Gazi Üniversitesi
Fen Bilimleri Dergisi
PART C: TASARIM VE TEKNOLOJİ

Gazi University
Journal of Science
PART C: DESIGN AND TECHNOLOGY

GU J Sci, Part C, 14(1): 516-527 (2026)

Performance Evaluation of a Geothermal Power Plant Using Energy and Exergy Analysis Methodology

Medine ÖZKAYA[1*]

[1]*Gazi University, Vocational School of Technical Sciences, Department of Machinery and Metal Technologies, Ankara, Turkey*

Article Info

Research article
Received: 06/03/2026
Revision: 24/03/2026
Accepted: 24/03/2026

Keywords

Geothermal energy,
Electricity generation,
Exergy,
Renewable energy.

Makale Bilgisi

Araştırma makalesi
Başvuru: 06/03/2026
Düzeltme: 24/03/2026
Kabul: 24/03/2026

Anahtar Kelimeler

Jeotermal enerji,
Elektrik üretimi,
Ekserji,
Yenilenebilir enerji

Graphical/Tabular Abstract (Grafik Özet)

In this study, electricity generation, energy, and exergy analyses were performed for 5 different temperature values of a geothermal source, and the obtained values were compared. / Bu çalışmada bir jeotermal kaynağa ait 5 farklı sıcaklık değeri için elektrik üretimi, enerji ve ekserji analizleri yapılmış ve elde edilen değerler karşılaştırılmıştır.

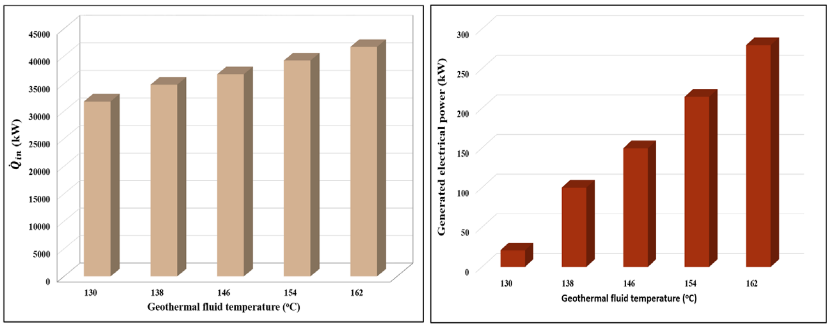

***Figure A**: The effect of geothermal fluid heat on total thermal power and generated electricity /**Şekil A:** Jeotermal akışkan ısısının toplam ısıl güç ve üretilen elektrik gücü üzerindeki etkisi*

Highlights (Önemli noktalar)

- *The electricity generation from geothermal energy sources has been investigated./ Jeotermal enerji kaynağının Elektrik üretimi incelenmiştir.*
- *The effects of different temperature values of geothermal fluid on the system were compared./ Jeotermal akışkanlığa ait farklı sıcaklık değerlerinin sistem üzerindeki etkileri karşılaştırılmıştır.*
- *The overall energy and exergy efficiencies of the system have been calculated./ Sistemin genel enerji ve ekserji verimleri hesaplanmıştır.*

Aim (Amaç): *The electricity generation potential, energy, and exergy analyses of geothermal energy sources have been evaluated. / Jeotermal enerji kaynağının elektrik üretim potansiyeli, enerji ve ekserji analizleri değerlendirilmiştir.*

Originality (Özgünlük): *The electricity generation potential of geothermal energy source was investigated at 5 different temperature values. / Jeotermal enerji kaynağının 5 farklı sıcaklık değerinde elektrik üretim potansiyeli incelenmiştir.*

Results (Bulgular): *Increasing the temperature of the geothermal energy source has increased electricity production, energy and exergy efficiencies. / Jeotermal enerji kaynağının sıcaklığının artması elektrik üretimini, enerji ve ekserji verimlerini arttırmıştır.*

Conclusion (Sonuç): *The highest energy and exergy efficiencies were obtained from geothermal fluid at a temperature of 162°C, calculated to be approximately 0.67% and 3.75%, respectively. / En yüksek enerji ve ekserji verimleri 162°C sıcaklığa sahip jeotermal akışkandan elde edilmiş olup sırasıyla yaklaşık olarak %0,67 ve %3,75 olarak hesaplanmıştır.*

*Corresponding author, e-mail: medineozkaya@gazi.edu.tr
DOI: 10.29109/gujsc.1903986

GU J Sci, Part C, 14(1): 516-527 (2026)

Gazi Üniversitesi
Fen Bilimleri Dergisi
PART C: TASARIM VE TEKNOLOJİ

Gazi University
Journal of Science
PART C: DESIGN AND TECHNOLOGY

http://dergipark.gov.tr/gujsc

Performance Evaluation of a Geothermal Power Plant Using Energy and Exergy Analysis Methodology

Medine ÖZKAYA[1*]

[1]*Gazi University, Vocational School of Technical Sciences, Department of Machinery and Metal Technologies, Ankara, Turkey*

Article Info

Research article
Received: 06/03/2026
Revision: 24/03/2026
Accepted: 24/03/2026

Keywords

Geothermal energy,
Electricity generation,
Exergy,
Renewable energy.

Abstract

Increased energy supply leads to increased energy production. The fact that fossil fuels, which are available in limited quantities for energy production, will be depleted in the near future and also cause environmental problems hass led to increased research and the use of renewable energy sources. Geothermal energy is one of the renewable energy sources. Türkiye ranks 4th in the world in terms of underground geothermal energy resources. This study investigated the electricity generation from a geothermal well. Exergy and energy analyses have been performed on all the main components of the electricity generation plant integrated into this geothermal well. Enthalpy-entropy values were obtained for geothermal fluid temperatures of 130, 138, 146, 154, and 162 °C using the Engineering Equation Solver (EES) program. For these different temperature values, the heat input to the system, electrical power, energy efficiency, and exergy efficiencies were obtained and compared. The lowest energy and exergy efficiencies of the system were calculated as 0.065% and 0.45%, respectively, when the geothermal fluid temperature was 130 °C. The highest energy and exergy efficiencies of the system were calculated as 6.7% and 3.75% at a geothermal fluid temperature of 162 °C.

