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Contribution of geothermal resources that could be used in district heating system to türkiye economy and analysis in terms of carbon emissions

Bölgesel ısıtma sisteminde kullanılabilecek jeotermal kaynakların türkiye ekonomisine katkısı ve karbon salınımı açısından analizinin yapılması

***Yazar(lar) (Author(s))**: Vehbi MEŞİN[1], Abdulhakim KARAKAYA[2]*

ORCID[1]: 0000-0002-7171-3177

ORCID[2]: 0000-0003-1119-6945

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Contribution of Geothermal Resources that Could Be Used in District Heating System to Türkiye Economy and Analysis in terms of Carbon Emissions

Highlights

- *District heating system*
- *Carbon emission*
- *Geothermal*
- *Economic contribution*

Graphical Abstract

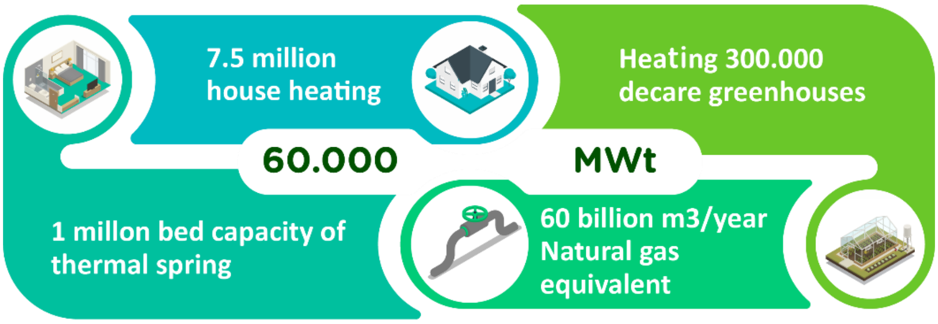

Figure. 60,000 MWh heat potential equivalent

Aim

In this study, potential areas where the geothermal sourced district heating system can be applied in Türkiye were determined and compared with the existing heating systems in terms of carbon emissions and economics.

Design & Methodology

In this study, numerical methods were used.

Originality

A comparison of various fuel costs and carbon emissions of potential areas for geothermal district heating projects in Türkiye has not been studied in this area.

Findings

As a result of using a geothermal-sourced district heating system, there will be a 1.58% reduction in annual greenhouse gas emissions in Türkiye. The payback period of the geothermal sourced district heating system application for the equivalent of 1,000,000 residences is approximately 13 years with the current investment amounts.

Conclusion

Environmental policies and investments to be developed in Türkiye should be planned in line with existing potentials. In this way, Türkiye will quickly become one of the countries that produce environmentally sustainable targets and contribute to the world ecosystem, leaving the list of countries with rapidly increasing CO_2 *emissions.*

Declaration of Ethical Standards

The author(s) of this article declare that the materials and methods used in this study do not require ethical committee permission and/or legal-special permission.

Contribution of Geothermal Resources that Could Be Used in District Heating System to Türkiye Economy and Analysis in terms of Carbon Emissions

Araştırma Makalesi / Research Article

Vehbi MEŞİN[1],*, Abdulhakim KARAKAYA[2]

[1]Institute of Science, Department of Energy Systems Engineering, Kocaeli University, Kocaeli, Turkey.

[2]Faculty of Technology, Department of Energy Systems Engineering, Kocaeli University, Kocaeli, Turkey.

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ABSTRACT

Energy, which has an important position both in the world and in Türkiye, is essential for many primary areas, such as heating-cooling and production. After the industrial revolution, replacing simple machines with steam engines started the adventure of energy dependence and gave strategic energy importance. This situation has played a critical role in reshaping human history. In addition, due to the limited fossil energy resources and the continuous increase in energy costs, countries have started to develop new energy policies for their interests. Thus, scientists have accelerated their work in the field of energy efficiency. District heating systems, one of the best examples of renewable energy use, are the main subject of this study. District heating can be defined as the heating of a building, neighborhood, or city with power plants installed in one or more centers. This study aims to calculate the financial benefit of the district heating systems to be created with the use of geothermal resources in Türkiye to the Türkiye economy and its contribution to the goals of carbon neutrality. As a result of the use of a geothermal-sourced district heating system, a 1.58% reduction will be achieved in Türkiye's annual greenhouse gas emissions. With current investment amounts, the amortization period of 1,000,000 residential equivalent geothermal sourced district heating system implementation is approximately 13 years. Numerical methods were used in this study.

Keywords: District heating, carbon recovery, geothermal, economic contribution.

Bölgesel Isıtma Sisteminde Kullanılabilecek Jeotermal Kaynakların Türkiye Ekonomisine Katkısı ve Karbon Salınımı Açısından Analizinin Yapılması

