EFFECTIVENESS IN SPACE AND ENERGY UTILIZATION IN HVAC SYSTEM SELECTION

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ABSTRACT

EFFECTIVENESS IN SPACE AND ENERGY UTILIZATION IN HVAC SYSTEM SELECTION

In Turkey, energy consumption for heating constitutes an important part of the total energy consumed. The choice of heating system and the preferences in the use of related energy sources, excessive energy consumption and environmental impact cause high costs and significant area losses. A large number of parameters must be evaluated for the correct system selection. These parameters determine the installation cost of the system, heating and cooling loads during the construction period, and the environmental impact of energy consumption.

This study aims to obtain the most economical and environmental friendly energy resource in a housing structure and accordingly, heating system and the system spatial value. The use of fossil fuels such as coal, fuel oil and natural gas and the geothermal energy as a renewable energy source are planned to be investigated. The analysis was carried out on how the climate conditions and economic values of the provinces of İzmir, Balıkesir, Kütahya and Ağrı, which are located in different climatic regions will be effected and where direct use of geothermal energy is concerned, will affect the results of the different system usage.

Life Cycle Cost assessment was performed to investigate the relationship between the initial investment in a housing structure and the use of energy source and system selection. Geothermal energy is the best source of energy both for installation and renewal and for fuel consumption and environmental purposes. Geothermal heat exchangers selected for the source take up 36 times less space than coal boilers, and the economic reflection of this area is approximate 8000 if given the example of İzmir province. While considering the environmental impacts, CO_2 emissions of geothermal energy are 15 times less than natural gas and 50 times less than coal.

ÖZET

ISITMA SOĞUTMA VE HAVALANDIRMA SİSTEM SEÇİMİNDE ENERJİ VE MEKAN KULLANIM ETKİNLİĞİ

Ülkemizde ısıtma amaçlı enerji tüketimi, tüketilen toplam enerjinin önemli bir kısmını oluşturmaktadır. Isıtma sistem seçimi ve ilgili enerji kaynaklar kullanımındaki tercihler, enerji tüketiminin ve çevresel etkilerinin fazla olması, yüksek maliyetlere ve büyük alan kayıplarına neden olmaktadır. Doğru sistem seçimi için, çok sayıda parametrenin değerlendirilmesi gerekir. Bu parametreler sistemin kurulum maliyetini, yapı ömrü boyunca ısıtma ve soğutma yüklerini ve enerji tüketimi ile çevresel etkilerini belirlemektedir.

Bu çalışma, bir konut yapısında en ekonomik ve çevreci enerji kaynağını ve buna bağlı olarak ısıtma sistemini ve sistem mekânsal karşılığını elde etmeyi amaçlamıştır. Konutların ısıtılmasında fosil yakıtlardan olan kömür, fuel oil ve doğalgaz ile jeotermal yenilenebilir enerji kaynağının kullanımının araştırılması planlanmıştır. Farklı iklim bölgelerinde yer alan ve jeotermal enerjinin direkt kullanımının söz konusu olduğu İzmir, Balıkesir, Kütahya ve Ağrı illerinin iklim koşulları ile ekonomik değerlerinin, farklı sistem kullanımından kaynaklanan sonuçları ne kadar etkileyeceği üzerine analizler yapılmıştır.

Bir konut yapısına yapılan ilk yatırım ile enerji kaynağının ve sistem seçim kullanımı arasındaki ilişkiyi Yaşam Döngüsü Maliyet analizi göstermiştir. Jeotermal enerjinin hem kurulum ve yenileme hem yakıt tüketim maliyeti hem de çevresel açıdan en iyi enerji kaynağı olduğu görülmüştür. Jeotermal kaynak için seçilen ısı eşanjörleri kömür kazanlarına göre 36 kat daha az yer kaplamakta, bu alanın ekonomik yansıması İzmir ili için örneğin yaklaşık 8000$ olmaktadır. Jeotermal enerjisinin çevresel etkileri düşünüldüğünde ise CO_2 emisyonu kömüre göre 50 kat, doğalgaza göre 15 kat daha azdır.

to my little brother,

my mom and dad…

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LIST OF SYMBOLS

A	:	Area	[m^2]
a	:	Air Leak Coefficient	[m^3/mh]
B_y	:	Annual Fuel Amount	[kg]
CDD	:	Cooling Degree Day	[°C.day]
C_{source}	:	Fuel Unit Price	[TL/m^3]
$FSEG$	:	CO_2 Emission Conversion Coefficient	[CO_2 /kWh]
h	:	Convection Heat Transfer Coefficient	[W/m^2K]
H	:	State of the Building Coefficient	[$Wh/m^3\ ^oC$]
H_u	:	Lover Heat Value of the Fuel	[kJ/kg]
HDD	:	Heating Degree Day	[°C.day]
k	:	Thermal Conductivity of Material	[W/mK]
L	:	Length or thickness of the material	[m]
M_y	:	Annual Fuel Cost	[TL]
$\dot{q}$	:	Heat Flux	[W/m^2]
$\dot{Q}_{year}$	:	Heat Transfer Rate	[W]
Q_h	:	Incremental Heat Requirement Coefficient	[W]
Q_i	:	Infiltration Heat Load	[W]
R	:	Thermal Resistance Coefficient	[m^2K/W]
R_i	:	Inside Thermal Resistance	[m^2K/W]
R_o	:	Outside Thermal Resistance	[m^2K/W]
$SEGM$		Annual CO_2 Emission Amount	[CO_2 /kWh]
T	:	Temperature	[^oC]
T_i	:	Indoor Temperature	[^oC]
T_o	:	Outdoor Temperature	[^oC]
U	:	Overall Heat Transfer Coefficient	[W/m^2K]
V	:	Volume	[m^3]
Z_D	:	Combined Increase Coefficient	
Z_H	:	Direction Increase Coefficient	
Z_W	:	High-fold Increase Coefficient	
η	:	Efficiency	

CHAPTER 1

INTRODUCTION

Urban development and industrialisation lead to an increase in energy demand with rapid population growth in developing countries. The World population is expected to increase by 1.6 billion in 2040 to reach the level of 9 billion [1]. As a result, more and more people are going to demand more energy. Energy is one of the basic needs that determine the quality of life of the community. In our daily lives, we need efficient and uninterrupted energy sources. In response to the increasing demand, the existing energy sources are depleted and insufficient. The energy density, which shows the added value generated due to energy and the energy used, is one of the most important indicators that reflect the economic and social development potential of a country. The economic, cultural and scientific levels of the country are also related to how effective communities are using energy. Energy, which has an indisputable significant impact on our lives, can be found in different ways, such as chemical, nuclear, mechanical, thermal, geothermal, hydraulic, solar, wind, and it can be transformed into one another, and these energy transformations determine how effective energy is used in the environment along with its effects on the environment.

Renewable energy can be obtained from natural sources, which can survive long term depletion and renew itself over time. With the use of renewable energy, the emission of carbon damaging to the environment will be reduced, and it will play an active role in reducing the country's dependence on exports by not requiring imports as they are local resources. Renewable energy sources used in the world are hydraulic, geothermal, biomass, solar and wind energy. These sources of energy are considered to be the primary sources of energy for the future because of its superiority over fossil fuels in the world.

In parallel with the increasing demand for energy, countries are taking important steps in diversifying energy resources and using alternative renewable energy sources. In the 2000s, the search for renewable energy gained momentum, and many developed countries have created future predictions to meet all of their energy needs from renewable sources. Because fossil energy sources are such as coal, oil, natural gas, which can be depleted in a short period, these resources constitute a large part of the world's energy consumption. Today, 28.1% of the world's energy needs from fossil sources are covered by coal, 24.1% by natural gas, 33.3% by oil. These fossil fuels are estimated to be extinguished after 114 years, 53 years and 51 years respectively [2].

Urbanisation and rapid population growth in today's conditions, along with the number of individuals living in Residences is increasing. Most of the energy is used for heating buildings. Different systems and fuels are used to meet the heating loads of buildings. In Turkey, coal, fuel oil and diesel were used as fuel in central heating until about thirty years ago. Today, natural gas is preferred to use in many provinces by laying natural gas lines. In addition to all this, the considerable increase in oil prices in the 1970s has made a massive impact on the world and has changed people's concerns about energy. This change has led to significant results for energy and environmental policies [3]. Environmental impacts associated with energy use play an important role, taking into account that the orientation to sustainable resources has increased. In this context, renewable resources such as wind, solar, geothermal have become part of potential solutions and continue to increase its effectiveness in our country.

The fuel that will be used in building heating is required to be cheap and the least emission-emitting fuel to the environment. In houses, fuel preference can be made according to the heating system; in terms of fuel type, it is possible to choose to heat. The fuel and building typology used in the selection of a heating system will be taken into account, but fuel cost, emission values, first investment and heating costs should be analysed, and economic analysis should be done. Besides, the preferred system should be taken into consideration in consideration of the user's usage options and results considering the volumetric equivalent of the place where the housing will occupy.