Bir Jeotermal Güç Santralinin Enerji ve Ekserji Analizi Yöntemiyle Performans Değerlendirmesi

Makale Bilgisi

Araştırma makalesi
Başvuru: 06/03/2026
Düzeltme: 24/03/2026
Kabul: 24/03/2026

Anahtar Kelimeler

Jeotermal enerji,
Elektrik üretimi,
Ekserji,
Yenilenebilir enerji

Öz

Artan enerji arzı daha fazla enerji üretimini beraberinde getirmektedir. Enerji üretimi için kısıtlı miktarda olan fosil yakıtlarının hem yakın zamanda tükenecek olması hem de çevresel sorunlara neden olması yenilenebilir enerji kaynaklarının araştırılmasını ve kullanımını arttırmıştır. Yenilenebilir enerji kaynaklarından biri de Jeotermal enerjidir. Türkiye yeraltı jeotermal enerji kaynağı bakımından dünyada 4. sırada yer almaktadır. Çalışmada bir jeotermal kuyunun elektrik üretimi incelenmiştir. Bu jeotermal kuyuya entegre edilen elektrik üretim tesisinin tüm ana bileşenlerinin hem ekserji hem de enerji analizleri yapılmıştır. Jeotermal akışkanın 130, 138, 146, 154 ve 162 ºC sıcaklık değerleri için mühendislik Engineering Equation Solver (EES) programı ile entalp entropi değerleri elde edilmiştir. Bu farklı sıcaklık değerleri için Sisteme giren ısı, elektrik gücü, enerji verimi ve ekserji verimleri elde edilip karşılaştırılmıştır. Sistemin en düşük enerji ve ekserji verimleri Jeotermal akışkan sıcaklığının 130 ºC olduğunda sırasıyla %0,065 ve %0,45 olarak hesaplanmıştır. Sistemin en yüksek enerji ve ekserji verimleri ise Jeotermal akışkanın 162 ºCsıcaklığında %6,7 ve yüzde 3,75 olarak hesaplanmıştır.

1. INTRODUCTION (GİRİŞ)

The rapid increase in global energy demand and the environmental problems caused by fossil fuels have made the shift towards sustainable and clean energy sources imperative [1,2]. Many studies aimed at solving problems such as global warming and carbon emissions focus on carbon neutrality and sustainable processes. For this reason, studies in areas such as energy storage devices, energy conversion, and the use of renewable energy sources are at the forefront. Renewable energy sources such as solar, wind, hydroelectric, and geothermal energy will reduce dependence on traditional fossil fuel energy systems and contribute to solving problems such as global warming. While renewable energy sources like solar and wind power do not provide regular and continuous energy production, uninterrupted and continuous energy production is

*Corresponding author, e-mail: medineozkaya@gazi.edu.tr
DOI: 10.29109/gujsc.1903986

possible from hydraulic and geothermal sources [3]. Geothermal resources, obtained by extracting energy stored as heat beneath the earth's surface, are found in different regions of the world. One of the regions with these underground geothermal resources is Turkey, which ranks 4th in the world [4]. Geothermal resources in our country are generally used in balneotherapy, greenhouse farming, heating homes, and electricity generation. There are many studies related to renewable energy sources. One of the aims of these studies is to use energy resources efficiently by conducting energy and energy analysis [5,6]. Many studies have been conducted on the use of geothermal energy. Ding et al. investigated the system's electricity generation, cooling load, and hydrogen production by integrating biomass, geothermal, and solar energy sources [7]. Inanc and Midilli CO2 capture system, an integrated geothermal hydrogen production system, and an integrated wind energy and methanol production system have been integrated to create a complete system. Energy and exergy analysis of this system has been performed [8]. Siddiqui et al. developed a triple energy production system by combining a geothermal energy source, a solar energy system, and a hydrogen production facility. The system's hydrogen production quantity, energy, and energy analyses have been performed [9]. Wang et al. conducted a study on supporting a carbon capture and storage system with a geothermal source and compared the data obtained with that of a 300 MW coal-fired power plant [10]. Halit et al. have integrated a system combining geothermal and solar energy to provide heating, cooling, electricity for buildings, hot water, and hydrogen production. These proposals were compared in terms of system exergy, energy, and system efficiencies. Furthermore, a cost analysis of the system was performed [11]. Canısı et al. conducted energy and exergoeconomic analyses of the system by combining solar and geothermal energies. In addition, multiple integrated systems were connected to the system, and a separate cost analysis was performed for the entire system for both summer and winter months [12]. Nkinham et al. conducted an analysis of geothermal energy extraction technologies, challenges, potential, and recommendations for widespread use. Geothermal energy has been highlighted as a vital component for a clean energy future [13]. Willems and Nick emphasized that optimizing the spacing between injection production wells and the distance between individual pairs of wells increased heat recovery efficiency to a certain extent [14]. Elbir, a geothermal source has been integrated as a preheating unit into a conventional fossil fuelsystem with a Rankine cycle. Thus, the system's energy and exergy analysis, exergy destruction cost, capital cost, etc., were evaluated. As a result, it is stated that this added heat increased the turbine power output by 25% and reduced the boiler heat input by 18% [15]. Aryanfar and Wu used different working fluids to measure the energy and exergy efficiencies of a Rankine cycle integrated double-stage geothermal power plant, as well as its environmental impacts on global warming and ozone layer depletion potential. In conclusion, when the effects of different working fluids were examined, it was emphasized that different working fluids and pressure optimization positively affected efficiency [16].

In this study, a turbine generator system was integrated into a geothermal well with a temperature range of 130°C to 162 °C. Unlike previous studies, this work calculated electricity production for different temperature ranges (130, 138, 146, 154, and 162 °C) of a geothermal well integrated with a constant pressure flash chamber of 250 kPa. Energy and exergy analysis of the entire system was performed using the Engineering Equation Solver (EES) program. The obtained data were used to calculate electricity production and both the exergy and energy efficiency of the entire system.