ÖZ

Hem Dünya'da hem de Türkiye'de önemli bir konuma sahip olan enerji, ısıtma-soğutma ve üretim gibi birçok temel alanda ihtiyaçların karşılanması için gereklidir. Sanayi devrimi ile birlikte basit makinelerin yerini buhar makinelerinin alması enerjiye bağımlılık serüvenini başlatmış ve enerjiye stratejik önem kazandırmıştır. Bu durum insanlık tarihinin yeniden şekillenmesinde kritik bir rol oynamıştır. Tüm bu durumlara ek olarak dünyada enerji maliyetlerinin giderek artması ve fosil kaynak kullanımının sınırlı olmasından dolayı ülkeler, kendi çıkarları doğrultusunda yeni enerji politikaları geliştirmektedir. Bu doğrultuda bilim insanları da enerji verimliliği alanındaki yürütmüş oldukları çalışmalara hız kazandırmışlardır. Yenilenebilir enerji kullanımının en güzel örneklerinden olan bölgesel ısıtma sistemleri bu çalışmanın konusunu oluşturmaktadır. Bölgesel ısıtma bir sitenin, mahallenin ya da kentin bir veya birkaç merkezde kurulu santrallerle ısıtılması olarak tanımlanabilir. Bu çalışmanın amacı Türkiye'deki jeotermal kaynakların kullanımı ile oluşturulacak bölgesel ısıtma sistemlerinin, Türkiye ekonomisine mali faydasını ve karbon nötr hedeflerine yönelik katkısını hesaplamaktır. Jeotermal kaynaklı bölgesel ısıtma sisteminin, konut ısıtmasında kullanılması sonucunda Türkiye'de yıllık sera gazı emisyonlarında %1,58 oranında azalma sağlanacaktır. 1.000.000 konut eşdeğeri jeotermal kaynaklı bölgesel ısıtma sistemi uygulamasının geri ödeme süresi, mevcut yatırım tutarları ile yaklaşık 13 yıldır. Bu çalışmada numerical metotlar kullanılmıştır.

Anahtar Kelimeler: Bölgesel ısıtma, karbon kazanımı, jeotermal, ekonomik katkı.

1. INTRODUCTION

Today, advancing technology, advanced buildings, and living standards are developing with a gradual increase. Accordingly, the source used in our homes and workplaces in central heating systems started as fuel oil and continued to change to coal and natural gas. It is known that 30%-40% of existing resources are consumed throughout the life cycle of buildings, and there is a parallel relationship with the increase in carbon emission rates [1]. Türkiye aims to be a carbon-neutral country by 2053. Various steps are being taken to present realistic and concrete plans for a zero-carbon economy and to disseminate innovative and robust solutions. The first of these steps was to take a step towards becoming a carbon-neutral country by consenting to the Paris Climate

**Sorumlu Yazar (Corresponding Author)*
e-posta : vehbimesin@outlook.com

Agreement in 2015. It has also been emphasized that the planned implementation of all medium and long-term development programs in Türkiye will be prepared under the guidance of the structural transformation required by the green development revolution [2]. A district heating system is the distribution of thermal energy, usually in the form of hot water or steam, from a central source to residential, commercial, and industrial consumers for space heating, used hot water heating, process heat, cooking, and humidification. This way, instead of producing heat energy separately in each facility, it can be made and distributed from a single heat source. The District Heating System was implemented in Denmark, the closest to Türkiye, in 1903 using the energy obtained from waste landfill fuels [3]. Since those years, the basic philosophy in district heating systems has been to meet the region's resource potential as heating. Since İzmir and its region are rich in geothermal, it has gone down in history as the first place in Türkiye to experience a district heating system [4]. Since geothermal energy, a domestic resource, is in the same area as the settlement in the region, district heating systems have been actively used for home and workplace heating. No studies were found in the literature review regarding the application and results of district heating systems in potential areas. Therefore, comparisons could not be made from this perspective. When the literature is reviewed regarding heater sources, it is seen that there are many sources for district heating systems. The most common ones are used with geothermal resources, use with biomass, use with waste garbage, and use together with thermal and solar panels [5]. According to the studies conducted in Türkiye, it has been determined that there are more than 600 geothermal resources with a total thermal capacity of 2420 MW, and the probable geothermal potential is approximately 31,500 MW [6]. The most suitable source selection for district heating systems is geothermal. It is primarily provided by geothermal resources for district heating systems worldwide. District heating is sustainable, environmentally friendly, and economical. In this study, potential areas where the geothermal sourced district heating system can be applied in Türkiye were determined and economically compared with the existing heating systems. The contribution of the district heating system to the economy has been calculated. The total amount of carbon gain is predicted. In addition, contributions were made to the heating systems of regions with a certain potential.

2. MATERIAL and METHOD

The primary purpose of this research is to identify potential areas where geothermal-based district heating systems can be applied in Türkiye and to compare existing heating systems in terms of carbon emissions and economy. For this, the heat potentials of the potential areas where the Geothermal District heating project can be applied in Türkiye have been determined at the level of MWh. A financial statement is presented by comparing this determined value with the values currently spent for heating. In addition, a comparison was made in terms of carbon emissions.

The knowledge and experience among industry professionals and experts may not always be fully accessible to all researchers. Therefore, a secondary aim of this research is to provide important information to professionals, experts, and academic research communities on district heating systems. Innovative research and analysis have been undertaken in line with these ambitious research objectives. Geothermal energy; As seen in Figure 1, the capillary cracks formed on the earth are formed by the infiltration of snow and rainwater on the planet and the transfer of this energy to the surface.