1.1 Problem Statement

There have been many researches on central heating systems for buildings to select the most appropriate system by considering the energy consumption of the buildings and to estimate the fuel cost by assuming several types of fuel. They have tried to find eco-friendly solutions for decreasing of CO_2 emissions. Energy evaluation of buildings, renovation of architectural elements and central system, first capital investment, business and life-cycle costs were discussed.

To the best of the authors' knowledge, this world is one of the first study considering spatial losses due to the HVAC system in the building and their economic provisions. In previous studies, energy consumption and the cost analysis were evaluated according to the conditioned area and the heating load of the building, and the selection of the heating system were not discussed. This has been as a shortcoming and constitutes the main problem to be addressed during this study.

1.2 The Objective of the Study

The main objectives of this thesis are as follows:

- To estimate the energy consumption of the reference building by selecting the appropriate structural elements in the related climate region.
- To calculate the system size and cost with four different fuel types, coal, oil, natural gas and geothermal energy, to provide the heating loads of the building.
- To evaluate the spatial usage of the selected systems in the building and examine them economically.
- To evaluate these results for four different climate regions in Turkey including İzmir, Balıkesir, Kütahya and Ağrı.

1.3 Limitation of the Study

There were certain limitations in undertaking this research work. As it is understood that the limitation is a part of the project they have been overshadowed by the benefits of the study.

- TS825 Thermal Insulation Requirements for Buildings and TS2164 Principles for the Prefaration of the Projects of the Central Heating Systems from Turkish standards were based on the calculation of heat requirement values.
- Data of the General Directorate of Meteorology was used for external weather temperature data.
- Pipes, pumps, water storage etc. are assumed to be approximately the same for all system. Therefore, storage and boiler system were based.

- The catalogues of some companies like Baymak and Alarko were used to select the suitable boiler and heat exchangers.
- Unit prices of the housing according to cities were selected from the report of Central Bank of Turkey.

1.4 The Methodology of the Study

Mathematical calculations are the primary research method of the study. According to obtained results, it is aimed to make a comparison technique based on the energy sources and to make a systematic evaluation based on the results of these choices. Steps of the research and contribution of a methodological framework to the research is shown in Figure 1. 1.

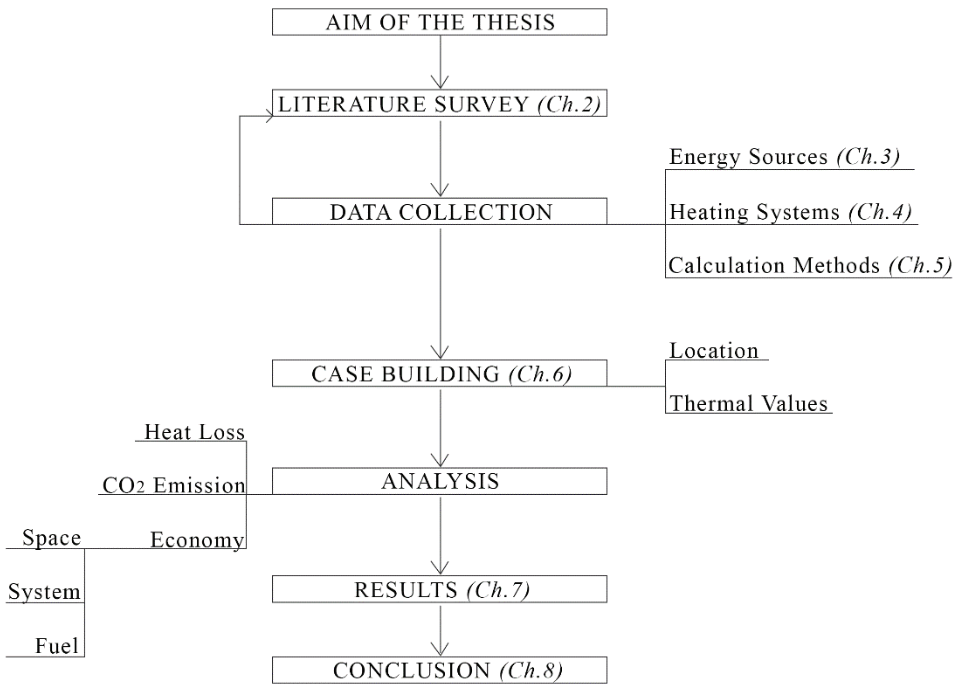

Figure 1. 1 The thesis process

In the first stage of the study, a comprehensive and critically acclaimed literature survey was conducted, and this research revealed the terminology of the intended study. In order to provide support to the literature, a detailed examination was carried out by using calculation methods and system and Resource Research. Secondly, case building has been designed, and the location of it has been selected. According to the locations, heating loads have been calculated. In TS825 buildings, material values of building components have been selected following the Thermal Insulation Rules [4]. According to these data, annual heat demand is calculated. The outside temperatures of the four cities selected within the four climate zones were accepted according to TS2164 for calculating the size of the heating systems.

According to the collected data, the current energy consumption, CO_2 emission values and economic analysis of the buildings were made taking into account the climate conditions of the provinces. It is aimed to reveal the comfort level of the building, increase the energy efficiency level, and selects the appropriate system and the amount of fuel and to measure the effects of these comprehensively.

According to the defined values, calculations were made for coal, heating fuel, natural gas and the geothermal energy. System sizes and the annual fuel consumption of each situation are determined. As a result of this study, the size of the areas that should be allocated to the systems inside the building for central heating systems that operate with coal, fuel oil, natural gas and geothermal energy, and the economic equivalents of these quantities were determined. The use of more space and the economic results of this usage were studied according to the systems obtained from the space reserved for the mechanical room.

CHAPTER 2

LITERATURE SURVEY

Many studies have focused on selecting the most appropriate system by considering the energy consumption of buildings and trying to calculate the cost of fuel compared to different types of fuels. They have tried to find eco-friendly solutions for CO_2 emissions. In this chapter, the literature survey of the study that is focused on residence building especially is presented.

When designing a low energy building, many parameters such as thermal characteristics of materials, the efficiency of selected HVAC systems, design criteria are to be taken into consideration. HVAC systems in buildings are intended to provide thermal comfort at a certain level. However, this means a great deal of energy consumption and high cost. All of these criteria determine the energy consumption and lifecycle cost throughout the lifecycle. Ruiz, Flor, Felix, Lissen and Martin [5]; have worked in Spain to estimate annual energy demand, life cycle cost and energy rating with a building design example in the scenario 2028 in 12 climate regions. They offer a SEDICAE research project based on the optimisation of construction design elements to minimise lifecycle costs and energy rating of buildings. In the second phase, the optimum climate control system was chosen to take into account system cost and CO_2 emissions. This article shows the relationship between the energy efficiency index and the investment. Besides, the best energy ratio is achieved with the application of HVAC systems in the integrated optimisation method for residential buildings. This methodology reduces investment, reduces energy demand, and selects the best construction materials to examine costs in different economic scenarios.

Rüştü Güntürk and Hasan Şahin compare the energy sources in terms of economy in heating a building in their studies [6]. In this study, fuel oil and coal were selected as an energy source for traditional heating methods and geothermal energy in renewable energy sources were selected. Economic comparison of the heating was made. A four-storey reinforced concrete structure has been chosen in Simav district of Kütahya province. It is assumed that the heating system was installed for geothermal heating in the building and insulation was made on the upper floor. The first investment and annual heating costs of these systems that are boiler fired and coal boiler heating system are compared to each other. Changes in these costs by years have been examined. The economic life of heating systems was taken as ten years in comparison. During the comparison period, two separate assumptions were made for the price increase rates of fuels. According to the first assumption, price indices calculated in TÜFE (Consumer Price Index) for the past ten years and inflation rates realised in the same period were used. The real price change in fuel has been acknowledged to be valid in the next ten years. According to the second assumption, unit fuel cost estimates for the next ten years were used by using the exponential regression equation for the current prices of the fuel costs for the past ten years.

In the calculation of initial investment costs for building heating system, all the elements used in the system and the purchase price of these elements based on US$ are taken into consideration. Annual repair, maintenance and fuel costs in geothermal energy and central heating system are almost negligible. However, the subscription fee that is paid to Simav municipality according to the size of the house heated is considered. The first participation fee, connection fee and installation cost are added to these costs. Cost of the installation consists of material costs and labour costs.

Annual fixed costs and annual variable costs are used in the calculation of annual cost [6]. Annual variable expenses consist of annual fuel costs, labour costs and repair and maintenance expenses. According to the results, both assumptions also shape and the use of heating with other energy sources, geothermal energy is more economical than the cheapest. Fuel types except for geothermal energy costs quite expensive with the increasing oil prices and transportation costs. The most economical energy source for the first investment expenditures is coal, followed by geothermal energy and heating fuel oil respectively. Geothermal energy is the most abundant source of energy in the world. After that, lignite coal and heating fuel constitute alternative energy sources. Given for ten years annual fuel costs with geothermal energy it is concluded that geothermal energy is still the most economical option.

