Proceedings World Geothermal Congress 2020+1
Reykjavik, Iceland, April - October 2021

Fuel Consumption and Environmental Effect of Heating System Selection

Gizem Elbiz*, Tahsin Başaran*, Saeid Jalilinasrabady**

*İzmir Institute of Technology Department of Architecture Urla/İzmir/TURKEY

**Kyushu University Earth Resource Engineering Fukuoka/JAPAN

gizemelbiz@iyte.edu.tr

tahsinbasaran@iyte.edu.tr

jalili@mine.kyushu-u.ac.jp

Keywords: Energy, Geothermal District Heating, Fuel Consumption, CO_2 Emission

ABSTRACT

In this study, the amount of energy that is required, annual resource consumption and environmental impact were compared using four different energy sources as coal, fuel oil, gas and geothermal energy, for reference specified building, according to the city in three different heating zones in Turkey. Thermodynamic relations were used to specify the heat changes for any system. Design of the building and local climate were effective for the calculation of heating energy demand. The different energy requirements depending on the local conditions require the use of appropriate methods in building design. Therefore, Degree Day, Annual fuel consumption and CO_2 emission approaches were used in order to make the mentioned comparisons.

1. INTRODUCTION

Energy is one of the fundamental needs that determines the quality of life of society. In our daily lives, we need efficient and uninterrupted energy sources. Urban development and industrialization lead to increased demand for energy, with rapid population growth in developing countries. In parallel with rising energy demand, countries are taking significant steps to diversify their energy sources and use alternative renewable energy sources. By the 2000s, the orientation to renewable energy sources, both economic and environmentalist, had gained momentum in many developed countries rather than fossil resources. With the use of renewable energy, environmentally damaging carbon emissions will be reduced, and local resources will play an active role in reducing the country's dependence on exports by not requiring imports.

When the sectoral distribution of energy consumed in Turkey is analyzed, its share in housing is 24% and most of this energy is used to cover heating loads (Türkiye 2017). Until about 30 years ago, fuel oil and diesel were used in central heating systems of the building, while natural gas usage is widespread today. Although Turkey is a country rich in renewable resources such as wind, solar and geothermal, it is unable to use its potential efficiently.

This paper mainly addresses the comparison of selected energy sources that are coal, fuel oil, natural gas and geothermal energy resources through the required energy, environmental effects for a residential building according to the heating zones in Turkey. on the other hand, it is aimed to comprehensively compare CO_2 emissions for both consumers and countries and to make the most appropriate choice.

2. METHODOLOGY

Changing energy needs depending on ambient conditions requires the use of a practical calculation method in building design. Heat transfer through any process in any system can be determined by using thermodynamic relations. The requirement for heating energy is calculated to base on accepted ambient conditions and building design parameters.

2.1 Degree Day Method

Heating degree days (HDD) explains the intensity of the cold taking into calculation for the temperature of the external environment and room at a specific time. Many factors such as structural characteristics of the building, climate conditions and general preferences of building users affect the determination of degree day.

The degree-day values are one of the most straightforward measurement units used to estimate the annual energy needs of a building in any location or place. Annual heat requirement of a building can be calculated by using the average overall heat transfer coefficient values of the exterior elements of the building.

The heat loss from all surfaces of the reference building considers, the annual energy is obtained from the equation given below.

$$Q_{year} = 24\, k\, \text{HDD}\, U\, A \qquad (1)$$

where Q_{year}, k, U and A are annual heat loss (W), surface multiplication coefficient (-), overall heat transfer coefficient (W/m^2K) and the heat transfer surface area of calculation (m^2), respectively.

The reference unit that was designed for use in the calculations during the study was provided to comply with building and climate standards. This building is residential unit with discrete layout, where the height of each floor is 3 m.

2.1.1 Location of the building

The location of the reference building was accepted in three different cities in Turkey. The provinces represented three different climate zones, are İzmir/Dikili, Denizli/Sarayköy, and Ankara/Kızılcahamam as shown in Figure 1. The common trait of all provinces is that each city represents different climate heating zone according to different temperature groups in Turkey. The other reason to select these cites is that they have geothermal resources, and they are actively using geothermal district heating.