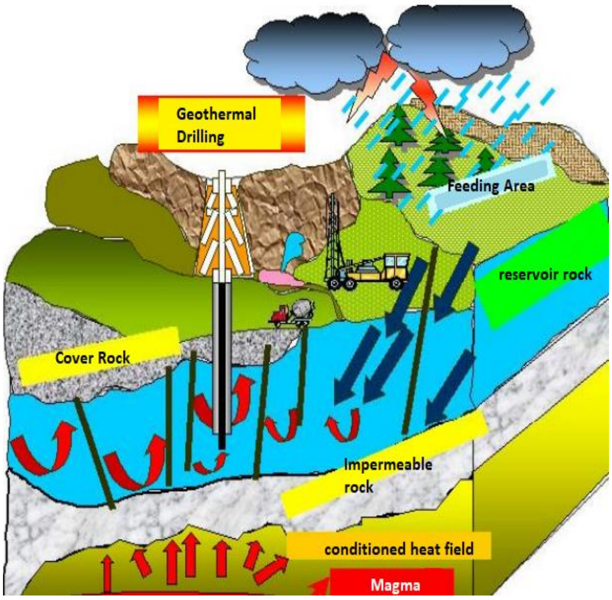

Figure 1. Schematic Representation of the Geothermal System [5]

Various weather events have been taking place on earth for centuries. Rain and snow can reach the depths of the earth's crust and magma through the cracks they find in the earth's crust. With this fluid movement, the earth's waters reaching the magma are loaded with thermal energy and move towards the earth again. This thermal energy transport process continues without the need for any processing. Earth waters, which carry this thermal energy from magma, are also rich in energy and minerals.

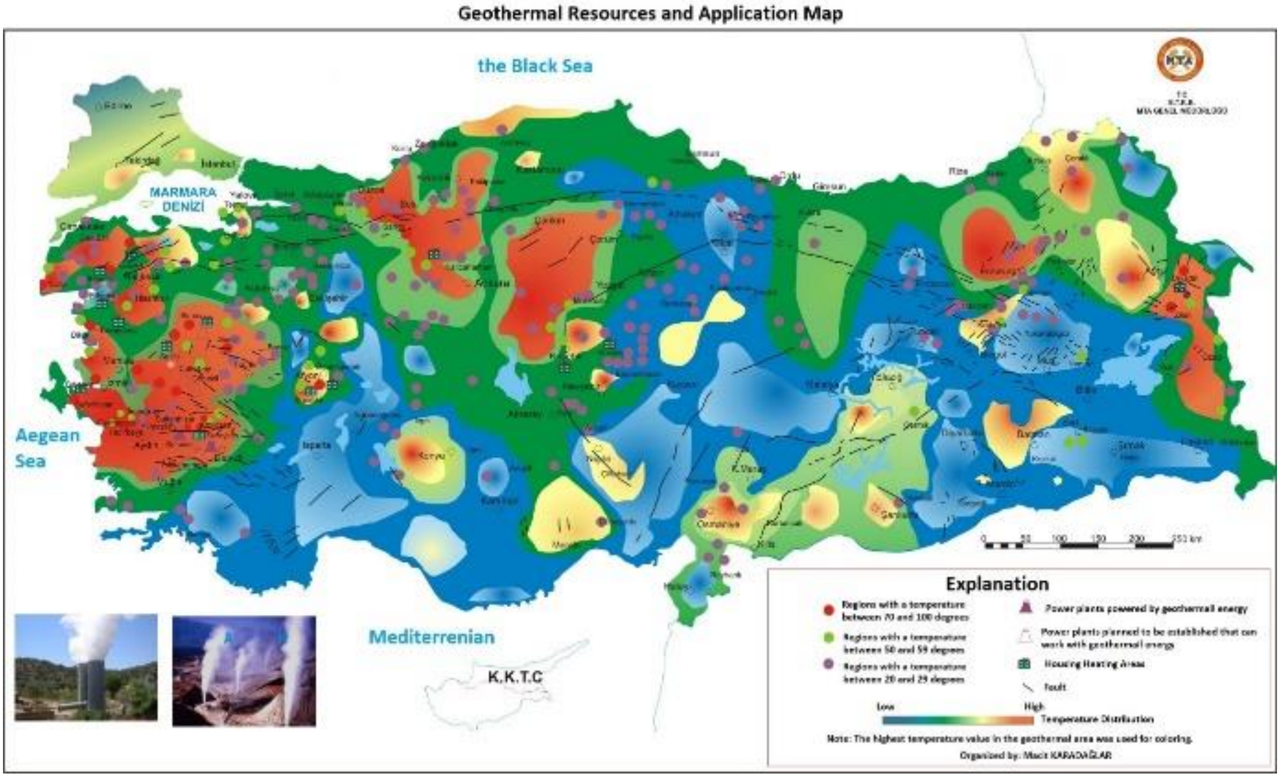

Figure 2. Geothermal Resources and Application Map in Türkiye [6]

Due to its geological and geographical location, Türkiye is on an active tectonic belt. Therefore, it is in a wealthy position compared to the world's countries in geothermal resources. As seen in Figure 2, there are approximately 1,000 geothermal resources in different temperatures in the form of natural outlets in Türkiye [7]. The springs with an outlet temperature between 70 °C and 100 °C are densely seen around Aydın, Manisa, and Balıkesir provinces. There are also springs between 70 °C and 100 °C around Ankara, Bolu, Çankırı, and Erzurum provinces. Around the high-temperature geothermal springs are medium-temperature springs between 50°C and 69°C. The Black Sea coasts are surrounded by medium-temperature springs. There is no data on TRNC [8].