Yazıcı, Akçay and Özer have chosen a building constructed as housing and workplace in their study [7]. Within the scope of the study, the amount of natural gas, coal, diesel and fuel oil that meet the annual heat needs of this building were determined. Fuel costs and CO_2 emissions were calculated using the fuel quantity determined according to the fuel type. Although the cost of lignite coal and natural gas is close to each other, fuel cost increases twice as much if fuel oil and diesel are used. It has been concluded that the amount of fuel needed to meet the annual heat requirement of the building is the lowest in cases where the furnace is used. When the annual fuel cost is calculated, natural gas is considered as the most economical option. When CO_2 emissions are analysed, the lowest emission values were measured in natural gas, and the highest emission values were measured in coal. The study showed that the use of natural gas to meet the building heat requirement was the cheapest compared to coal, diesel and fuel oil, and the lowest emission-emitting fuel compared to other fuels.

Jacura made his study economically heating system elements, not over fuels [8]. The use of fossil and renewable energy sources in modern and efficient heating systems on the gas boiler and heat pump comparative analysis samples in individual houses was discussed. Comparative analysis of heating systems on energy, economics and ecology are aimed of this study. LCC (Life Cycle Cost) based ecological method was performed to compare the effects of proposed heat sources on environmental problems. The LCC method estimates the cost at the total investment and operating costs of the heating system using the specified life time. According to the economic analysis, the use of a condensing gas boiler has more advantageous solution. The total cost for the gas boiler heating system is 11% lower than the heat pump. In terms of environmental assessment, both the annual emission of individual pollutants and the equivalent emission values were found to be lower. The use of a condensing gas boiler as a heat source enables the efficient use of the chemical energy in gas fuel and reduces its impact on the natural environment and provides economic applicability that balances the required investment costs and energy costs.

High energy consumption also means high emissions. Reducing the energy consumption and environmental impact of the building and its energy systems is a goal to be pursued. Xiang-Li, Zhi-Yong and Lin [9] have created a mathematical model for energy consumption and carbon emissions in order to understand the role of buildings' energy systems for the potential effect of global warming in China. Two regional heating systems for the residential building and nine central heating and cooling systems for public buildings are selected. Dalian as a cold region of China is selected for the working field. The energy and emission model for achieving the targeted result is based on the LCA assessment theory. This assessment covers four phases as overall production, construction, running maintenance and demolition disposition until the end of the service life of the building. Compared to the traditional systems, the cost of carbon reduction in the life cycle is less than China's carbon tax, economic features are about to reduce energy savings and carbon emissions.

The energy source of the energy saving potential and its economy depend on the unit price of the fuel, thermal value of the fuel, and the efficiency of the boiler where the fuel is burned. Because fuel prices are constantly changing due to various reasons, the comparison of systems using different fuels is repeated continuously. Karslı, Güllüce and Saraç [10] have studied the cost of energy used in various buildings, the advantages of high effienct new modern systems that will ensure efficient use of energy, the implementation of energy management in buildings, comparison of systems with different fuels and environmental criteria. The comparison of new technology products that have been modified according to the different fuels such as heat pump, boiler, furnace, absorption cooling systems used in the air conditioning industry was made in terms of operating costs. The initial investment costs in the determination of operating costs were taken into consideration, installation of the system and commissioning. Efficient operation of the system, depending on the type of fuel used directly affected the results.

According to the results examined in detail [10], it is observed that by the commissioning of natural gas heating/cooling units in Turkey, it provides more savings in terms of environmental, safety, health and all other energy efficiency criteria compared to the different fuels. Natural gas cooling helps to reduce energy costs of commercial and industrial users by reducing electricity consumption when cooling loads are high. The user should choose the most appropriate fuel and system according to the region where it is located and replace the existing low-efficiency models. In these modifications, the initial investment cost, operating cost, repayment period and environmental criteria should be taken into consideration, and new high-efficiency models should be preferred.

Sustainable development is one of the essential elements of the contemporary world. According to Milwicz and Palavski, the main idea is to maintain the balance between user comfort and economic direction with limited environmental impact [11]. Many regulations, such as ISO standards, can easily follow the instructions found in all courts. This trend helps to draw economic attention and to recognise the environmental problem. Researchers compare heating systems in Poland. The objective is to control the weather conditions on sustainable energy efficient solutions and to show the profits derived from the application of modern systems. Electricity, heat pump, peller, oil, natural gas and coal have chosen the source of heating energy mostly used in Poland. In the beginning, the comparison was conducted from the sustainability point of view, environment, user comfort and economy. The second phase shows the economic comparison of each option from the economic point of view in the life cycle in diverse time horizon. When the results are evaluated, traditional energy sources require a less initial investment and demand more service and are sensitive to price changes. Even if energy efficient solutions require a more considerable initial investment, they draw away traditional systems with low energy consumption, environmental and user-friendliness.

Researchers' studies have focused on the use, consumption and environmental impacts of energy resources. Studies or measures that may be taken to bring the structure to an adequate level in terms of energy have been evaluated, and economic analyses related to them have been made. In this study, different from other researchers, it is desired to show the spatial value of the selected systems and the effects of the economic values of these areas.

CHAPTER 3

ENERGY RESOURCES AND THEIR OPERATIONS

Energy sources are significant in terms of economic and social development. After the Industrial Revolution, human demand for energy sources increased, and this increase continues today. Most of the energy needed in the world is supplied from fossil sources. These fuels, which are defined as fossil energy sources or traditional energy sources, are used extensively in every field in our daily life. In particular, fossil fuels have found a common use area both because they are cheap and because of the developments in production technology for the last two centuries. After the Industrial Revolution, oil and natural gas were added to the coal-based energy supply in the following years. However, after the 1973 Oil Crisis, there was a problem of confidence in these energy sources. The world countries have turned to new energy sources. At the same time, the serious environmental pollution of fossil resources has accelerated this quest.

The reason why having energy resources are so significant is due to the fact that energy is one of the essential elements for the development, prosperity and development of countries at the same time. Energy is continuously needed to operate machinery, facilities and factories that are now integral parts of human life and to contribute to human life for economic development, prosperity and development. Renewable energy sources, which have been known and used for many years, but cannot compete with fossil fuels, have started to gain importance as a result of the risky limits of fossil fuel reserves. Global energy consumption is projected to increase by 28% by 2040 [2]. Most of this increase is due to countries outside the OECD (Organisation for Economic Co-operation and Development) and developing countries. The high economic growth rates of developing countries increase their energy consumption. Energy consumption of non-OECD countries, especially China and India, surpasses the total energy consumption of OECD countries and this difference is expected to increase further in the coming years. In particular, the EU countries, which are not rich in fossil resource reserves, and the US, which has an extensive energy consumption with industrialised Far East countries, have pioneered the development and expansion of these resources [12].

In addition, the geopolitical environment of uncertainty, approaching limits in the context of sustainability in fossil fuel use, and climate change, which is starting to signal for dramatic changes, obliges countries to re-create their energy cycles as soon as possible. While producing solutions for climate change, we need to focus not only on increasing alternative energy sources but also on developing solutions for energy efficiency that will reduce energy consumption.

In spite of the increase of renewable energy sources and the use of these sources, it is thought that coal, oil and natural gas will continue to be effective until 2040 and global energy consumption will still be provided from fossil fuels by 2040[2]. Natural gas is expected to be the fastest growing type of energy among fossil fuels. According to BP World Energy Statistics for 2017, primary energy consumption reached to 13.246 million TEP. Oil is the most widely used energy sources with 33.3% according to the utilisation rates of the primary energy sources. After oil, coal is following by 28.1% and natural gas is followed by 24.1% (Figure 3.1) [2]. After the Industrial Revolution, a particular energy source has gained significance in every period. Coal has been replaced by oil in time, and natural gas has gained importance in the following years. Renewable energy sources are expected to gain more significance in this process.

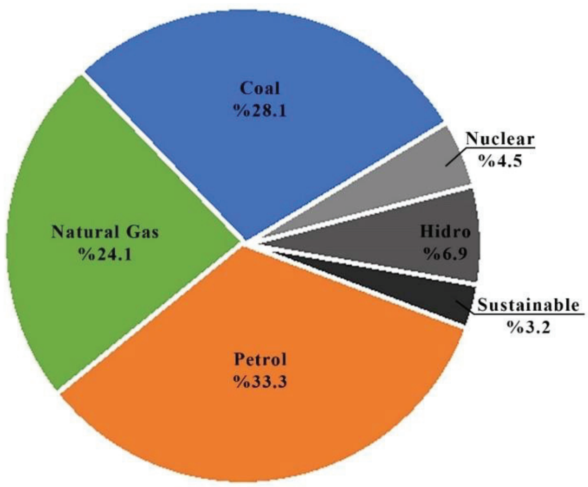

Figure 3.1 Use of primary energy in 2017 in the world [2]

Nuclear energy consumption worldwide is expected to be the second fastest growing sources of energy in the world with a 1.5-fold increase in the period of 2018-

2040. To get rid of dependence on energy is of great importance in terms of achieving economic independence for the countries that are energy importer and foreign dependent in this field. Also, the uncertainty of the geopolitical environment, approaching limits in the context of sustainability in fossil fuel use and climate change which is starting to signal dramatic changes obliges countries to recreate their energy cycles as soon as possible. While producing solutions for climate change, we need to focus not only on increasing alternative energy sources but also on developing solutions for energy efficiency that will reduce energy consumption.