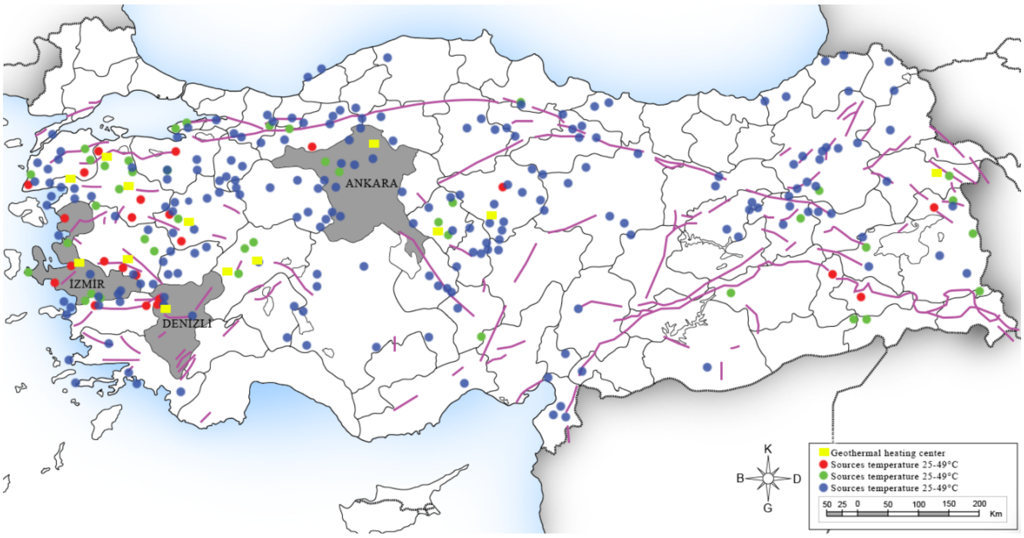

Figure 1 Distribution map of geothermal source

The main parameter for the thermal performance of the regional heating system is the climate data, and the climate effect is mainly due to the external air temperature. It is based on below 15°C when heating is required to achieve 20°C internal temperature (Jalilinasrabadi 2004). If the outdoor temperature is above 22°C, heating is not necessary (DMİ, n.d.). Considering heating degree days methods , the average daily temperature data for 2018 for İzmir, Denizli, and Ankara were used in the calculations. The HDD value was calculated at 916°C.day according to data for İzmir/Dikili for 2018. These values can be given respectively for Denizli/Sarayköy and Ankara/Kızılcahamam as 1184°C.day, 1951°C.day.

2.1.2 Building Components

In Turkey, components of the building should be designed according to TS825 (Turkish Building Heating Rules Standards) (Turk Standartlari Enstitusu 2009). TS825 shows the recommended U value according to the thermal insulation regions of Turkey (Table 1). İzmir, Denizli and Ankara are in the district 1, 2 and 3 respectively as shown in Table 1. During the design phase of new buildings, the energy requirement is calculated by selecting the material, the size of the elements and the specific solution.

Table 2 Recommended overall heat transfer coefficient for building components

	U_{wall}	$U_{basement}$	U_{roof}	U_{window}
District 1	0.70	0.70	0.45	2.40
District 2	0.60	0.60	0.40	2.40
District 3	0.50	0.45	0.30	2.40

2.2 Annual Fuel Consumption

The annual heating energy requirement requires an energy to ensure that the building remains at a constant indoor temperature of 20°C during the heating season. A controlled heating system saves significant energy when buildings are used at low capacity or are not used at all due to different factors such as weather conditions and usage conditions. Therefore, the annual fuel consumption of the building is basically calculated for coal, fuel oil and natural gas by taking into account the annual heating energy need (Prof.Dr. Osman F. GENCELİ 2018).

$$B_y = Q_{year} / H_u \eta_b \quad (2)$$

where H_u and η_b are lower heating value of the fuel (kJ/kg) used, and the efficiency of the heating system, respectively. The main energy in geothermal energy is met from hot water. The temperature of water from each geothermal source varies. For these reasons, geothermal energy account for the amount of fuel required coal, fuel oil and natural gas cannot be calculated with the methods used. The energy source needed is equal to the value of heat loss, as the efficiency for heating systems is considered to be 1.

$$B_y = Q_{year} / \eta_b \quad \text{and } \eta_b = 1 \quad (3)$$

2.3 CO_2 Emission

Carbon emission, in the simplest sense, means the release of the carbon into the atmosphere. Global warming and the climate change, which have accelerated in recent years in the rise in CO_2 emissions, have been highly effective. 85% of the waste gases resulting from the burning of the fuels used in the combustion system are CO_2. Therefore, CO_2 emissions are taken into account as a general approach in calculations. According to the regulation on energy performance, environmental developments are targeted by limiting annual CO_2 emissions. Depending on the energy source used, conversion coefficients (FSEG) are given to determine the amount of CO_2 released as a result of the final energy consumption.