2. MATERIALS AND METHODS (MATERYAL VE METOD)

2.1. SYSTEM DESCRIPTION (Sistem Açiklamasi)

A system for generating electricity from geothermal energy has been designed. Figure 1 is a schematic representation of the designed geothermal electricity system. When Figure 1 is examined, it can be seen that the heat of the fluid taken from a geothermal source and the pressure of the geothermal fluid in the flash chamber reach 600 kPa and its temperature reaches 158.8 °C. The fluid then passes through a separator, and a portion is sent to the steam turbine. The steam entering the turbine is converted into mechanical energy through the vanes. This mechanical energy is transferred from the turbine to the generator via the shaft, where it is converted into electrical energy. The remaining portion of the fluid that passes through the separator is transferred to line number 5.The fluid coming from line 5 and the fluid exiting the turbine combine and pass into line 6. The geothermal fluid can then be sent for use in greenhouses or residential areas as needed, or any excess can be sent to the reinjection well.

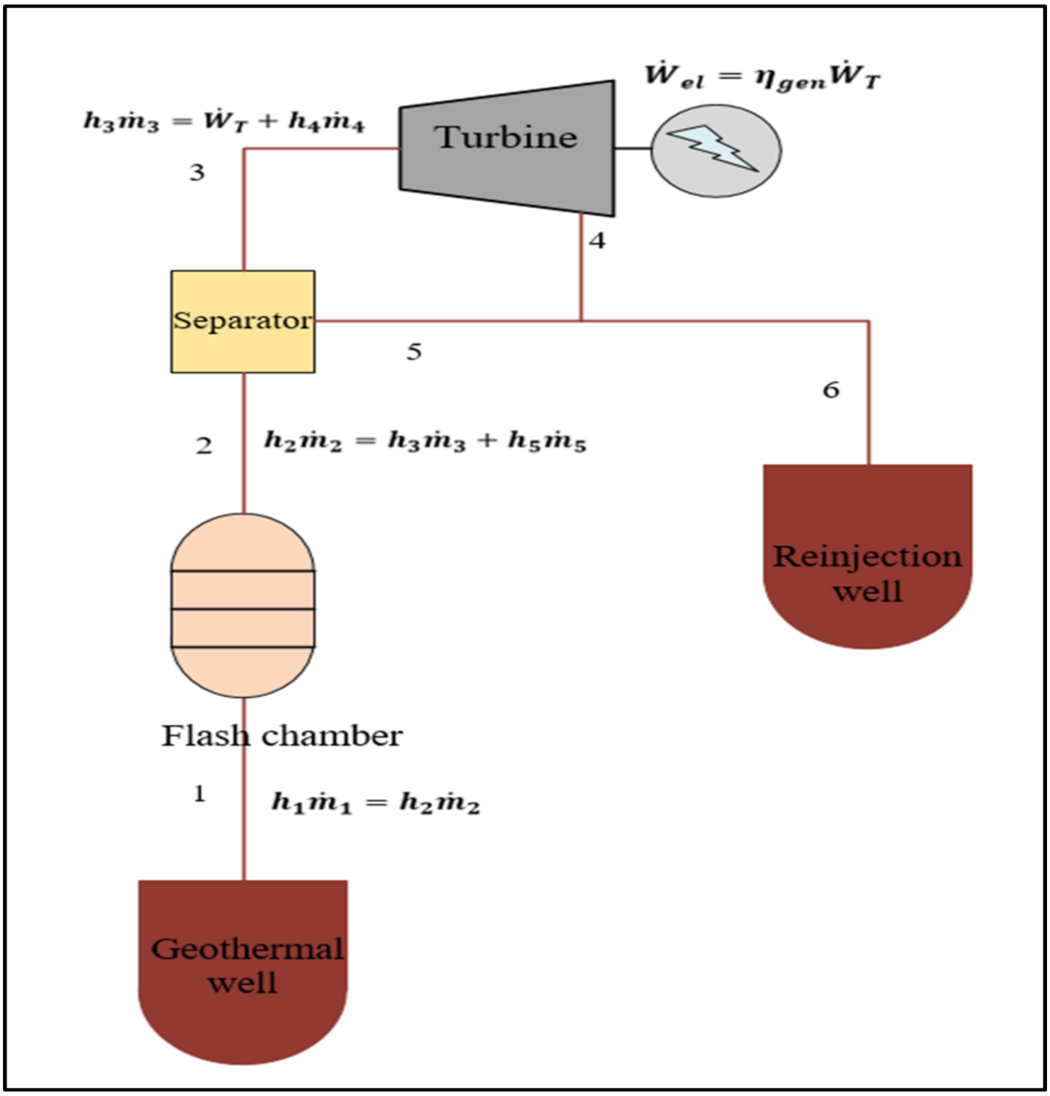

Figure 1. Schematic representation of a geothermal energy-based system developed for electricity generation (Elektrik üretmek üzere geliştirilen jeotermal enerji tabanlı sisteminin şematik gösterimi)

In this system, electricity production quantity and extraction analysis were carried out based on geothermal resource data located in Simav, Kütahya [17]. The constraints and input parameters required for geothermal electricity generation used in this design are given in Table 1.

Table 1. Design requirements and input parameters (Tasarım şartları ve giriş parametreleri)

Input parameter	**Value**
Location chosen	Kütahya / Simav [17]
Geothermal fluid inlet condition	Saturated liquid [17]
Geothermal well temperature	130-162 °C [17]
Geothermal fluid flow rate	72 kg/s [17]
Geothermal fluid inlet pressure	650,34 kPa [11]
Geothermal fluid flashing pressure	250 kPa [18]
Turbine isentropic efficiency	80%
Generator efficiency	80%

3. System analysis (Sistem Analizi)

Thermodynamic analysis of each main component of the designed geothermal power generation system was performed using energy and exergy approaches. The assumptions accepted in the analysis are listed below.

- The steady-state conditions exist.
- The turbine is assumed to have 80% isentropic efficiency.
- Reference conditions were accepted as 1 bar 25°C.
- Heat losses of the system have been neglected.
- At 162°C, the geothermal fluid is in the saturated liquid phase [17].
- The change in potential and kinetic energy has been ignored.
- The separator and flash chamber are assumed to be adiabatic.