3.1 Use of Energy Resources in Turkey

In Turkey, the use of energy concerning primary energy sources is parallel to the general average situation in the world. Total primary energy supply in 2016 is 129.2 million TEP. In the allocation of this supply to resources, the first place was oil with 31% of the total supply. Natural gas with 28%, coal with 28%, hydraulic resources with 5% [2]. Turkey's dependence on foreign energy is around 70%. It is inevitable to encourage the use of the domestic and renewable increase in the future. In addition, efficient use of energy is significant in terms of countries that buy energy from outside especially in Turkey. Increasing energy efficiency leads to more efficient use of resources, creating supply security in energy, saving goods and services more cost-effectively and reducing the damage caused to the environment. The restructuring and liberalisation process in the energy sector has started with the laws and regulations enacted in Turkey since 2001. Today, many regulations are being made to produce electricity from renewable energy sources and for the efficient and effective use of this energy produced. The main objective of these regulations is to support production with domestic resources by reducing dependence on external energy.

Sectoral distribution of energy consumption in Turkey is shown in

Figure 3.2 for 2016 [12]. If the distribution of energy consumption according to sectors are analysed, the highest rate is industry and transportation flow it. The share of energy consumption in housing corresponds to 24%.

In our country, energy consumption for heating purposes has very high rate such as 70% of total energy consumed. In the European Union, this rate is 57%, and 25% is used for hot water production. Besides, annual energy consumption for old buildings is

200-200-250kWh/m^2, while this value is 100-150kWh/m^2 in the new buildings. Forecasting and modelling of energy consumption and production are essential for national short- and long-term energy planning and plant investments [13].

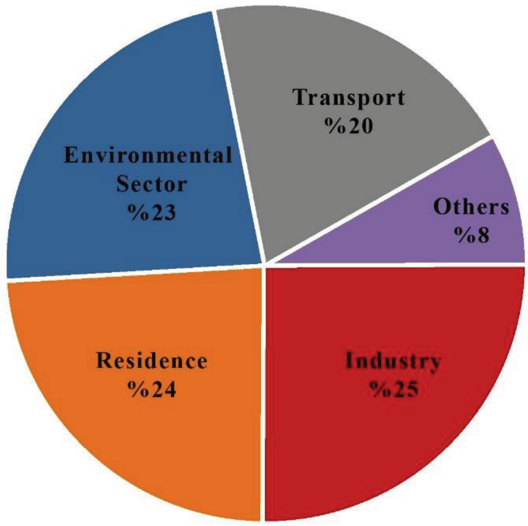

Figure 3.2 The sectoral breakdown of energy consumption in Turkey [12]

The analysis is critical to find a share of the domestic sector in total energy consumption and to determine the economic, efficient heating system for families. Otherwise, energy load estimation methods are continuously researched and developed, as it will allow the consumer to determine the most suitable by comparing the prices and energy consumption of different systems. In this study, it was aimed to compare the different fuel types selected from both primary energy sources and renewable sources with the central heating system and the volume equivalents of energy, environment, cost and systems.

3.2 Fossil Resources

Fossil sources are called all sources of energy, which have a high amount of hydrocarbon, which reaches the present day by dissolving organisms in an oxygen-free environment for millions of years. Coal, oil and natural gas are among the primary fossil sources used all over the world.

3.2.1 Coal

It is a flammable rock that contains organic and inorganic materials in its structure and consists of heterogeneous content with different physical and chemical properties, bacteria effect and geological processes. Coal, among other rock strata, has occurred among other rock strata during millions of years as a result of heat, pressure and microbiological effects [14]. Coal mainly consists of carbon, hydrogen and oxygen, a small amount of sulphur and nitrogen compounds forming the organic structure of elements; and inorganic substances like moisture and minerals. Coal contains organic matter more than 50% of the weight and more than 70% as volumetric, and it refers to sedimentary rock [15]. The amount of carbon determines the quality of the coal. The coal with high carbon is considered to be of better quality.

The steam coal formed by Anthracite and other bituminous coal is generally used in three fields.

- It is used to produce electricity and steam in power plants. Most of the steam produced is sold to tertiary persons, especially for local heating.
- It is used to produce heat or steam in industrial, residential, agricultural and transport areas.
- Coke is used in coke ovens to produce coke. In some countries, such as Germany, Poland and Turkey, a portion of electricity production is used to obtain heat or steam.

3.2.1.1 Formation of Coal

Mostly vegetables and other organic substances accumulate in the swampy, and they buried deep into the soil with the accumulation of sediments and various geological functions. The accumulated organic masses are affected by the pressure and temperature conditions of the atmosphere formed by the burial. Physical and chemical changes occur in the structure of the substance into coal. This process takes place in millions of years. Geologically, the ages of coal range from 400 million years to 15 million years. In this process, the ideal conditions and ambient temperature should be dominant and increase over time. The temperature of the earth increases when it goes more in-depth, but in regions where volcanic activity, fault movements and radioactive elements are abundant, the temperature of the earth is higher than usual. The organic matter called turf is formed. Turf is transformed to lignite, sub-bitumen, anthracite, hard coal and graffiti according to the amount of organic matter if the conditions are appropriate.

3.2.1.2 Classification of Coal

Coal is classified under two headings: scientific and commercial. Scientific classification is interested in the origin, content, structure and basic properties of coal. Commercial classification is interested in the market value, purpose of use and technological characteristic of coal [16].

Countries which are advance use and technology of coal make a classification according to the properties of coal produced by them. This classification is based on properties such as thermal value, volatile matter amount, carbon content, moisture content, and odour. Scientists and major coal importers often use two main classification systems. One of them is ASTM (American Society for Testing Materials), and the other one is International Coal Classification of the Economic Commission for Europe UN-ECE.

3.2.1.3 Coal Reserves and Consumption Values in the World

Coal is a fossil fuel that has been used as an energy source for hundreds of years. It pioneered the industrial revolution in the 19th century, and it also led to the start of the electronic age in the 20th century. Coal, which maintained its importance as the world's primary source of energy until the 1960s, was replaced by oil at the end of the 60s, but the importance of electricity production continued to maintain its position when it was understood. Although alternative energy sources are being used together with the developing world, the presence of coal in large quantities and general worldwide increases the importance of coal to meet the increasing energy demand. With its large share in international trade, it maintains its source position.

World coal production has doubled in the last thirty years. The increase in coal production is due to the demand for electricity from the Asian continent especially China. In the first quarter of 2000, especially after the growth rate of Far East countries, it slowed down gradually until 2009. Even though it started to rise again in 2010, it started to descend again due to the global crisis. In the next two periods that are 70s-80s and 80s-90s where production is very high, the OECD countries have almost no contribution to this growth. China, India and Indonesia pioneered the increase in production in the 2000-2010 period. According to 2017 BP World Economic Statistic outlook, there are approximately 892 billion tons of finalised coal reserves. 509 billion tone coal that is 57.1% of these reserves is located in the United States, Russia and China [1]. China is at the top of the list with 3.7 billion tones which are in equipoise to 47.7% of world coal production, despite a decline of 9% in coal production in 2016 compared to 2015. USA, India and Australia followed China as shown in Table 3. 1 [17].

Table 3. 1 Coal reserves in the world according to countries
(Source: Republic of Turkey Ministry of Energy and Natural Resources [1])

COUNTRY	**Amount (gigaton)**	**Total Share in the World**
USA	237.3	26.6%
Russia	157.0	17.6%
China	114.5	12.8%
Australia	76.4	8.6%
India	60.6	6.8%
Germany	40.5	4.5%
Ukraine	33.9	3.8%
Kazakhstan	33.6	3.8%
Republic of South Africa	30.2	3.4%
Indonesia	28.0	3.1%
WORLD TOTAL	**892**	**100%**

Hard coal and lignite are used for heating purposes in thermal power plant, electricity production, industry and house. World hard coal consumption decreased by 3.9% in 2016. The production of hard coal had reached its highest value in 2013 from at the end of the '70s when the production was stared. However, the decrease in these values has started to be seen in the ongoing years. According to the data of 2015, the total production of the OECD countries declined from 1.07 billion tonnes to 917 million tonnes in 2016. OECD countries have a 17% share in quarrying production, while China is at the top of the list with a 50% share. Germany ranks first with 171.9 million tons of consumption despite a 2.9% drop in lignite used for electricity production and heating purposes [17].