The amount of CO_2 emissions per year (SEGM) according to the type of fuel used depending on the net energy consumption of the building is calculated from the equation below according to the annual heating energy requirement (Yazıcı Hilmi, Akçay Mehmet 2012).

$$SEGM_y = 0.278\text{x}10^{-3}\, B_y\, H_u\, FSEG \quad (4)$$

where $SEGM_y$, B_y, H_u, and $FSEG$ are the annual amount of CO_2 emission, the required amount of fuel, lower heating value and CO_2 emission conversion coefficient by fuel type, respectively. For geothermal energy emission calculation is like equation 4.

$$SEGM_y = Q_{year}\, FSEG \quad (5)$$

Emission conversion coefficients (FSEG) depend on the type of fuel to meet energy needs. The conversion coefficients specified in Table 2 were used for calculating CO_2 emissions (Yazıcı Hilmi, Akçay Mehmet 2012).

Table 2 CO_2 emission conversion coefficient by fuel type

Fuel Type	**FSEG** (kg eqv. CO_2 /kWh)	**Fuel Type**	**FSEG** (kg eqv. CO_2 /kWh)
Coal	0.433	Natural gas	0.234
Fuel oil	0.33	Geothermal	0.20

3. RESULTS & DISCUSSIONS

Some information on the theoretical and actual capacities of the systems, the amount and temperature of geothermal resource production for İzmir/Dikili, Denizli/Sarayköy and Ankara/Kızılcahamam which are located in three heat zones with geothermal heat center are given in Table 3 ("İzmir Jeotermal Enerji San. Tic. A.Ş.," n.d.). An equivalent residence represents a standard residential structure of $100m^2$. In this study, the total amount of fuel used by the houses in the selected regions and the amount of CO_2 emissions reflected to the environment by the energy generated from these fuels were considered to be the same number of houses for all fuel types.

Table 3 Geothermal district heating systems ("İzmir Jeotermal Enerji San. Tic. A.Ş.," n.d.)

		Amount of Production m³/h	**Temperature °C**	**Theoretical Capacity**	**Actual Capacity**
				Equivalent Residence	**Equivalent Residence**
District 1	**İzmir - Dikili**	200	80	2500	1500
District 2	**Denizli - Sarayköy**	260	145	5000	2200
District 3	**Ankara - Kızılcahamam**	270	75	3000	2400

3.1 Heat Loss Calculation

The actual dimensions and thermophysical properties of the building materials selected for use in analysis based on TS825 Thermal Insulation Rules and one-year average exterior temperature data were used in the simple residence unit. The building was considered a single volume (Gizem 2019), and the heat loads of the same formed units in different heating zones were calculated with the help of degree day methods. The distribution of the annual heat loads of the building for cities is shown in Figure 2. According to the compared heat zones, the province with the lowest HDD value is in İzmir that is located in District 1. In other words, the energy that should be given to the building was the lowest for İzmir. In this case, it was observed that the heating was the correct ratio between the day temperature and the annual heat loss of the building.