District heating systems are the most used in places with high thermal load density and annual load factor. The working principle generally transfers and spreads the collective heat obtained from various thermal sources to the desired target area with pipes from underground or above ground. A high load density is required to cover the initial investment cost for transmission and distribution systems, often 50% or more of the total cost, which usually accounts for a significant portion of the initial investment cost for the entire system. Utilization of geothermal energy is third place in Türkiye due to the initial investment cost [9]. Applications are typical in densely populated cities and high-density building clusters (high-rise buildings) with high thermal loads. In addition, urban settlements where valuable real estate is the most ideal for district heating systems. Because these settlements increase the use of building areas by moving the heating equipment of the building users out of the area, the district heating system has three essential components. The source, distribution system, piping, and user connections are the heat center. Each of these components has strategic importance in terms of efficiency. Fossil fuels provide the thermal source in most systems. This is the reason why systems are preferred to respond to peak temperatures.

However, neutral carbon policies and global climate change have made the source in district heating systems necessary to be environmentally friendly. In Europe, it is aimed to prefer renewable energy and thermal waste recovery systems for fewer carbon emissions in district heating systems until 2040. Therefore, fourth-generation district heating systems will provide more efficient heating than geothermal fluids at low temperatures, thanks to advanced technology [10]. District heating systems are more widely used in regions where thermal demand is intense. It is a highly preferred system in Northern Europe and North America, whose adventure of use, which started with the meeting of the thermal demand in industrial facilities in the 19th century, has continued until today. In the literature review, the number of district heating systems in Europe in 2016 was 4174. It has been recorded that 4174 district heating systems meet 10% of the total heating need of the whole of Europe [11].

In this study, potential areas where geothermal-sourced district heating systems can be applied in Türkiye were determined and economically compared with existing heating systems. Its contribution to the economy has been calculated. The total amount of carbon gain is predicted. Türkiye's existing geothermal energy potential is evaluated together with the district heating systems.

Table 1 lists district heating systems applied in regions with potential in Türkiye and their values.

Table 1. December 2020 Türkiye Geothermal Energy District Heating Table [12, 13]

City	District	Production Amount	Temperature	Number of Houses	Distance
İzmir	Balçova ve Narlıdere	2020 m³/hour	90 C° 144 C°	37.500	3 km
Afyon	Merkez	1500 m³/hour	95 C°	25.600	15 km
Afyon	Sandıklı	1440 m³/hour	80 C°	17.000	10 km
Kütahya	Simav	828 m³/hour	130-150 C°	17.500	5 km
Manisa	Salihli	540 m³/hour	88 C°	9000	6 km
Balıkesir	Edremit	1440 m³/hour	58 C°	5150	4 km
Bursa	Merkez	1080 m³/hour	88 C°	350	-
Denizli	Sarayköy	260 m³/hour	145 C°	5000	10 km
Nevşehir	Kozaklı	34 m³/hour	94 C°	3000	2 km
Balıkesir	Bigadiç	54 m³/hour	98 C°	1500	18 km
Ankara	Kızılcahamam	63 m³/hour	75 C°	2100	2 km
İzmir	Dikili	200 m³/hour	80 C°	1500	10 km
Balıkesir	Gönen	19 m³/hour	60 C°	3400	2 km
Yozgat	Sarıkaya	180 m³/hour	57 C°	2000	-
Ağrı	Diyadin	180 m³/hour	78 - 85 C°	570	5 km
Kırşehir	Merkez	983 m³/hour	55 C°	1800	1 km
Yozgat	Yerköy	648 m³/hour	65 C°	1000	-
İzmir	Çeşme	49 m³/hour	57 C°	-	-
İzmir	Bergama	180 m³/hour	65 C°	450	8 km
Yozgat	Sorgun	-	90 C°	2100	2 km
Balıkesir	Güre	-	70 C°	1400	-
Balıkesir	Sındırgı	-	98 C°	2500	12 km

In the "EGEC-European Geothermal Energy" council organized by Belgium in 1999 in Ferrara, Italy, Balçova Geothermal District Heating System was accepted as one of the seven most successful facilities in the world in terms of technology and sustainability [14]. The geothermal resource, which meets the heating needs of 37,500 houses 3 km below the ground, between 90 °C and 140 °C in the Izmir Narlıdere and Balçova region, has been active since 1996.