76.7% of coal that is produced in many places in the world and traded open to competition is consumed by five countries respectively China, India, USA, South Africa and Japan. Important countries and consumptions values of hard coal are given in Table 3.2 [17]. When the world coal consumption values are examined, coal consumption is expected to increase by 1.16% between 2015 and 2040. It is thought that coal consumption will not increase in OECD countries, and there will be a 50% increase in 2010 figures in 2040, depending on demand in developing and less developed countries. It is estimated that the coal demand of OECD countries will continue at the level of 2010 figures.

Table 3.2 Important countries and consumption quantities in coal consumption (Source: Turkish Coal Authority [17])

COUNTRY	2014	2015	2016
China	3207.3	3141.4	2959.5
India	740.1	746.6	761.4
USA	742.5	633.2	582.9
Rep. of S. Africa	189.6	180.5	178
Japan	137	138.9	138.3
Korea	100.1	100.6	101.8
Indonesia	79.1	86.8	90.6
Russia	77.4	58.5	83.4
Poland	61	58.3	62.8
Kazakhstan	62.6	57.3	59.6

3.2.1.4 Coal Reserves and Consumption Values in Turkey

Turkey is considered as a medium level in lignite and as a low level in hard coal according to world production data. 1.6% of total world lignite reserves are in Turkey[18]. Because most of the lignite removed is low thermal value, the use of it come into prominence in thermal power plants. Approximately 46% of lignite reserves in Turkey are located in Afşin-Elbistan Basin [18]. Turkey's essential quarrying reserves are located in Zonguldak and its environs. With the production of 246 million tons of quarrying since 1942, it has an essential share in the development of the country.

The thermal values of lignite coal produced from Turkish coal reserves range from 1000-5000kcal/kg. Approximately 68% of total lignite reserves are low-calorie, 23.5% between 2000-3000kcal/kg, 5.1% between 3000-4000kcal/kg, 3.4% between 4000kcal/kg.

The share of coal in Turkey's total primary energy consumption is 31% in 2017. After natural gas and oil, 17.67% of the shares of hard coal are used. With a share of 9.02%, the hard coal is followed by lignite [17]. As of the end of 2013, coal-based power plant power is 12563MW, which accounts for 20% of the total installed power. Although this value is 4048MW, it is based on imported coal; 8515MW is based on domestic coal. In 2012, 37.7% of the hard coal supply was consumed in electricity production, and 31.5% were consumed for heating purposes. The share of coke factories is 17.1%, and the share of other industry is 14.7% [19].

3.2.1.5 The Importance of Coal and Its Effects on the Environment

The common feature of all scenarios related to the world's energy demand is that the demand for energy for the 21st century will increase. Under normal conditions, energy needs are estimated to be at least twice the current level by 2050 [17]. About 25% of the world's primary energy supply and 40% of electricity production is coal. It is thought that it will continue to maintain its positions in the coming years.

Coal as a fossil energy source has several advantages. When compared to other fossil energy sources, oil and natural gas depletion live 50 years, while coal depletion life is 100-120 years. In addition to the abundance of reserves, coal is produced in more than 50 countries spread over a wide geographical area, coal resources are located in more stable regions in terms of political and administrative aspects than petroleum and natural gas, and the fact that coal is produced adds distinct importance as raw materials.

Two crucial areas of use of coal are the iron and steel industry and thermal power plants. From this point of view, it is seen that coal will maintain its importance as the basis of development and has a positive future. However, this positive future depends on today's technological research and the worldwide implementation of innovations developed as a result of this research.

Contrary to all this, coal use is an activity that is effective on the environment and causes environmental pollution at certain levels. Especially in the last 20-25 years, positive developments have been achieved about the effects of coal on the environment. CO_2 emissions resulting from burning coal and causing global warming ranks first among the environmental problems caused by coal. Studies are being carried out on the development of clean coal technologies in order to solve the effects of CO_2 emissions as well as global warming.

The world CO_2 emissions of fossil fuels have increased by 38% since 2000. In the same period, the increase in CO_2 emissions from coal was 62%. As of 2011, 69% of the world CO_2 emissions resulting from coal consumption are intended for electricity and heat generation. The emission shares of coal used in the manufacturing industry and construction sector is 26%, while the utilisation share of coal for heating, transportation, agriculture and other purposes is 6%.

Since Turkey is a developing country, the need for energy will be higher than in other countries. For this reason, the application, research and development of methods that reduce emissions and increase combustion efficiency is also essential for our country. In addition to the use of enriched coal to reduce emissions in the world, the separation of emissions in the flue environment and methods to increase the efficiency of combustion using different combustion technologies are applied and try to develop. Thus, both emissions are reduced, and the unit quantity is increased from coal.

3.2.2 Fuel Oil

Petrol is a substance that has been known since began to remember the history of humanity and has been used for various purposes. The oil either came out of a rock covering the top of an underground reserve in layers or was seen as gas leakage. This substance known from ancient times has been used in a variety of areas, although it does not have a commercial value. Mortar and coating materials by builders, cauldrons by shipbuilders, as well as medical materials and warheads with oil-soaked arrows, which are called Greek Fire and were used as weapons. Later, the techniques developed for enlightenment and warming began to be used, home and daily life have become a very active state. Petrol has become one of the essential energy sources along with the development of technology and economy in the world since the second half of the 19th century, and it has become the most critical element that shapes international relations. Many wars were fought in order to lead the oil world politics. The first people who understood the importance of oil and started to operate in this area have become as rich and powerful as the companies they set up and the states. Oil, an indispensable element of the modernised world due to technological developments, was the essential energy source of the 20th century when coal was replaced as an energy source upon understanding its commercial value towards the end of the 19th century. The importance of oil, which is an indispensable source of energy in the 21st century, is increasing in all areas of the modern world and especially by consuming it by industrial countries.

3.2.2.1 Formation of Fuel Oil

There are different ideas about the origin and formation of oil. It is accepted by many scientists that oil has an organic origin. C and H that is produced by plant and animal residues in the sea or swamp for millions of years are transformed into fuel oil by pressure, temperature, bacterial effects, radioactive bombardment and catalytic reactions.

Oil is unsalted natural mineral oil, composed of hydrocarbons, having a dark, distinctive smell. It is a very complex compound consisting mainly of hydrogen and carbon and contains nitrogen, oxygen and sulphur, and has no simple formula. Since the main components of crude oil and natural gas are hydrogen and carbon, they are called hydrocarbons. Crude oil cannot be used as it is extracted. In today's refineries, oil has to go through a process called distillation. Crude oil boiling at different temperatures causes the chemical components inside to be separated from the crude oil structure. Products that can be used in different areas are produced as a result of the components that are separated and changed from each other. Crude oil, 43% gasoline, 18% fuel oil, 11% LPG, 9% jet fuel, 5% asphalt and 14% other products are obtained after Refinery Operations. The main products of oil refineries are:

- Petrochemical products (plastic)

- Asphalt
- Diesel
- Fuel oil
- Gas
- Kerosene
- Liquefied petroleum gas (LPG)
- Paraffin
- Coal Tar

Fuel oil is a dark coloured, low-viscosity petroleum product that is used as fuel in different types of combustion devices in various climate and operating conditions. The chemical composition consists of carbon and hydrogen and contains only a small amount of foreign substances such as sulphur. Fuel oil used in electrical, heat or steam systems is preferred in all industrial factories, facilities and buildings. It pumps quickly, burns and saves energy.

Oil quality is measured by "gravity". Gravity defines the degree of density of oil and is one of the most critical points for cost accounting in oil production. Due to different concentrations of income, international agreements have been made, and specific standards have been introduced to the gravity of the oil. According to these agreements, the gravity of the American Petroleum Institute is used. High-grade oil refining is mostly light and white products such as gasoline, kerosene and diesel, and heavy and black products such as fuel oil and asphalt are obtained in the refining of low-grade oil.

3.2.2.2 Fuel oil in the World

According to the "BP 2017 World Energy Statistics outlook", there are 1.7 trillion barrels of proven oil reserves worldwide. On a regional basis, the Middle East region has 47.6% of the world's oil reserves. Central and South America follow the Middle East with a reserve of 19.5% and North America with a reserve of 13.3%. Then, Eurasian 8.5%, Africa 7.5%, Asia Pacific 2.8% and Europe 0.8% share respectively [12]. The sizes of proven oil reserves in the world are shown in Table 3.3 respectively.