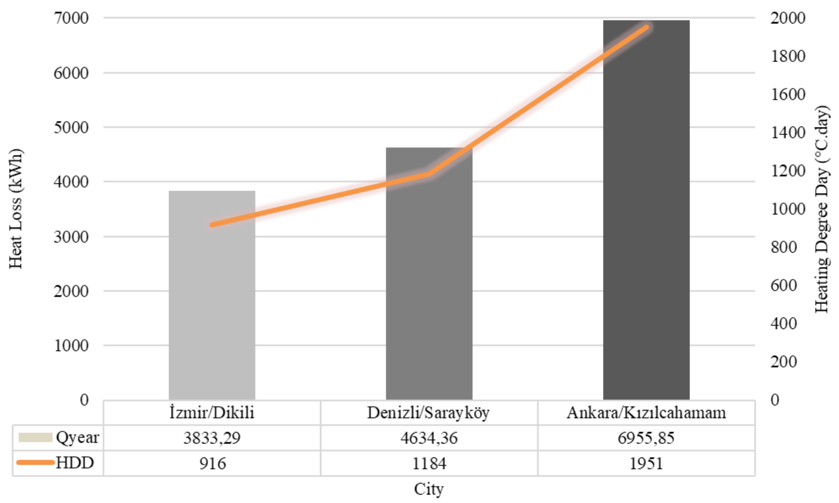

Figure 2 Heat losses for a simple residential unit and HDD values according to cities

3.2 Fuel Consumption Analysis for a Simple Residence Unit and Cities

The annual heating energy is the energy requirement during the heating season when the building is in continuous regime (20°C indoor ambient temperature). When buildings are used at low capacity and are not used at all, a significant energy saving is also achieved by the controlled operation of the heating system. Annual fuel consumption of reference residence for İzmir, Denizli and Ankara are given in Table 4. This table has been evaluated both for a single referential circle and for all of the circles using geothermal energy in the region. It has been observed how fuel consumption rates and CO_2 emission values change when these apartments use coal, fuel oil and natural gas instead of geothermal energy. The amount of fuel needed annually is linked to the lower thermal value of the fuel.

According to Table 4, the annual fuel consumption was calculated as the highest from fossil fuels per kg, 1725 tons in the case of coal use, and 800 tons in the case of natural gas use, the lowest fuel consumption. The most consumed fuel for the annual heating of the building was coal. The reason coal is the most consumed fuel is because the lower thermal value of coal is lower than the other three types of fuel.

3.3 CO_2 Emission Calculation

According to the types of fuel used for heating in houses, annual CO_2 emissions amount (SEGM) are calculated as shown in Table 4 by taking the CO_2 emission coefficients (FSEG). It has again been observed that fossil fuels have far more environmental impacts than renewable resources such as geothermal energy.

CO_2 emission from values energy sources was compared in this study. The emission increases mostly due to uncontrolled population growth, industrialisation, urbanisation demand, green areas and climate change on a global scale. In this sense, it has been shown once again that the most sensitive energy source to the environment is one of the renewable energy sources. CO_2 emission from geothermal energy is 3.5 times less than coal and 1.9 times less than fuel oil and the emission value is nearly equal to natural gas.

Table 4 Amount of energy sources and CO_2 emission of a simple residential area and provinces

			İZMİR		DENİZLİ		ANKARA	
			per unit	city	per unit	city	per unit	city
Coal	Q_{year}	MWh	3.83	5749.94	4.63	10195.60	6.96	16694.05
	H_u	kJ/kg	20000		20000		20000	
	η_k	\	0.60		0.60		0.60	
	B_y	ton	1.15	1724.98	1.39	3058.68	2.09	5008.21
	FSEG	kg eqv.CO_2 /kWh	0.433		0.433		0.433	
	SEGM	ton eqv.CO_2	2.77	4152.86	3.35	7363.71	5.02	12057.18
Fuel Oil	Q_{year}	MWh	3.83	5749.94	4.63	10195.60	6.96	16694.05
	H_u	kJ/kg	41600		41600		41600	
	η_k	\	0.80		0.80		0.80	
	B_y	ton	0.41	621.99	0.50	1102.89	0.75	1805.85
	FSEG	kg eqv.CO_2 /kWh	0.30		0.30		0.30	
	SEGM	ton eqv.CO_2	1.44	2157.95	1.74	3826.41	2,61	6265.28
Natural Gas	Q_{year}	MWh	3.83	5749.94	4.63	10195.60	6,96	16694.05
	H_u	kJ/m^3	34485		34485		34485	
	η_k	\	0.75		0.75		0.75	
	B_y	ton	0.53	800.34	0.65	1419.13	0.97	2323.66
	FSEG	kg eqv.CO_2 /kWh	0.234		0.234		0.234	
	SEGM	ton eqv.CO_2	1.20	1795.42	1.45	3183.57	2.17	5212.71
Geothe.	Q_{year}	MWh	3.83	5749.94	4.63	10195.60	6.96	16694.05
	FSEG	kg eqv.CO_2 /kWh	0.20		0.20		0.20	
	SEGM	ton eqv.CO_2	0.77	1149.99	0.93	2039.12	1.39	3338.81