General exergy and energy balance equations were used in the analysis of the geothermal power generation system.

$$\dot{Q}_i + \dot{W}_i + \sum_i \dot{m}_i(h_i) = \dot{Q}_o + \dot{W}_o + \sum_o \dot{m}_o(h_o) \quad (1)$$

$$\sum_i \dot{m}_i(ex_i) + \dot{Ex}^Q + \dot{Ex}_{win} = \sum_o \dot{m}_o(ex_o) + \dot{Ex}^Q + \dot{Ex}_{wo} + \dot{Ex}^Q + \dot{Ex}_{dest} \quad (2)$$

In the sub-indices used in advertisements 1 and 2, i represents the input, o represents the output, $\dot{m}$ represents the mass flow rate, and $\dot{Q}$ represents the heat transfer rate. Furthermore, h represents enthalpy, $\dot{W}$ represents the rate of work, and $\dot{Ex}_d$ represents the exergy proximity. The energy and exergy balance equations for each component of the geothermal power generation system are given below [19].

- Flash Chamber

$$h_1\dot{m}_1 = h_2\dot{m}_2 \quad (3)$$

$$ex_1\dot{m}_1 = ex_2\dot{m}_2 + \dot{Ex}_{dest,FC} \quad (4)$$

- Separator

$$h_2\dot{m}_2 = h_3\dot{m}_3 + h_5\dot{m}_5 \quad (5)$$

$$e\dot{x}_2m_2 = ex_3\dot{m}_3 + ex_5\dot{m}_5 + \dot{Ex}_{dest,sep} \quad (6)$$

- Turbine

$$h_3\dot{m}_3 = \dot{W}_T + h_4\dot{m}_4 \quad (7)$$

$$ex_3\dot{m}_3 = \dot{W}_T + ex_4\dot{m}_4 + \dot{Ex}_{dest,T} \quad (8)$$

- Electricity generation

$$\dot{W}_{el} = \eta_{gen}\dot{W}_T \quad (9)$$

Where $\dot{W}_T$ represents the mechanical work done by the turbine and η_{gen} represents the generator efficiency. The system's overall energy and negative energy efficiency are calculated using the following formulas.

$$\eta_{en,ov} = \frac{\dot{W}_{el,G}}{\dot{m}_1(h_1+h_6)} \quad (10)$$

$$\eta_{ex,ov} = \frac{\dot{W}_{el,G}}{\dot{m}_1(ex_1+ex_6)} \quad (11)$$

4. Results and discussion (Sonuçlar ve Tartışma)

Geothermal electricity generation using a turbine generator system integrated into a geothermal well has been investigated. The Engineering Equation Solver (EES) software was used in the calculations of the system that was established. In this system, geothermal energy was used solely for electricity generation. Geothermal fluid temperatures are 130, 138, 146, 154, and 162 °C. The thermophysical properties of the system's main components at their respective state points for these temperature values are given in Table 2. Table 2 shows that the thermophysical properties are considered separately for each temperature value. For a temperature of 130°C, the exergy, pressure, mass flow, enthalpy, and entropy values are given in Case 1. Case 2, Case 3, Case 4, and Case 5 show data related to temperatures of 138, 146, 154, and 162 °C, respectively. In calculations solely for electricity generation, the net energy efficiency of the system, based on the given temperature values, was calculated as 6.5% at the lowest temperature of 130°C and 67% at the highest temperature of 162°C. Geothermal fluid from Kütahya Simav [17] with a calorific value of 162 °C is sent to a flash chamber at a pressure of 250 kPa, and the saturated fluid and saturated steam from this chamber then go to a separator. The saturated liquid and saturated vapor arriving at the separator are separated and sent to line 3 and line 5. The amount of vapor and liquid varies depending on the temperature of the fluid entering the flash chamber and is given in Table 2. Saturated steam enters the turbine from line 5 at a pressure of 250 kPa and a temperature of 127.4 °C, and wet steam exits the turbine at a pressure of 150 kPa and a temperature of 111.3 °C.

Table 2. Thermophysical properties of the state points of the main components used in the system (Sistemde kullanılan ana bileşenlerinin durum noktalarına ait termofiziksel özellikler) [20]

	State point	Substance	Mass Flow rate (kg/s)	Temperature (°C)	Pressure (kPa)	Specific enthalpy (kJ/kg)	Specific exergy (kJ/kg)	Specific entropy (kJ/kgK)
case 1	1	Water	72	130	313,22	546,4	63,545	1,635
	2	Water	72	127,4	250	546,38	63,51	1,635
	3	Water	0,364	127,4	250	2716,5	618,3	7,052
	4	Water	0,364	111,35	150	2645,328	533,35	7,098
	5	Water	71,636	127,4	250	535,35	60,68	1,6072
	6	Water	72	160,5	150	546,019	63,075	1,635

	State point	Substance	Mass Flow rate (kg/s)	Temperature (°C)	Pressure (kPa)	Specific enthalpy (kJ/kg)	Specific exergy (kJ/kg)	Specific entropy (kJ/kgK)
case 2	1	Water	72	138	348,188	588,6	80,776	1,7184
	2	Water	72	127,4	250	588,6	74,3	1,74
	3	Water	1,758	127,4	250	2716,5	618,3	7,052
	4	Water	1,758	111,35	150	2645,328	533,35	7,098
	5	Water	70,242	127,4	250	535,35	60,68	1,6072
	6	Water	72	160,5	150	586,857	72,222	1,741

	State point	Substance	Mass Flow rate (kg/s)	Temperature (°C)	Pressure (kPa)	Specific enthalpy (kJ/kg)	Specific exergy (kJ/kg)	Specific entropy (kJ/kgK)
case 3	1	Water	72	146	426,576	614,95	82,5	1,801
	2	Water	72	127,4	250	614,95	81,036	1,805
	3	Water	2,63	127,4	250	2716,5	618,3	7,052
	4	Water	2,63	111,35	150	2645,328	533,35	7,098
	5	Water	69,37	127,4	250	535,35	60,68	1,6072
	6	Water	72	160,5	150	612,35	74,94	1,807

	State point	Substance	Mass Flow rate (kg/s)	Temperature (°C)	Pressure (kPa)	Specific enthalpy (kJ/kg)	Specific exergy (kJ/kg)	Specific entropy (kJ/kgK)
case 4	1	Water	72	154	530,024	649,468	92,787	1,88
	2	Water	72	127,4	250	649,468	89,86	1,89
	3	Water	3,77	127,4	250	2716,5	618,3	7,052
	4	Water	3,77	111,35	150	2645,328	533,35	7,098
	5	Water	68,23	127,4	250	535,35	60,68	1,6072
	6	Water	72	160,5	150	645,74	85,414	1,894

