is high in the months with the highest production, and the capacity factor is low in the months with the lowest production.

NOMENCLATURE

m : Meter
MW: Megawatt
MWe: Megawatt electricity
MWA: Megavoltampere
AWG: AWG in the American system as the unit for measuring cable (conductor wire) thickness -American Gauge Wire
kV:Kilovolt
km:Kilometer
MWh: Megawatt hour
W:Watt
Hz: Hertz
hPa: Hectopascal
°C: Degrees Celsius
%: Percentage
kg: Kilogram
m^2: Square meters
m^3:Cubic meters
sec: Second
P_a = Actual Production Amount
μ = Efficiency
ρ =Density of water
Q = Flow rate of water coming to the turbine
g = Gravitational acceleration
h=Net head

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DECLARATION OF ETHICAL STANDARDS

The authors of the presented article declare that nothing required for the implementation of the article requires ethics committee approval. However, data usage permission records have been obtained from Zagros Energy Production Inc., Elbi Electric Production Manufacturing Construction Industry and Trade Inc. and Şırnak Meteorology Provincial Directorate. Permission documents have been uploaded to your journal's system.

CONTRIBUTION OF THE AUTHORS

Edip Taşkesen: Writing – review & editing, Supervision,

Elif Nur Bilen: Analysis, investigation, writing, methodology

CONFLICT OF INTEREST

There is no conflict of interest in this study.

REFERENCES

[1] Berkün M, Aras E, Koç T. Barajların ve hidroelektrik santrallerin nehir ekolojisi üzerinde oluşturduğu etkiler. Türkiye Mühendislik Haberleri (TMH) 2008; 452(6): 41–48.

[2] Yıldız M. Dünyada ve Türkiye'de alternatif ve fosil enerji kaynaklarının geleceğe yönelik etüdü. Yüksek Lisans Tezi, Karadeniz Teknik Üniversitesi, Fen Bilimleri Enstitüsü, Trabzon, 2006.

[3] Ceyhunlu Aİ. Hidroelektrik enerji santrallerinde üretilen enerjinin kısa ve uzun süreli olarak tahmin edilmesi ve taşkın riskinin araştırılması: Doğançay hidroelektrik enerji santralleri örneği. Yüksek Lisans Tezi, Sakarya Uygulamalı Bilimler Üniversitesi, Lisansüstü Eğitim Enstitüsü, Sakarya, 2020.

[4] Kumuş Z. Hidroelektrik santrallerinin dışsallık çerçevesinde analizi: Akocak hidroelektrik santrali örneği. Yüksek Lisans Tezi, Recep Tayyip Erdoğan Üniversitesi, Lisansüstü Eğitim Enstitüsü, Rize, 2023.

[5] Faruk O, Behçet R, Aykut K. Hidroelektrik santral rezervuar verilerinin enerji üretimi amaçlı değerlendirilmesi. Bitlis Eren Üniversitesi Fen Bilimleri Dergisi 2017; 6(2): 29–38.

[6] Özdemir MS, Dalcalı A, Ocak C. Akarsu tipi hidroelektrik santraller ve bu santrallerde kullanılan türbin-generatörler. Mühendislik Bilimleri ve Araştırmaları Dergisi 2020; 2(2): 69–75.

[7] Güney G. Porsuk havzasında küçük ölçekli hidroelektrik enerji potansiyelinin araştırılması. Yüksek Lisans Tezi, Bilecik Şeyh Edebali Üniversitesi, Fen Bilimleri Enstitüsü, Bilecik, 2017.

[8] Toprak FZ, Eriş E. Biriktirmesiz hidroelektrik santraller: dünyada ve Türkiye'deki mevcut durumları. II. Su Yapıları Sempozyumu Diyarbakır: TMMOB İnşaat Mühendisleri Odası Diyarbakır Şubesi 2011; 89–96.

[9] Özbek G. Hidroelektrik santrallerinde enerji verimliliğine türbinin etkisi. Yüksek Lisans Tezi, Bitlis Eren Üniversitesi, Fen Bilimleri Enstitüsü, Bitlis, 2022.

[10] Kukah ASK, Owusu-Manu DG, Badu E, Edwards DJ. Exploring influencing factors for private sector participation in PPP power projects: case of Ghana. Journal of Facilities Management 2024; 22 (2): 310–324.

[11] Han S, Yuan Y, He M, Zhao Z, Xu B, Chen D, Jurasz J. A novel day-ahead scheduling model to unlock hydropower flexibility limited by vibration zones in hydropower-variable renewable energy hybrid system. Appl Energy 2024; 356: 122379.

[12] Saadaoui H, Dogan M, Omri E. The impacts of hydroelectricity generation, financial development, geopolitical risk, income, and foreign direct investment on carbon emissions in Turkey. Environmental Economics and Policy Studies 2024; 26(2): 239–261.