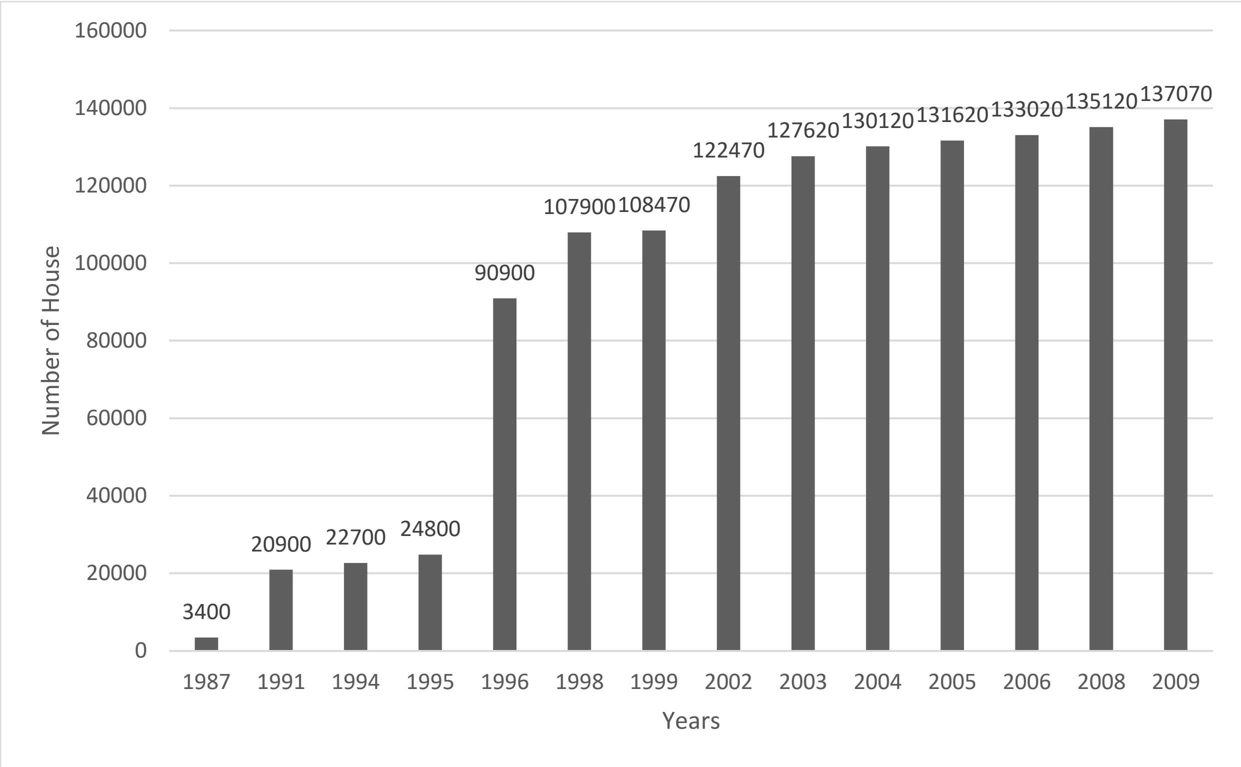

Figure 3. Number of Geothermal Source District Heating System Houses by Years in Türkiye

According to the study conducted in December 2020, there are geothermal energy-sourced district heating systems in 22 different regions for cities and residences in Türkiye. The installed power in Türkiye is approximately 1205 MWh, equivalent to 137,000 residences. The number of residences by year is shown in Figure 3. With the enactment of the Geothermal Resources and Natural Mineral Waters Law in 2008, it has been dealt with by a law regulating the exploration and operation of geothermal energy resources, which has been going on for many years. It filled various gaps and resulted in accelerated studies on the development of geothermal resources [12]. There are three major earthquake belts on the earth's surface. These are the Pacific seismic belt, the Alpine-Himalayan seismic belt, and the Atlantic seismic belt. Türkiye is located on the Alpine-Himalayan belt. Alpine-Himalayan is one of the important geothermal energy belts. According to the data made by the General Directorate of Mineral Research and Exploration (MTA), which has not yet been officially published, the geothermal heat potential of Türkiye is calculated to be at the level of 31,500 MWt. According to recent studies, it is predicted that this potential can reach up to 60,000 MWh [15]. In addition to the geothermal resource research activities carried out in Türkiye, the drilling programs initiated to improve the capacities of the existing potential areas in the Western Anatolia Region have led to many new fields and capacities. Many new fields continue to be explored by the MTA General Directorate. It is foreseen that the exploration and development processes of geothermal energy resources will continue increasing during the 11th Development Period (until 2023). As a result of the research, Türkiye ranked first in Europe and seventh in the world in terms of geothermal energy resources [16].

The heat potential conjugate is given below to understand the importance of Türkiye's 60,000 MWh heat potential.

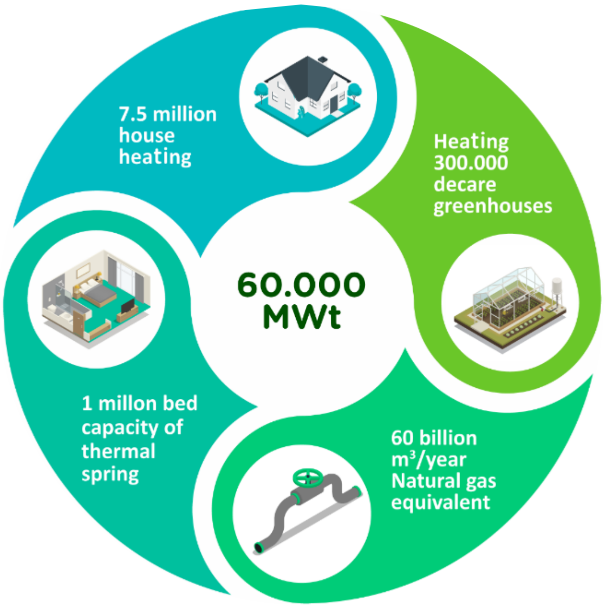

Figure 4. 60,000 MWh heat potential conjugate [14]

As seen in Figure 4, the potential of 60,000 MWh has a very priceless value. This potential represents a size equivalent to the heating need of 7.5 million residences or 300 thousand acres of greenhouses, 1 million hot spring beds, and 60 billion m3/year of natural gas [17]. Most of our country's geothermal energy resources have medium and low output temperatures. It is possible to carry out applications such as city heating, cooling, greenhouse heating, thermal facility heating, and spas with geothermal resources with medium and low output temperatures. In addition, with the EGS (Enhanced Geothermal System; Engineered Geothermal System) technology developed in recent years, it is possible to generate electricity with the energy obtained by injecting liquid from hot, dry rocks without fluid. With this developed technology, it is foreseen that there will be an increase in the existing heating and electricity generation potential.