	State point	Substance	Mass Flow rate (kg/s)	Temperature (°C)	Pressure (kPa)	Specific enthalpy (kJ/kg)	Specific exergy (kJ/kg)	Specific entropy (kJ/kgK)
case 5	1	Water	72	162	650,34	684,168	103,57	1,96
	2	Water	72	127,4	250	684,168	98,74	1,978
	3	Water	4,91	127,4	250	2716,5	618,3	7,052
	4	Water	4,91	111,35	150	2645,328	533,35	7,098
	5	Water	68,23	127,4	250	535,35	60,68	1,6072
	6	Water	72	160,5	150	679,31	92,94	1,98

Figure 1 shows that the thermal power entering the system increases depending on the temperature of the geothermal fluid. The thermal power of the geothermal fluid at a temperature of 130°C was determined to be approximately 31,786.5 kW, while the thermal power at the highest temperature of 162°C was determined to be approximately 41,707.3 kW. The increase in thermal power due to the temperature of this geothermal fluid also positively affects energy efficiency.

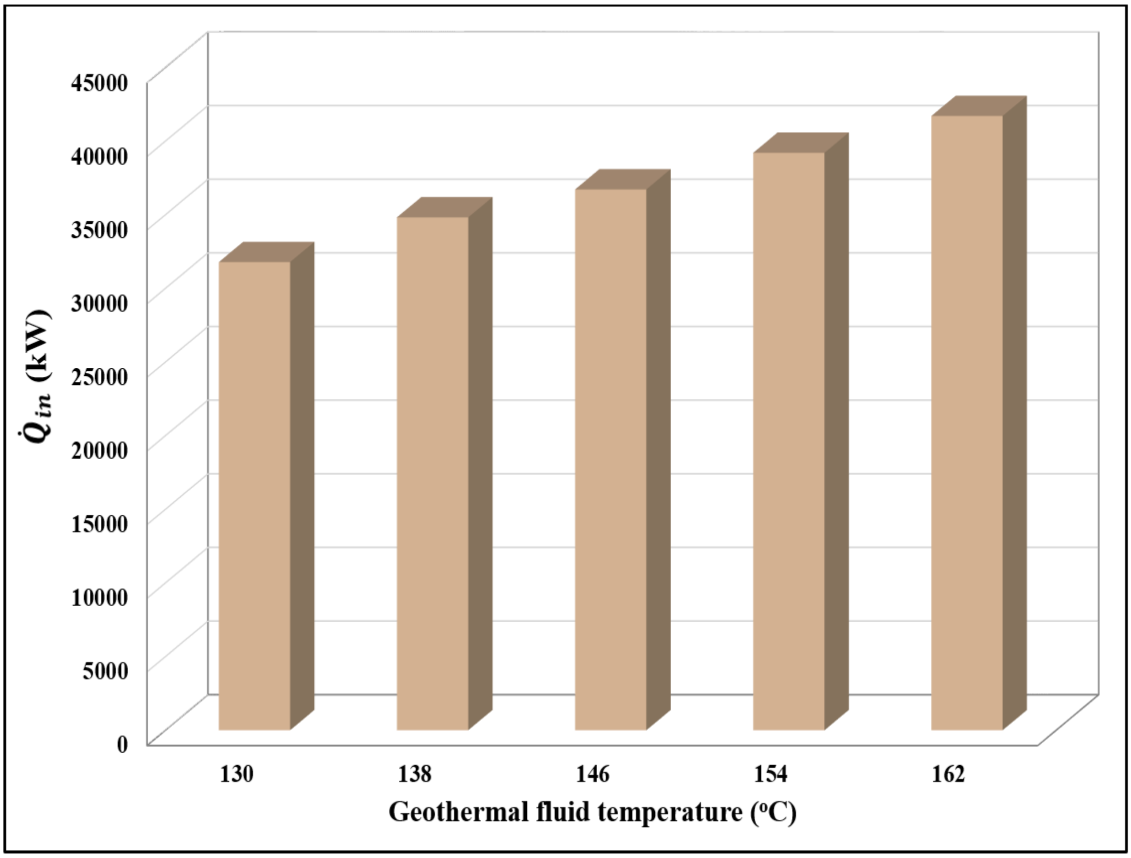

Figure 1. The effect of geothermal fluid heat on total thermal power (Jeotermal akışkan ısısının toplam ısıl güç üzerindeki etkisi)

The generator used in the system operates with 80% efficiency . The effect of geothermal fluid heat on electricity generation is shown in Figure 2. As can be seen in Figure 2, the variation in geothermal fluid temperature between 130 and 160 has a positive effect on electricity production. The net electricity generation for temperature values of 130, 138, 146, 154 and 162 °C was calculated as 20.73, 100.07, 149.60, 114.48 and 279.70 kW, respectively.