Table 3.3 World proven oil reserve by region in 2017 [20]

REGION	Amount (gigaton)	Total Share in the World
Middle Eastern	807.7	47.6%
Middle and S. America	330.1	19.5%
North America	226.1	13.3%
Eurasia	144.9	8.5%
Africa	126.5	7.5%
Pacific Asia	48	2.8%
Europe	13.4	0.8%

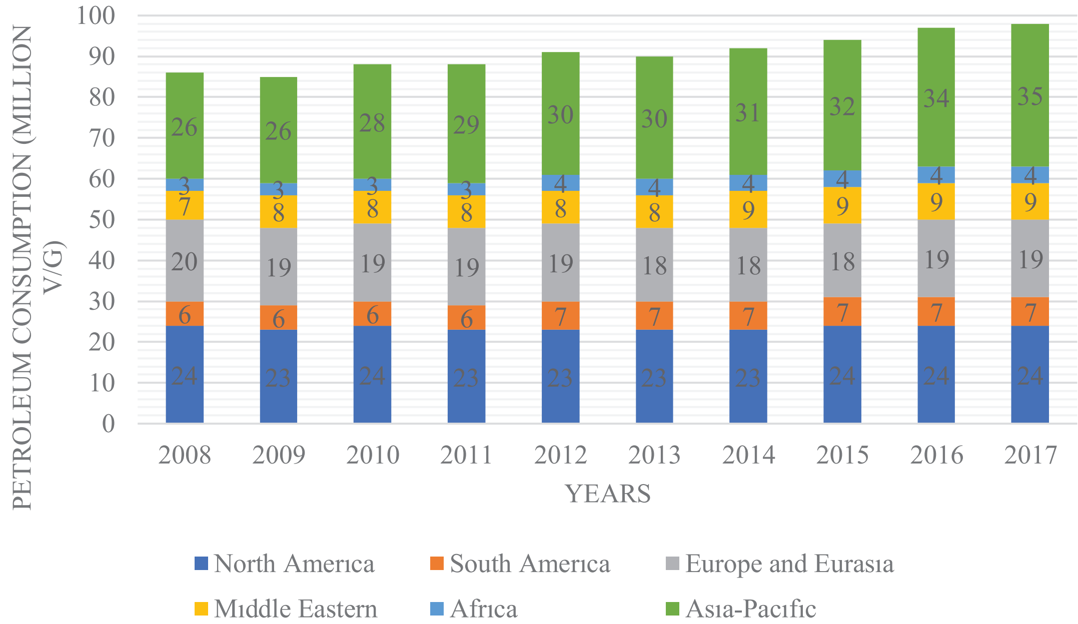

Figure 3.3 2008-2017 World petroleum consumption by region

(Source: Sectoral Report by Türkish Petroleum [12])

Oil production, which was recorded as 92 million tons/day in 2016, increased by 0.68% to 92.6 million tons/day in 2017. 34.5% of this production was realised in the Middle East. Production growth in Canada (8.1%), Brazil (4.8%), Kazakhstan (10.8%) and Iran (8.2%) are some of the countries where production growth was experienced in 2017. In Libya (102.9%), where there is domestic turmoil as a ratio, the production increase was the most in the United States as an amount[12]. There was no increase in production after OPEC agreement in Saudi Arabia and Russia which are one of the world's largest producers. According to "Petrol Report" of the International Energy Agency, production capacity is expected to increase 6.4 million in the 2017-2023 period, and the increase in the first phase is expected to be sourced from the United States. In the report, the United States and other countries that will experience the increase will be Brazil and Canada.

The world oil reserves are continually rising along with technological developments. The world's crude oil reserves were 1.7 trillion barrels in 2016, while the reserve life was 50.2 in 2016. When the reserve amounts are analysed, The Middle East is first, middle and South America is second, and North America is third. With discoveries, the introduction of new reserves, existing reserves that can be produced more economically thanks to developing technologies, and the acquisition of liquid fuel from coal and gas, it should be taken into account that this life can change depending on demand.

World oil consumption, which was 96.5 million tons/day in 2016, was approximately 98 million tons/day in 2017, with a 1.8% increase (Figure 3.3). The most significant increases by region were realised in the Asia Pacific (3.3%) and Europe and Eurasia (1.9%) [12].

3.2.2.3 Fuel oil in Turkey

Oil production in Turkey started in 1946 with 544 tones. The increased production value reached its highest level in 1991 with 4.4 million tonnes. Since this year, oil production has started to decline and has dropped to 2.3 million tonnes in 2012. 70% of the oil produced are covered by the Turkish Petroleum Corporation (TPAO) from the field in the south eastern Anatolia region [12]. With the oil law which came into force in 1954, Turkey was divided into 18 different oil regions and allowed private and domestic companies to search and manufacture oil. Today, many companies, especially TPAO, are engaged in these activities.

In 2017, Turkey's recoverable oil reserve was recorded as 324 million barrels. If discoveries are not made, considering the actual production quantity, the remaining production recoverable oil reserves have a lifespan of approximately 18 years. 93% of the oil fields discovered in Turkey are a small field, and 7% are middle-sized field classes. There are no significant reserves of 500 million barrels entering the large field class. Most of the sites are old sites, so well yields are falling steadily [12]. In this context, the techniques used in increasing production in the fields are of great importance in terms of the efficiency of Wells. As part of the activities to meet the increasing oil and gas demand from domestic sources, recent studies have gained momentum, especially in the Black Sea and Mediterranean Sea areas. The total domestic investment for oil exploration and production was $90 million in 2002, while the total investment in 2016 was $135 million. In particular, significant increases have been observed in oil exploration and production as of 2010. The amount of domestic investment made by the Turkish Petroleum Corporation (TPAO) for oil exploration and production in 2002 was 42 million dollars, while the amount of investment realised in 2016 was 90 million dollars.

As of the end of 2016, 27.6 million tons of crude oil consumption was realised throughout the country. When we look at crude oil consumption between 2002 and 2016, our crude oil consumption increased by 5.7% at the end of 15 years compared to 2002 [1].

Turkey's total oil imports are over 40 million tons by the end of 2016. According to the results of September 2017, imports of oil products for the first nine months of 2017 exceeded 32 million tons. The share of crude oil in total oil products was 60% over the year. Iraq, Russia and Iran became the most import-oriented countries in Turkey in 2017 [21].

Turkey plays a leading role in regional oil and gas projects with its geo-strategic position. In this context, Baku-Tbilisi-Ceyhan crude oil pipeline, Iraq-Turkey crude oil pipeline, Samsun-Ceyhan crude oil pipeline, Iraq-Turkey natural gas pipeline, Trans-Anatolia Natural Gas Pipeline and other existing and planned projects in order to become a reliable, stable and economic energy hub between Europe and consumer countries with rich hydrocarbon resources in Middle East, Caspian region and Central Asia. In the context of westward orientation, the emergence of Central Asia and the Caucasus from the Black Sea to the Mediterranean is essential in this context. Therefore, the straits have a distinct place in oil transport from Central Asia and the Caucasus. However, in recent years, transportation with pipelines is a leading solution. However, an essential option for the Mediterranean from Central Asia is still the Straits. As the demand for energy supplies increases, the Straits, which have narrow water and are a problematic transition region, seems to be problematic in terms of the environment. The straits are a situation that can be described as critical water for large energy transport.

3.2.3 Natural Gas

Global pollution that is one of the problems brought by industrial society is forcing people to protect the environment in which they live. In the 1970s and 1980s, reliability and economy in fuel choice was the main focus, while the environmental factor was the main focus in the 19990s. The most significant reason for the development of this awareness is the high cost of cleaning. Compared to the last 25 years in the New Policies scenario, the way the world's increasing energy needs are met varies dramatically. Natural gas has the impact of the leading position with rapidly rising renewable energy sources and energy efficiency.

3.2.3.1 Formation of Natural Gas

Natural gas is a fuel that is primarily composed of methane and hydrocarbons which are flammable, colourless, odourless and lightweight fossil source gas with the chemical conversion of the remnant of living things in our world millions of years ago between the layers of earth and under the pressure and temperature. The plant and animal residues that are known as an organic matter are moved down by lake and ocean, and it is covered with mud and sand as a result of a natural process. This organic material, which is increasingly buried deep, decomposes with the effect of pressure, temperature and possibly bacteria and radioactivity and forms oil coal and natural gas. The resulting natural gas has risen from the spaces where it is located and continued until it reached the non-permeable layer. The natural gas waiting between the non-permeable layers continued until the industrial use started. Since natural gas is lighter than petroleum, it fills the gaps in the layer above the oil. There is oil on the bottom and salt water on the bottom layer. Natural gas can be found on the layers of oil, or it can be found alone as a result of the drag of oil.

It can be used as it is removed from the source without being passed from any process. It is an oil derivative and is found in underground layers of nature, such as oil. Hydrocarbons forming natural gas are also components of underground petroleum. Natural gas has been seen as a useless waste occurring during oil production in the past and has been burned away in oil production facilities. Today, it is often used in homes and industries as a valuable and strategic energy source.