2.1. Economic Analysis

An insulated house of 100 square meters needs 14 thousand kWh energy annually. 10.500 kWh/year of this energy is consumed in heating, 1.680 kWh/year in hot water, and 1.800 kWh/year in lighting and electrical household appliances [18]. The annual heating need of a house with a size of 100 square meters: To make an economic comparison analysis by taking the value of 10,500 kWh as a reference, 1000 kcal unit costs of 7 different fuels were calculated by taking the unit prices of the fuels including the Value Added Tax (VAT) published monthly by the Installation Magazine as a reference. The calculations made are comparatively presented in Table 2.

Table 2. Cost comparison table of various fuels required for 1000 kcal heat requirement in residences [19, 20]

No	Fuel Type	Relating to Company	Fuel Lower Thermal Value	02 February 2022 in History Unit price		02 February 2022 Prices on Date*	02 February 2021 in History Unit Prices		02 February 2022 02 February 2021 (Unit price Change)
1	Geothermal Source District Heating	Afjet (Afyonkarahisar)	860 kcal/kWh	0,1613	₺/kWh	0,1876 ₺/1000 kcal	0,1613	₺/kWh	0,0%
2	1.000.001 - 10.000.000 m3/year For Natural Gas Consumption	İzmit İZGAZ PALMET	8250 kcal/m³	2,297582	₺/m³	0,260276 ₺/1000 kcal	1,589264	₺/m³	44,6%
3	Domestic Lignite +18 mm Washed Part-Bag	Soma Kısrakdere Manisa - TKİ ELİ	4750 kcal/kg	1,810120	₺/kg	0,586274 ₺/1000 kcal	0,949900	₺/kg	90,6%
4	Imported Siberian Coal Orange Type	İstanbul HAKAN COAL	7000 kcal/kg	4,400000	₺/kg	0,967033 ₺/1000 kcal	1,690000	₺/kg	160,4%
5	Electricity Residence (7 kWh/day and below)	Türkiye TEDAŞ	860 kcal/kWh	1,373327	₺/kWh	1,613022 ₺/1000 kcal	0,844331	₺/kWh	62,7%
6	Fuel-oil No: 4 Heating Fuel	İstanbul Avrupa Yakası SHELL TÜRKİYE	9875 kcal/kg	13,120000	₺/kg	1,660759 ₺/1000 kcal	5,050000	₺/kg	159,8%
7	Bulk Gas Housing LPG - Propane	İstanbul İPRAGAZ-AYGAZ	11100 kcal/kg	21,253682	₺/kg	1,806364 ₺/1000 kcal	9,940049	₺/kg	113,8%
EXCHANGE			TR Central Bank Effective Selling Price						Yearly Rate of Change
			on 02 February 2022			on 02 February 2022			

Table 2 (table continuation)**.** Cost comparison table of various fuels required for 1000 kcal heat requirement in residences [19, 20]

$	13,4731 ₺	7,1608 ₺	88%
€	15,2154 ₺	8,6354 ₺	76%

*Adapted from installation magazine fuel prices study

The calculations determined residential consumption in the geothermal-sourced district heating system as 0.1876₺ for 1000 kcal [19]. This amount is the most appropriate value in kcal units among the methods used in residential heating. The geothermal-sourced district heating system is followed by natural gas, domestic lignite coal, Siberian coal, electricity, fuel oil, and LPG-propane, respectively, in terms of cost.