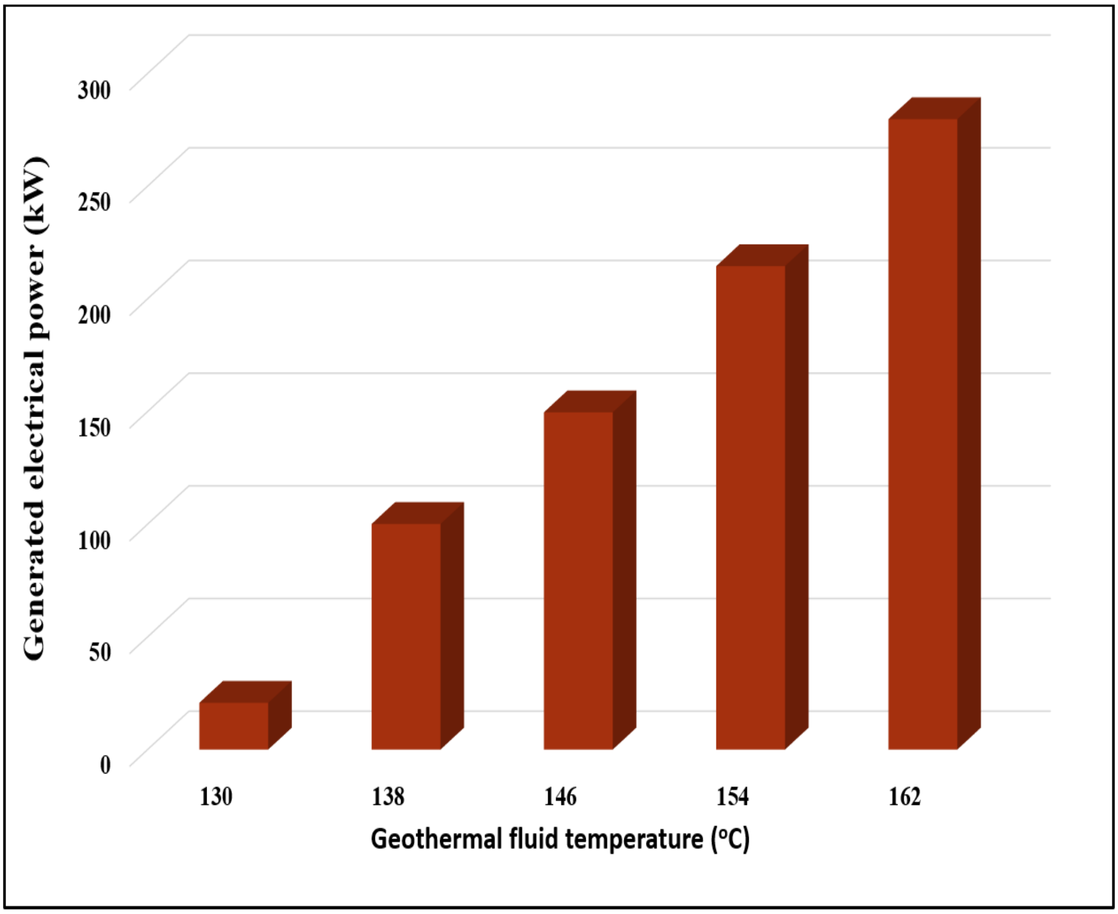

Figure 2. The effect of geothermal fluid heat on the electricity generated (Jeotermal akışkan ısısının üretilen elektrik gücü üzerindeki etkisi)

Geothermal fluid with a flow rate of 72 kg/s passes through the flash chamber and is then separated into steam and liquid in the separator. With this 72 kg/s flow rate, the flow rate of the steam passing through the flash chamber and sent to the separator varies depending on different temperature values. The pressure and temperature of the flash chamber are kept constant at 250 kPa and 127.41 °C, respectively. The lowest steam flow rate obtained from the separator to the turbine was approximately 0.36 kg/s at 130 °C, and the highest was approximately 4.91 kg/s at 162 °C. The steam produced is sent to a turbine, which in turn generates power.

In this study, which is based on the temperature of the geothermal fluid, both energy and exergy efficiencies were calculated using equations 10 and 11. Figure 3 shows the energy and exergy efficiencies of this system. Energy and exergy analysis of geothermal fluid temperatures were examined for 5 different cases, gradually increasing from 130 to 162°C. Energy and exergy analyses performed between temperatures of 130 and 162 °C indicate that electricity generation is possible within this temperature range. Thus, the effect of temperature variation in geothermal fluidity on the system was investigated.

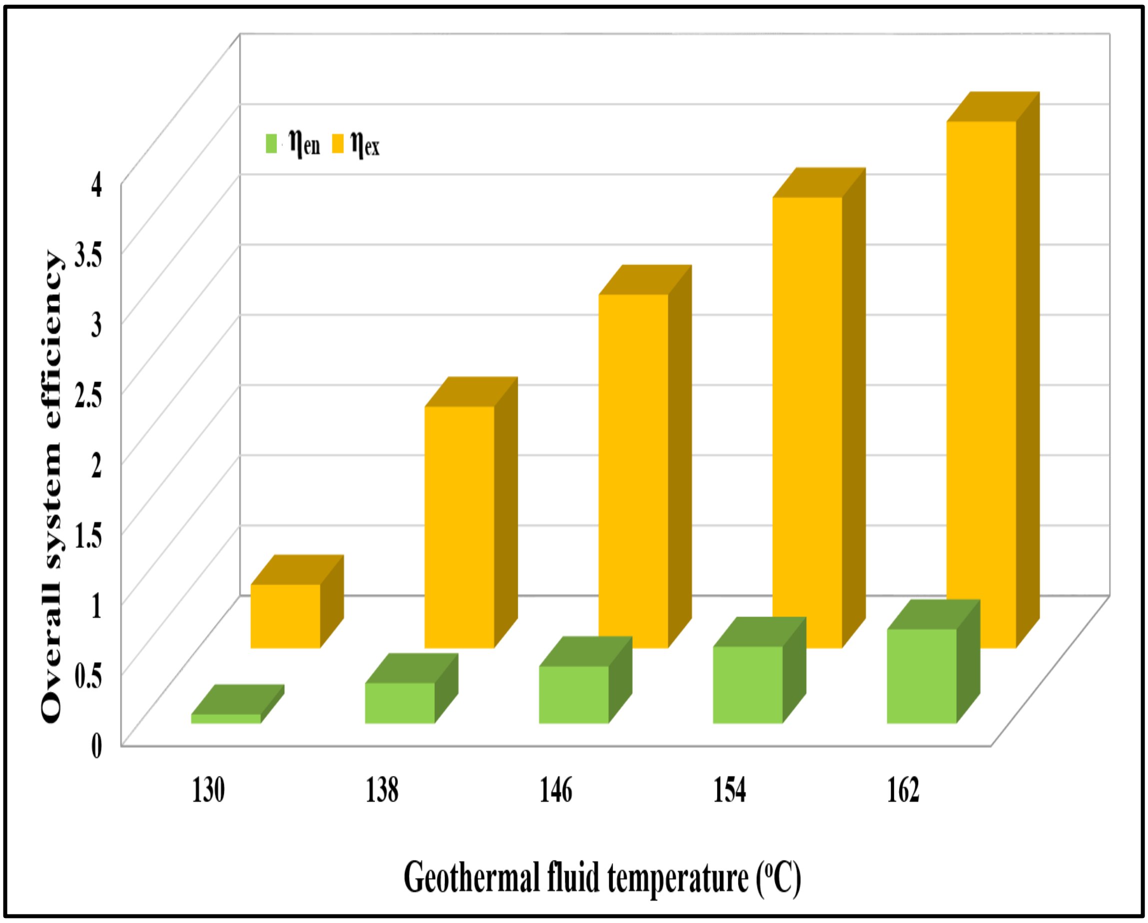

Figure 3. The effect of geothermal fluid heat on the overall efficiency of the system (Jeotermal akışkan ısılsın sistemin genel verimi üzerine etkisi)

Figure 3 shows that geothermal fluids with higher temperatures have higher exergy and energy efficiencies than those with lower temperatures. The lowest energy and exergy efficiencies were calculated at 130°C, approximately 0.065% and 0.45%, respectively. The highest energy and exergy efficiencies were calculated at 162°C, approximately 0.67% and 3.75%, respectively. Overall, the exergy efficiency of the system is found to be greater than the energy efficiency for all temperature values. The fact that exergy efficiency is greater than energy efficiency is a consequence of heat utilization at low temperatures. The fact that exergy efficiency is greater than energy efficiency is a consequence of heat utilization at low temperatures.