As a fuel, it ranks second in the ranking of importance after crude oil. The majority of natural gas (70-90%) consists of combustion of hydrocarbons called methane gas (CH_4). Other components are ethane (C_2H_6), propane (C_3H_8), butane gases (C_4H_{10}). It contains trace amounts of carbon dioxide (CO_2), nitrogen (N_2), helium (He) and hydrogen sulphide (H_2S). Density is between 0.6–0.8kg/m^3.

3.2.3.2 Usage Area of Natural Gas

Today natural gas is fossil fuel used in many fields for different purposes:

i. Natural Gas Use in Residence

Natural gas is used to prepare hot water in individual, centre and district heating systems in residence. Steel or casting boilers are used in central heating systems. These boilers can be blown or atmospheric burners. In individual heating, boilers, floor heaters, natural gas stoves, radiant heaters are used in residential and small-scale workplaces. Natural gas heaters are used in hot water preparation. It is also used for cooking in ovens.

ii. Natural Gas Use in Factory

It is used as an energy power for heating, cooling and cogeneration of natural gas, paper pulp, paper, metal, chemical and petroleum refining, stone, clay, glass and food processing plants and these factories. Ammonia, methane, hydrogen and petrochemical substances in a mixture, fertiliser, ink, adhesive, synthetic rubber, photographic film, detergent, paint, dynamite, plastics, antifreeze and some drugs are used as direct raw materials in the manufacture.

iii. Natural Gas Use for Electric Production

In the 80s, the number of power plants that produced electricity started to increase with the effect of natural gas being a relatively environmentally friendly and efficient fuel. The water vapour obtained as a result of the burning of natural gas is produced by turning the steam turbines or burning of natural gas directly within the gas turbines.

iv. Natural Gas Use as Engine Fuel

There are 2 million natural gas vehicles in the world. In Turkey, natural gas is used as fuel in some municipal buses in Ankara and Istanbul. Natural gas vehicles have the same performance as gasoline engines as their engine power, acceleration and maximum speed. Maintenance costs are lower than petroleum or diesel car. The distance of the vehicles can be shorter with a tank of natural gas, but the exhaust emissions of the vehicles are better than other sources.

Natural gas is also used in many areas such as white goods painting, metal cutting, ceramic making, antifreeze obtaining or heavy industry.

3.2.3.3 The Advantages of Natural Gas Than Other Fossil Resources

When precautions are taken, natural gas is as reliable as other fuels. Fuel costs, energy savings, lack of common control, lack of fuel preparation costs, effects on product quality and protection of worker health have the following advantages as well.

- When it is burned, it is no longer poisonous, ash-free and smokeless.
- It does not harm the environment and does not pollute the air.
- It is an odourless gas. However, in urban distribution, a special odorizing is performed for the understanding of leakage.
- Cheaper than other fuels.
- Consumption can be controlled.
- First used, then paid.
- There is no cost of storage and transportation.
- Storage space may be allocated to other usages.
- It provides a comfortable life.
- It is a clean source and cost of operation and maintenance is low.
- It is lighter than air, rises and do not accumulate when it is free.

3.2.3.4 Natural Gas Reserves and Consumption Values in the World

Natural gas, which is the primary raw material of various chemical products, meets an essential part of world energy consumption. The history of natural gas dates back hundreds of years. The use of the first known natural gas is for salt production in China in the 900 B.C. In these years, natural gas is known to be transported to the places of use with a bamboo cane. With the ease of transportation, processing and storage, the widespread use of natural gas began in England in 1790. Natural gas usage increased in the 1920s along with pipeline transport and II. It was even more developed after World War II. Modern production and consumption techniques in natural gas are first encountered in the USA. Natural gas pipes obtained from sources near the Earth were transported to consumption places and used in city lighting. The widespread use of natural gas, known by humans for centuries, has emerged after the oil crisis that broke out in 1973. In the 1950s, the rate of natural gas consumption in the world was lower than 10%. Today, 24% of energy consumption is covered by natural gas. Natural gas reserves known around the world are estimated to have a life span of about 53 years. However, with the introduction of new reserves with discoveries, with the introduction of existing reserves which can be produced more economically thanks to developing technologies, it should be taken into consideration that this life can change depending on demand. When the distribution of these reserves by region is examined, the Middle East is first, Europe and Eurasia are second, and the other Asian Pacific countries are third.

According to the data of the end of 2017, 40.9% of the world's natural gas reserves are located in the Middle East region. Europe and Asia region are second in reserve with 30.6%. The natural gas reserves of OECD countries constitute 9.2% of the total reserve. As of 2017, the countries with the most reserves are Russia, Iran, Qatar and Turkmenistan respectively [12].

In 2017, global natural gas demand increased by 3% compared to the previous year. Demand growth has recently been attributed to Africa (6.8%), Asia Pacific (6.2%), the Middle East (5.7%), Europe (5.5%) and Eurasia (0.6%). According to the UEA, the demand for World Gas is expected to increase by 1.6% each year by 2023. In this context, the highest increase in demand is expected to occur in the Asia Pacific and the

Middle East [12].

3.2.3.5 Natural Gas Reserves and Consumption Values in Turkey

Natural gas in Turkey was discovered in 1970 by the Turkish Petroleum Corporation (TPAO) in Kumrular and Hamitabat fields. The first usage was realised at Pinarhisar cement factory in 1976 [22]. The fact that domestic reserves and production quantities remain limited in the current and potential supply of natural gas increases due to the advantages introduced in the 1970s and that their usage rates are increasing day by day necessitated Turkey's natural gas imports [21]. Therefore 99.3% of the natural gas demand is imported. In Turkey, approximately 55 billion m^3 of natural gas was consumed in 2017, and 0.7% (354 million m^3) of this volume was covered by domestic production. In the distribution of Turkey's natural gas imports by countries in 2017, Russia ranks first with 52%. This country is followed by Iran (17%), Azerbaijan (12%) and Algeria (8%) [12]. With its geographical position between the countries with high levels of oil and gas dependency, especially among the EU countries, Turkey has strategic importance in the transportation of energy resources between the supply and demand regions. In particular, the TANAP (Trans Anatolian Natural Gas Pipeline Project) project that will transport Azerbaijan gas to Europe through Turkey has made Turkey's strategic importance even more prominent.

Natural gas comes from Russia, Azerbaijan, Turkmenistan and Iran via pipelines liquefied by the sea from Nigeria, Algeria, Egypt [21]. In 1988, natural gas was first used in Ankara, and in 1992, it was used in Istanbul and later in Bursa, Eskisehir, Izmit in the natural gas industry and housing. So far more than 70 natural gas distribution studies have started and are continuing. Considering the provinces and preparations to be tender, the majority of our country will be using natural gas soon.

53.3 billion m^3 of natural gas was consumed in Turkey in 2017. Natural gas consumption increased by 16% compared to 2016. The increase in the number of subscribers and the advantages of natural gas compared to other energy sources are the reasons for this increase. The percentages of natural gas in Turkey to 2017 sector consumption rates are shown in Figure 3. 4. According to this, 28% of natural gas usage is used in industry, 25% is used in housing, 6% is used in the service sector [23].

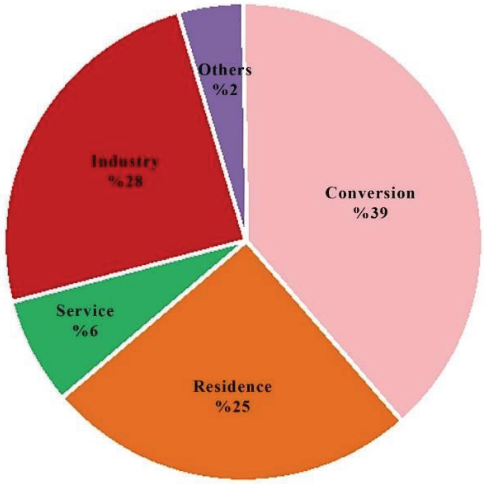

Figure 3. 4 2017 Sectoral consuption rate for Turkey [23]

3.3 Renewable Energy Sources

Renewable energy sources are called natural-environment-friendly resources, which are realised without any contribution of people, renew themselves and maintain their existence every day. Renewable energy sources that are widely used in the world are hydraulic energy, geothermal energy, biomass energy, solar energy and wind energy. In this study, geothermal energy was selected as a renewable energy source for comparison with the fossil fuel energy sources for heating purpose of building.

3.3.1 Geothermal Energy

Geothermal energy is the energy that is stored in the crust of the earth, generating thermal energy that is always over and over regionally atmospheric temperatures and can contain more molten minerals, various salts and gases than the surrounding surface and groundwater. This energy is also called geothermal fluid the fluid that carries the earth. Besides, geothermal energy is also used in underground “hot, dry rocks”, which is used in some technical methods, although it does not contain any fluids. It locates in the Alp-Himalaya belt, hot spots like Hawaii, in regions like Japan, the Philippines and North America where the plate borders are clotted. Energy obtained from such sources is called “Geothermal Energy” [24].