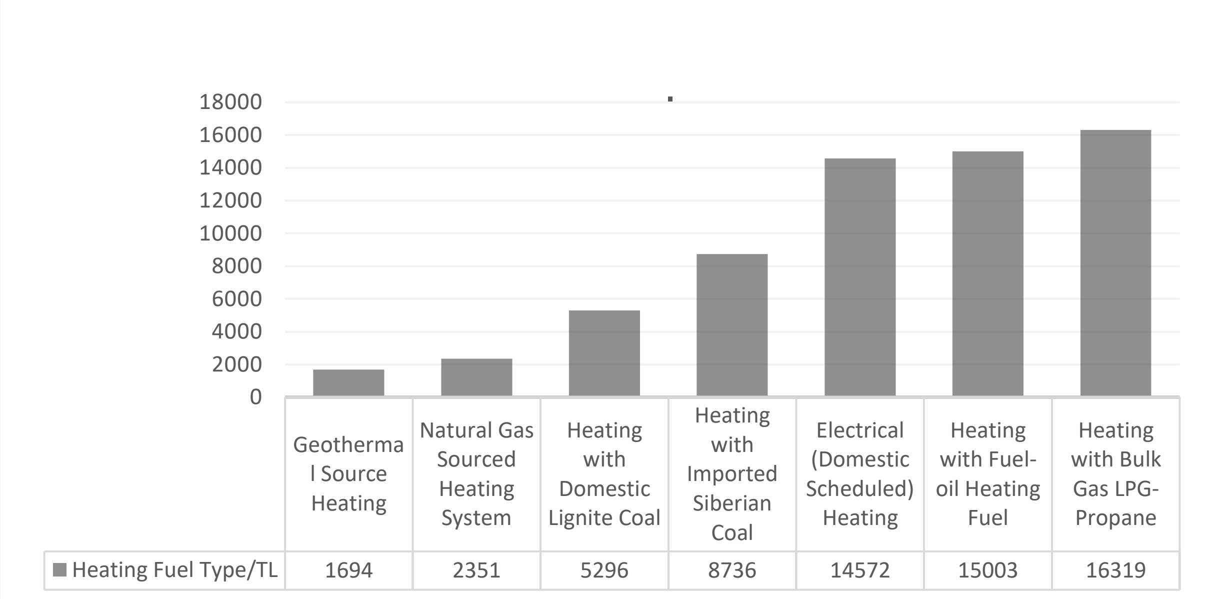

Figure 5. Annual fuel cost analysis of a 100 m2 house using various fuels

When Figure 5 is examined, when the necessary calculations are made by taking the annual heating need of a house of 100 square meters as 10.500 kWh as a reference; While the lowest cost was 1694 ₺/year for geothermal sourced district heating system, the highest cost was 16,319 ₺/year for bulk gas LPG-propane sourced heating system. In addition, when ranking in terms of economy, it has been observed that there are relatively fewer emission sources in terms of greenhouse gas emissions in the first two ranks.

Table 3. Potential Areas for Geothermal District Heating Project in Türkiye

City	Estimated Number of Potential Houses
İzmir	250.000
Denizli and its surroundings	120.000
Aydın and its surroundings	200.000
Balıkesir and its surroundings	27.000
Afyonkarahisar and its surroundings	55.000
Manisa and Turgutlu	45.000
Kütahya and its surroundings	30.000
Çanakkale and its surroundings	20.000
Sakarya, Akyazı, Kuzuluk	35.000
Salihli	30.000
Bolu and its surroundings	10.000
Yozgat and its surroundings	25.000
Nazilli	25.000
Erzurum	10.000
Şanlıurfa	20.000

Table 3 (table continuation). Potential Areas for Geothermal District Heating Project in Türkiye

Kırsehir	20.000
Dikili and Bergama	25.000
Manisa (Alaşehir)	15.000
Izmir (Aliağa)	15.000
Sivas	20.000
Bingöl	20.000
Van	25.000
Konya	25.000
Manisa (Ahmetli)	25.000
İzmir (Torbalı)	25.000
Ağrı (Diyadin)	15.000
Hatay	25.000
Nevşehir	25.000
Karaman	25.000
Tire	25.000
Bayındır	25.000
İstanbul (Silivri)	25.000
Various Other Settlements	25.000

As shown in Table 3, there are 1,307.000 residences in Türkiye where a geothermal-sourced district heating system can be applied. If we look at the identified potential areas in general, it is seen that there are various points in Türkiye. Currently, geothermal heating systems are used in these identified dwellings.

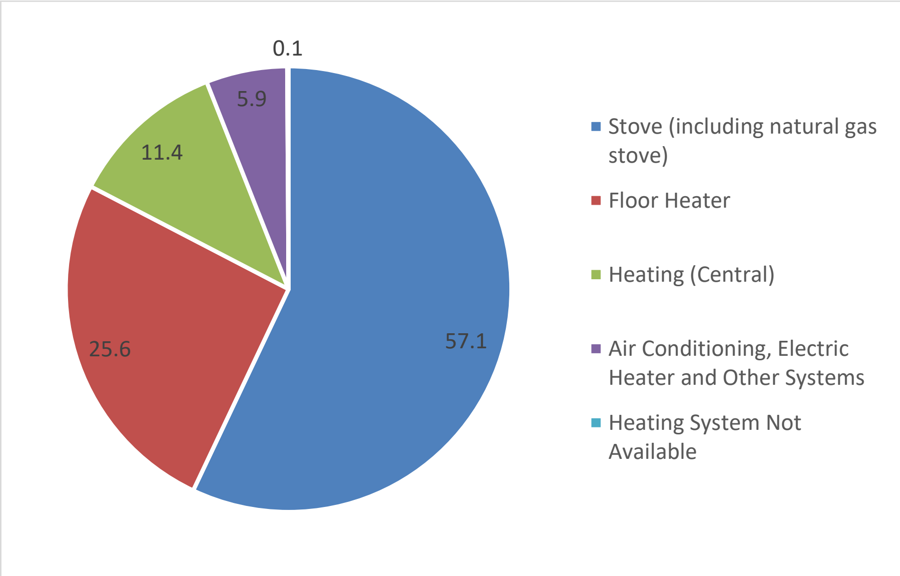

Figure 6. Household heating system of households [17]

Heating systems in households published by TUIK in 2011 are given in Figure 6. According to the Türkiye Statistical Institute (TUIK) housing heating data, if we rate 1,307.000 houses, 746,297 houses meet their heating needs by using coal stoves, 483,590 houses by using natural gas, and 77.113 houses by using various electrical devices [21].

Table 4. Heating cost table of target houses according to energy sources

	Heating with Local Lignite Coal	Heating with Natural Gas	Heating with Electricity
Number of Houses	764.297 houses	483.590 houses	77.113 houses
Housing Heating Cost	5296 ₺	2351 ₺	14.572 ₺
Total Seasonal Heating Cost	4.047.716.912 ₺	1.136.920.090 ₺	1.123.690.636 ₺

According to the cost study on 2023 geothermal energy targets and investment needs in the Eleventh Development Plan Mining Policies Specialization Report, An investment of 3 billion dollars is foreseen for the district heating project, which is equivalent to 1,000,000 houses [22].