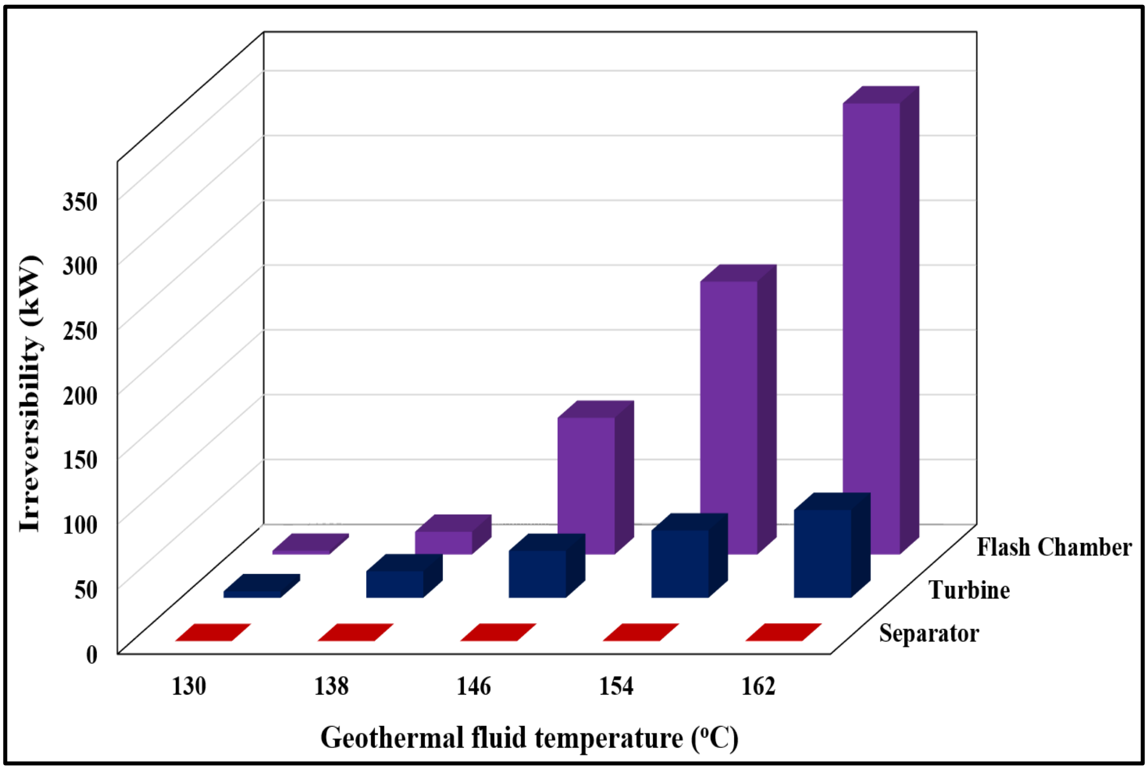

Figure 4. The effect of geothermal fluid heating on the irreversibility of system components (Jeotermal akışkan ısılsın system bileşenlerinin tersinmezliği üzerine etkisi)

Figure 4 shows the irreversibility graph of the system components as a function of temperature. When Figure 4 is examined, it can be seen that the least irreversibility occurs at 130 °C and the most occurs at 162 °C, depending on the increase in temperature. The highest levels of irreversibility were observed in the flash chamber at a temperature of 162 °C. Irreversibility occurs minimally in the separator, and the amount is negligible. As shown in Table 2, there is a change in the pressure of the geothermal fluid entering the system depending on the change in fluid temperature. The greater the difference between the pressure of the geothermal fluid entering the system and the pressure in the flash chamber, the greater the irreversibility. At 130°C, the irreversibilities of the turbine, flash chamber, and separator are approximately 5.02 kW, 2.92 kW, and 0.018 kW, respectively. The irreversibilities of these system components at 162°C are approximately 67.78 kW, 348.17 kW, and 0.25 kW, respectively.

Table 3. Comparison of energy and exergy yield of geothermal wells through various processes (Jeotermal kuyuya ait enerji ve ekserji veriminin çeşitli süreçlerle karşılaştırılması)

Reference	Type	Energy efficiency	Exergy efficiency
Present work	Geothermal energy	0,67%	3.75%
[12]	Solar and Geothermal energy	19.6%	19.1%
[15]	Solar and Geothermal energy	-	40%-50%
[10]	Solar, biomass and Geothermal energy	-	35.9%
[21]	Double-flash and binary geothermal power	26.2%	37.5%

The energy and exergy efficiencies of a geothermal well obtained in this study are compared with the results of different geothermal processes and geothermal energy integrated with different sources given in the literature in Table 3. In general, when a geothermal resource is integrated with other sources, both energy and exergy efficiency are higher.

5. CONCLUSION (SONUÇ)

This study investigates the electricity generation, energy, and exergy analysis of geothermal fluid at different temperatures. The findings obtained from the study are presented below.

- Increasing the temperature of the geothermal fluid has increased enthalpy, entropy, exergy, energy efficiency, exergy efficiency, thermal power input, and electricity production.

- A 30°C increase in geothermal fluid temperature created a difference of approximately 158.97 kW of electrical energy between the lowest and highest electricity production.

- The overall exergy efficiency of the system, depending on the lowest and highest temperatures of the geothermal fluid, showed a 716% increase compared to the lowest exergy efficiency. This indicates that the system's work capacity has increased eightfold.