As a result of the use of fossil fuels, the increase in CO_2 gas is causing more and more serious damage to nature every day. The increase in the density of CO_2 gas in the atmosphere also triggers global warming. The widest application ever made in the fight against climate change and global warming is the Kyoto Protocol, which came into force in 2005. Experts say the most severe climate impacts could be avoided if the average global temperature rise remains below 2°C between 1990 and 2100 (World Bank, n.d.). To achieve this goal by 2100, net emission amounts need to be reset.

If the total capacity of the Dikili, Sarayönü and Kızılcahamam geothermal heat centers given in Table 4 is to be used, the damage to the environment of the houses using fossil resources for heating purposes will be greatly reduced. In the light of the calculations stated in Table 4, if coal-heated houses are converted to geothermal systems, a 38% reduction in CO_2 emissions may be recorded for İzmir. For Denizli and Ankara, this ratio is 57% and 14% respectively. Compared to fuel oil, 20%, 30% and 8% decrease was achieved, while for natural gas, which is considered relatively more environmentally friendly, these percentages show 15, 22 and 5.

4. CONCLUSION

The most important point that we should pay attention to in energy consumption in our world is the effect of the energy source used on the environment. Because of the increasing intensity of the gases released into the atmosphere as a result of combustion, it is also known as greenhouse gas effect and it will shorten the life of the world so that we are worried that the warming of the world, the extinction of the water resources, and most importantly, the end of the energy resources that we are looking for.

This study compares environmental aspects of different heating systems and the energy sources for residential buildings. A sample residential building was assumed to be considered as a design sample to estimate parameters and design conditions as close as possible to real values (Gizem 2019). The effect of climate condition was investigated to understand their influence and relation with corresponding locations.

From the results, the following conclusions have been drawn:

- The most sensitive energy source to the environment is the geothermal energy as one of the renewable energy sources. CO_2 emission from geothermal energy is 3.5 times less than coal and 1.9 times less than fuel oil and 0.5 times less than natural gas.

- If the regions with geothermal resources are able to use all their capacity, they will offer an average of 60% more environmentally friendly solution compared to coal.

The study shows that geothermal energy is one of the best energy source in terms of fuel consumption and environmentally friendly, and it is a suitable solution for selected settlements in three different climatic regions of Turkey where having district heating systems. Turkey is the 20th most greenhouse gas emissions' country. Despite the large CO_2 emissions in the industrial sector in particular, the presence of small-scale structures such as housing should not be underestimated. Taking a participatory approach to the efficient use of energy at every stage from production to consumption of energy sources and taking steps in line with the global vision is seen as necessary.

REFERENCES

Bank, The World. n.d. "Worldbank Carbonpricingdashboard."

DMİ. n.d. "Isıtma ve Soğutma Gün Dereceleri - Meteoroloji Genel Müdürlüğü." http://www.mgm.gov.tr/veridegerlendirme/gun-derece.aspx#sfU.

Gizem, Elbiz. 2019. "EFFECTIVENESS IN SPACE AND ENERGY UTILIZATION IN HVAC SYSTEM SELECTIONS." İzmir Institute of Technology.

"İzmir Jeotermal Enerji San. Tic. A.Ş." n.d.

Jalilinasrabadi, Saeid. 2004. "Geothermal District Heating and Swimming Pool in the Sabalan Area , Iran," no. 7: 99–130.

Prof.Dr. Osman F. GENCELİ, Prof.Dr. Cem PARMAKSIZOĞLU. 2018. *Kalorifer Tesisatı*.

Turk Standartlari Enstitusu. 2009. "TS825 Binalarda Isi Yalitim Kurallari" 825: 80.

Türkiye, Petrolleri. 2017. "Sektör Raporu."

Yazıcı Hilmi, Akçay Mehmet, Özer Salih. 2012. "Denizli'de Bir Binanın Farklı Yakıt Türlerine Göre Yakıt Maliyeti CO2 Emisyon Mikyarının Belirlenmesi." *SDU International Technology Science* 4 (2): 59–69.