When the necessary calculations are made regarding the annual fuel costs of a 100 m^2 house, taking into account the TUIK data for 1,307.000 residential areas where geothermal-sourced district heating systems can be applied; It is estimated that 764.297 houses that are heated with stoves are 1,294,719,118 ₺, 483,590 houses that are heated with natural gas are 1,136,920,090 ₺, and 77,113 houses that are heated with electricity are 1,123,690,636 ₺ and a total of 6,308,327,638 ₺ annual heating costs are estimated. Türkiye imports most of these energy resources from abroad. It causes foreign dependency and a current account deficit for Türkiye. Suppose it is accepted that 1,307.000 houses are in the potential areas where the geothermal district heating project can be applied. In that case, a total heating cost of 2.214.058,000 ₺ is foreseen in the residential heating season. If we compare the sum of the costs in Table 4, which is 6.308.327.638 ₺, with the geothermal heating cost of 2.214.058,000 ₺, the geothermal district heating system will provide an economic advantage of 4.094,269,638 ₺ for each year.

2.2. Analysis of geothermal energy in terms of carbon recovery

No waste is thrown into the environment and atmosphere in applications made with geothermal energy. Therefore, geothermal energy is environmentally friendly. According to research by the US Office of Energy, geothermal resource use has emission values (kg-CO_2) close to biomass, wind, solar and hydroelectric resources [23].

Table 5. Carbon emission values by energy sources [23]

Type of Energy Source	Average greenhouse gas emissions (Ton CO_2/GWh)	Emissions per residence (kg CO_2/year)
Lignite	1054	11067
Imported coal	888	9324
Coal	888	9324
Fuel oil	733	7698
Natural gas	499	5241
Nuclear	66	693
Geothermal	38	399
Biomass	26	273
Hydroelectric	26	273
Sun	23	243
Wind	10	105

When calculations are based on the annual heating need of 10,500 kWh, the emission values per house are given in Table 5. According to this ranking, when wind energy is evaluated in terms of greenhouse gas emissions, it is observed that the lowest CO_2 emission is observed. When coal types are considered in terms of greenhouse gas, it is observed that it has the highest CO_2 emission. Coal and natural gas are Türkiye's two main sources of electricity generation [21]. This shows that heating with electricity will cause high CO_2 emissions.

Table 6. Total carbon emission values of target residences by energy sources

	Heating with Local Lignite Coal	Heating with Natural Gas	Geothermal District Heating System
Number of Houses	764.297 house	483.590 house	1.307.000 house
Emissions per dwelling (kg CO_2/year)	11067 kg CO_2/year	5241 kg CO_2/year	399 kg CO_2/year
Total emission (kg CO_2/year)	8.458.474.899 kg CO_2/year	2.534.495.190 kg CO_2/year	521.493.000 kg CO_2/year

According to the 2019 "Greenhouse Gas Emission Statistics" published by TURKSTAT, total greenhouse gas emissions were 506.1 Mt CO_2 equivalent in 2019. The total greenhouse gas emission per capita was calculated as 6.1 tons of CO_2 equivalent in 2019 [24]. The carbon emission values resulting from the heating systems in the target residences are given in Table 6. According to these data, an average of 8.458.474.899 kg CO_2/year is emitted from coal used in houses with stoves, and an average of 2.534.495.190 kg of CO_2/year is emitted as a result of the combustion of natural gas used in houses with natural gas. Considering all target residences have geothermal-sourced district heating systems, an average of 521,493,000 kg of CO_2/year is predicted. According to the calculated values, due to the use of geothermal and district heating systems in potential target residences, 10,471,480,089 CO_2 will be released to nature less. In light of the data obtained, the contribution of the geothermal-sourced district heating system to nature in terms of carbon emissions is seen.

3. CONCLUSION

According to the study's results, when the geothermal district heating system is used for 1,307.000 target houses in Türkiye, an annual economic contribution of 4,094,269,638 ₺ will be provided. In line with the data obtained, this value corresponds to an annual financial contribution of 3,132,570,495 ₺ for 1,000,000 residences. With the current investment amounts, the payback period of the geothermal source district heating system implementation for 1,000,000 housing.

equivalents is approximately 13 years. Since Türkiye imports other fuel types over exchange rates, the change in the exchange rate will not affect the back period.

According to the data obtained in carbon recovery, When a geothermal sourced district heating system is used, 10,471,480,089 CO_2 (10,471 Mt CO_2) will be released to nature less. This value equals 8,011 Mt CO_2 when the greenhouse gas emission statistics are compared with 1,000,000 residences.

As a result of the use of a geothermal-sourced district heating system, there will be a 1.58% reduction in greenhouse gas emissions annually in Türkiye. Environmental policies to be developed in Türkiye should be planned on the axis of existing potentials. In this way, Türkiye will quickly become one of the countries that produce environmentally sustainable targets and contribute to the world ecosystem, leaving the list of countries with rapidly increasing CO_2 emissions.

DECLARATION OF ETHICAL STANDARDS

The authors of this article declare that the materials and methods used in this study do not require ethical committee permission and legal-special permission.

AUTHORS' CONTRIBUTIONS

Vehbi MEŞİN: Regarding the problem addressed in the article collection of data, appropriate solution to the data determination of methods and solution methods the writing process of the article with the application of has done.

Abdulhakim KARAKAYA: He contributed to the application of the methods used in the study and the interpretation of the results.

CONFLICT OF INTEREST

There is no conflict of interest in this study.

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