These studies, conducted for different temperature values of geothermal fluid, suggest that the flash chamber pressure should be kept constant, and that future studies should focus on optimizing the flash chamber pressure according to temperature.

DECLARATION OF ETHICAL STANDARDS (ETİK STANDARTLARIN BEYANI)

The author of this article declares that the materials and methods they use in their work do not require ethical committee approval and/or legal-specific permission.

Bu makalenin yazarı çalışmalarında kullandıkları materyal ve yöntemlerin etik kurul izni ve/veya yasal-özel bir izin gerektirmediğini beyan ederler.

AUTHORS' CONTRIBUTIONS (YAZARLARIN KATKILARI)

Medine ÖZKAYA: She carried out the numerical analysis, analyzed the results and wrote the article.

Sayısal analizleri yapmış, sonuçlarını analiz etmiştir ve makalenin yazım işlemini gerçekleştirmiştir.

CONFLICT OF INTEREST (ÇIKAR ÇATIŞMASI)

There is no conflict of interest in this study.

Bu çalışmada herhangi bir çıkar çatışması yoktur.

REFERENCES (KAYNAKLAR)

[1] H. Doğan, & N. Yılankırkan, Türkiye'nin enerji verimliliği potansiyeli ve projeksiyonu. Gazi Üniversitesi Fen Bilimleri Dergisi Part C: Tasarım ve Teknoloji, 3:1 (2015) 375-384.

[2] E. Bayır, & H. H. Açıkel, Hydrogen Production using a Hybrid System Built with Renewable Energy Resources in Yenice. Gazi Üniversitesi Fen Bilimleri Dergisi Part C: Tasarım ve Teknoloji, 114 (2023) 1244-1260.

[3] N.A. Vafeas, "Geothermal Energy: Barriers and Advantages to Adoption in Ireland,", 2021, 7.

[4] https://enerji.gov.tr/bilgi-merkezi-enerji-jeotermal, 25.Şubat.2026.

[5] A. Acır, M. Emin Canlı, İ. Ata, & H. E. Tanürün, Effects of a circular-shaped turbulator having varying hole numbers on energy and exergy efficiencies of a solar air heater. International Journal of Ambient Energy, 40:7 (2019) 739–748. https://doi.org/10.1080/01430750.2017.1423385

[6] I. Ata, H. E. Tanürün, S. Uzun, S. Bayrak, & A. Acır, Exergy analysis and determination of irreversibility of a thermal power plant. Heat Transfer Research, 53:2 (2022) 1–12. https://doi.org/10.1615/HeatTransRes.2021039997

[7] G. C. Ding, J. I. Peng, & G. E. N. G. Mei-Yun, Technical assessment of Multi-generation energy system driven by integrated renewable energy Sources: Energetic, exergetic and optimization approaches. Fuel, 331 (2023) 125689. https://doi.org/10.1016/j.fuel.2022.125689

[8] S. Inac, & A. Midilli, On geothermal and wind energy integrated methanol production by using green hydrogen. Energy, 318 (2025) 134712.

[9] O. Siddiqui, H., Ishaq, & I. Dincer, A novel solar and geothermal-based trigeneration system for electricity generation, hydrogen production and cooling. Energy conversion and management, 198 (2019) 111812.

[10] F. Wang, S. Deng, J. Zhao, J. Wang, T. Sun, & J. Yan, Performance and economic assessments of integrating geothermal energy into coal-fired power plant with CO2 capture. Energy, 119 (2017) 278-287.

[11] Khalid, F., Dincer, I., & Rosen, M. A. (2017). Techno-economic assessment of a solar-geothermal multigeneration system for buildings. International Journal of Hydrogen Energy, 42(33), 21454-21462. https://doi.org/10.1016/j.ijhydene.2017.03.185

[12] F. Calise, M. D. d'Accadia, A. Macaluso, A. Piacentino, & L. Vanoli, Exergetic and exergoeconomic analysis of a novel hybrid solar–geothermal polygeneration system producing energy and water. Energy Conversion and Management, 115 (2016) 200-220.

[13] C. M. Nkinyam, C. O. Ujah, C. O. Asadu, & D. V. Kallon, Exploring geothermal energy as a sustainable source of energy: A systemic review. Unconventional Resources, 6, (2025) 100149. https://doi.org/10.1016/j.uncres.2025.100149

[14] W. Yuan, D. Zhang, Y. Zhang, J. Gao, T. Liu, H. Zhai,... & B. Zhang, Performance of Multi-Well exploitation and reinjection in a Small-Scale shallow geothermal reservoir in Huailai County. Frontiers in Earth Science, 9 (2021) 786389. https://doi.org/10.3389/feart.2021.786389

[15] A. Elbir, Optimization of Fossil-Geothermal Hybrid Energy Systems: Thermodynamics and Exoeconomic Approach. Thermal Advances, (2026) 100121. https://doi.org/10.1016/j.thradv.2026.100121

[16] Y. Aryanfar, & W. Wu, Energy and exergy analysis of a double-flash geothermal-based organic Rankine cycle system. Renewable Energy, (2026) 125187. https://doi.org/10.1016/j.renene.2026.125187

[17] A. Tuğcu, O. Arslan, R. Köse, & N. Yamankaradeniz, Jeotermal destekli absorbsiyonlu soğutma sisteminin termodinamik ve ekonomik analizi: Simav örneği. Isı Bilimi ve Tekniği Dergisi, 36:1 (2016) 143-159.

[18] R. DiPippo, Miravalles power station, Guanacaste PROVINCE, Costa Rica. Geothermal power plants: principles, applications, case studies and environmental impact. Amsterdam: Butterworth-Heinemann, (2008) 331-47.

[19] Y. A. Cengel, & M. A. Boles, Thermodynamics: an engineering approach. Sea, 1000:8862 (2002) 287-293.

[20] https://fchart.com/ees/demo-file.php/, 30. January. 2026.

[21] Yilmaz, F., Ozturk, M., & Selbas, R. (2022). Modeling and design of the new combined double-flash and binary geothermal power plant for multigeneration purposes; thermodynamic analysis. *International Journal of Hydrogen Energy*, *47*(45), 19381-19396. https://doi.org/10.1016/j.ijhydene.2021.09.180