[13] Alahmad H, Taşkesen E, Bilen EN, Arlı F, Dumrul H. Hydroelectric energy potential assessment: a case study of Sirnak province. Internatıonal Congress on Advanced Energy Studıes (ICES) New York: iksadamerica 2024; 17–29.

[14] Bilen EN. Hidroelektrik santrallerde enerji üretimine etki eden parametreler: Şırnak örneği. Yüksek Lisans Tezi, Şırnak Üniversitesi, Lisansüstü Eğitim Enstitüsü, Şırnak, 2024.

[15] Gürsakal H, Uyumaz A. Pompaj depolamalı hidroelektrik santrallerin optimizasyonunda karlılık analizi ve çalışma süresi tayini. Mühendislik Bilimleri ve Tasarım Dergisi 2021; 9(2): 436–452.

[16] Yıldız S, Karakuş CB, Bayrak F. Coğrafi bilgi sistemi ile hidroelektrik enerji üretimi amaçlı mini hidroelektrik santrali yeri seçimi: Sivas Kızılırmak Havzası örneği. Ömer Halisdemir Üniversitesi Mühendislik Bilimleri Dergisi 2024; 13(2): 500-508.

[17] Şavkar E. Yenilenebilir enerji zemininde hidroelektrik enerji ve Türkiye potansiyeli.Oğuzhan Sosyal Bilimler Dergisi 2024; 6(1): 51–58.

[18] Alkan BU. Hidroelektrik santrallerinin değerlemesi üzerine model önerisi. Yüksek Lisans Tezi, Gebze Teknik Üniversitesi, Fen Bilimleri Enstitüsü, Gebze, 2015.
[19] Demir B. Orta kapasiteli hidroelektrik santrallerinde fizibiliteye göre verilen enerji üretimi etki faktörlerinin incelenmesi ve analizi. Yüksek Lisans Tezi, Giresun Üniversitesi, Fen Bilimleri Enstitüsü, Giresun, 2019.
[20] Tören M, Mollahasanoğlu H, Koç E. Mikro tip hidro elektrik santrallerinde kullanılacak farklı tip senkron jeneratörlerin performans etkilerinin incelenmesi. I. Elektrik-Elektronik Mühendisliğinde Güncel Gelişmeler Sempozyumu (EEMGG'21), Trabzon: TMMOB Elektrik Mühendisleri Odası 2021.
[21] Bekiroğlu E, Bayrak A. Sanal elektrik makinaları laboratuarı: senkron jeneratör deneyleri. Gazi Üniversitesi Mühendislik Mimarlık Fakültesi Dergisi 2013; 25(2): 405–413.
[22] Turhan E, Özdil NF, Tantekin A. The evaluation of hydrological drought and energy efficiency relation in the context of pumped storage hydroelectric power plants (PSHPPs) issue: The case of Adana. International Energy & Engineering Conference 2016.
[23] Dağhan MM. Hidroelektrik enerji üretimi için baraj yeri seçiminde coğrafi bilgi sistemlerinin (CBS) kullanılması ve uygulamaları (Seydisuyu havzası). Yüksek Lisans Tezi, Bilecik Şeyh Edebali Üniversitesi, Fen Bilimleri Enstitüsü, Bilecik, 2018.
[24] Altınkök A, Demir B, Altınkök S. Investigation and analysis of meteorological factors of energy generation according to feasibility in medium capacity hydroelectric power plants. Karadeniz Fen Bilimleri Dergisi 2022; 12(1): 425-447.
[25] Serencam U. Küçük hidrolik santrallerde kapasite faktör analizi ve Giresun özelinde bir uygulama. Gümüşhane Üniversitesi Fen Bilimleri Enstitüsü Dergisi 2019; 9(4): 691–698.
[26] Büşra P. Ermenek çayı üzerinde pompaj depolamalı hidroelektrik santral sistemlerinin uygulanabilirliğinin araştırılması. Yüksek Lisans Tezi, Konya Teknik Üniversitesi, Lisansüstü Eğitim Enstitüsü, Konya, 2022.
[27] Acar E. Doğu karadeniz bölgesindeki hidroelektrik santrallerin (HES) kapasite faktörlerinin değerlendirilmesi. Uluslararası Doğu Anadolu Fen Mühendislik ve Tasarım Dergisi 2020; 2(2): 296–307.
[28] Yıldız D, Yıldız D, Özgüler H. Hidroenerji raporu yekdem'e kayıtlı hes'lerin üretim verimliliği 2019.
[29] "Silopi Bölgesinde Yıl Boyu İklim ve Hava Durumu," Weather Spark. Accessed: Dec. 02, 2024. [Online]. Available: https://tr.weatherspark.com/

[30] "Uludere Bölgesinde Yıl Boyu İklim ve Hava Durumu," Weather Spark. Accessed: Dec. 02, 2024. [Online]. Available: https://tr.weatherspark.com/