Geothermal energy is a renewable, sustainable, non-exhaustive, cheap, reliable, environmentally friendly, indigenous and green energy type. Because the water that forms the fluid of the geothermal resource is of meteorological origin, it continuously protects its underground potential with feedback and the resource can be renewed. Depletion of geothermal resources out of the question, unless there is no consumption above the supply [25]. Other advantages of geothermal energy can be listed as follows:

- It is clean and eco-friendly. Because the combustion event does not occur at the steps of the system, the emission is close to zero.
- It has a wide usage area like housing, public building, hotel, spa, industrial, agricultural, greenhouse heating.
- It works independently of meteorological events such as wind, rain and sun.
- Because it has no factors to threaten the environment like fire, explosion, poisoning, it is safe energy.
- The maintenance of power plants is relatively easy. It is protected from superficial hazards.
- It makes the country politically independent as it does not require superior technology, and also provides foreign exchange savings because it is a domestic resource.
- According to the other energy types such as wood, coal, fuel oil fuels, minimum facility area is required.

One of the criteria that are used the limitation of geothermal resources is the enthalpy of the geothermal fluids that are moving from deep hot rocks to the surface; in other words, is field reservoir temperatures. Geothermal fields are areas where the reservoir temperature is more than 20°C continuously. Enthalpy refers to the thermal energy of the fluid. Geothermal fields are grouped into three groups: high enthalpy, medium enthalpy and low enthalpy. Low enthalpy areas are areas between 20-70°C. Medium enthalpy 70-150°C and high enthalpy ones are areas with a temperature higher than 150°C. This grouping is based on the energy content of fluids and the total energy of reservoirs. The most important use of high-temperature geothermal resources is electricity generation. Geothermal resources at low and medium temperatures are used more in residential and greenhouse heating. Geothermal heat pumps are used for heating and cooling from geothermal sources below 20°C. Table 3.4 shows the classification of geothermal resources according to several criterions.

The most common systems in the world are geothermal systems with temperatures ranging from 125°C to 225°C. The vapour pressure of a liquid is directly proportional to the temperature of the liquid. The best-known example can be said as Larderello in Italy and Geysers in California.

Table 3.4 Classification of geothermal resources according to several criterions (Source: Anderson D.N., Jund J.W. [26])

	Muffler and Cataldi/1978	Hochstein 1990	Benderitter and Cormy /1990	Nicholson 1973	Axelsson and Gunnlaugsson 2000
Low Enthalpy Resource	<90°C	<125°C	<100°C	150°C	<190°C
Intermediate Enthalpy Resources	90-150°C	125-225°C	100-200°C	-	-
High Enthalpy Resources	>150°C	>225°C	>200°C	>150°C	>190°C

3.3.1.1 Geothermal Energy Generation

Meteorological vadose water flowing from the Earth, the heat efficiency of the magma that has not lost the properties of heating, geothermal gradients and other chemical factors get heated, and collect in porous rocks and form geothermal fluid reservoirs. They carry various gases dissolved in their bodies due to their relationships with minerals, salts and magma, which they melt from the rocks in contact with during the drainage and gathering of hot water from the Earth. Much mineralised geothermal fluid is expressed with the terminological term by various researchers. These are hot water, mineral water, thermal mineral water, and thermal water. Geothermal fluids, depending on temperature and pressure, may be in the form of meteorological water, liquid or steam, and water in most cases.

A geothermal structure consists of magma, fluid, reservoir rock and cover rock forming heat source. Heat energy from the magma is heated according to the heat permeability of the rocks, and sometimes the heated fluid can form a mixture system by heating the collected reservoir and the previously collected cold underground water in it. Generally, the reservoir is fed through the filtration of meteorological waters from the broad feeding areas of the Earth. As it is known, hydraulic cycle in the world (water falling to the Earth, falling to the ground, rising to the Earth, evaporating and coming back in the form of rain) creates an endless feeding system for the reservoir. For this reason, if the reservoir is produced less than the amount of nutrition, it is possible to obtain a renewable fluid, and therefore geothermal energy.

After the heat energy of the geothermal fluid is produced by drilling wells in underground and heat energy is received by the exchanger, its physicochemical properties are protected, and they are sent back underground from reinjection wells at the appropriate temperature. In this way, as they do not pollute the environment, feeding the reservoir and its parameters are ensured not to change. If reservoir pressure level above the topography, the fluid resulting from faults from the source that is named for natural emptying. This is the natural splash in the drilling wells called artesian. If the pressure level is below the topography, production is made in the well. A significant amount increases the amount of heat and flow rate compared to the natural resource as the fluid is taken deeper during the drilling. Because natural resources do not provide sufficient production and the flow rate-temperature-physicochemical properties can be changed with various factors, production is safer employing drilling.

3.3.1.2 Geothermal Energy Areas of Usage

A different area of usage for geothermal energy shows an alteration according to the temperature of the water and capacity from the source. Significant steps are being taken in terms of electricity generation and direct use. Geothermal energy is the oldest and most widely used form of energy. There are many uses in different areas on a large or small scale.

i. Closed area heating
ii. Ground source heat pump
iii. Thermal tourism
iv. Greenhouse heating
v. Agricultural usage
vi. Industrial usage
vii. Bathroom and pool heating

i. Closed Area Heating

District heating is heating from a central location of hot water or steam through a pipe to individual homes or residential blocks. The difference between district heating and ground heating is that it covers a geothermal well per structure in space heating. The distribution network that carries hot water to the user is an expensive investment. Main investment costs are production and injection wells, circulation pumps, heat exchangers, pipelines and distribution network, flow meters, valves, control equipment. However, operating expenses can be carried out with a much lower budget. For this reason, high heat demand is required to heat the economically selected region.

88% of the total installed power, 89% of annual energy use is region heating. In terms of annual energy use, China, Iceland, Turkey, France and Germany are leading regional heating. Turkey, the USA, Italy, Slovakia and Russia are the most significant users of the particular heating industry [27].

ii. Ground Source Heat Pump

A geothermal heat pump is known as a ground source heat pump. The choice of heat pumps for heating or cooling in homes is increasing day by day. The use of heat pump systems in residential heating is essential in terms of both economic gain and protection of natural resources and reducing environmental pollution. It is used in many HVAC system designs. The rate of the ground source heat pump is 55.3% of geothermal energy that is used [27].

It corresponds to 70.95% of installed capacity and 55.30% of annual energy use. Installed power 49.898MWt, annual energy use 325.028TJ/year is with a capacity factor of 0.21. Although most of the installations occur in North America, Europe and China, the number of countries with installations increased from 26 in 2000 to 48 in 2015.

iii. Greenhouse Heating

Greenhouse heating can be done in a variety of ways: finned pipe, finned coils, soil temperature, and plastic pipe. However, using geothermal energy for heating can reduce operating costs and allow operation in cold climates that are usually not economically viable. Greenhouses are one of the fastest growing applications in the direct use industry.

Geothermal energy has been used worldwide in greenhouses and indoor heating and has risen 19% in capacity and 16% in annual energy use. Installed power is determined as 1.830MWt and 26.662TJ/year in energy usage. A total of 31 countries report geothermal greenhouse heating (compared to 34 from WGC 2010), the leading countries in annual energy use being: Turkey, Russia, Hungary, China and Netherlands[27].

iv. Bathroom and Pool Heating

Table 3.5 Areas of use of geothermal energy according to the temperature [28]

Temperature (°C)	Usage Area
180	Evaporation of high concentration solutions, electricity generation.
170	Diatomite drying, heavy water and hydrogen sulphide production
160	Timber drying, fish drying
150	Aluminium alloy with Bayer's method
140	Canned food, fast drying of farm products
130	Sugar industry, salt industry
120	Obtaining fresh water with distillation
110	Cement drying
100	Organic materials drying, wool washing and drying
90	Fish drying (stockfish))
80	Ground and greenhouse heating
70	Cooling (Lower Limit Temperature)
60	Greenhouse, barn and poultry heating
50	Mushroom growing, balneological baths
40	Soil heating
30	Swimming pools, fermentation, distillation
20	Fish farms

Geothermal energy for swimming pools and spas is the earliest form of use of the resource. Human beings have used geothermal water and mineral waters for thousands of years to bath and be healthy. The practice of using natural mineral water for the treatment of diseases has a long history. Since the Bronze Age, mineral waters have been used for bathing. Greeks, Romans and Turks have been famous throughout history in the use and development of the spa.

The use of geothermal energy according to the temperature values is shown in detail in Table 3.5 [28].

3.3.1.3 Important Geothermal Generations in the World

The geothermal systems in the world are located on active continental edges, mid-ocean ridges, active continental crevices and volcanic islands as a result of the collision of plates. As shown in

Figure 3.5, there are geothermal resources in the North and South American coasts of North America, Mexico, El Salvador, Argentina, the Mediterranean countries of Turkey, Greece, Italy, China, Thailand, the Philippines, The East and Southeast Asian countries of Indonesia, New Zealand, Japan, Portugal-Azores, the African continent, and Iceland.

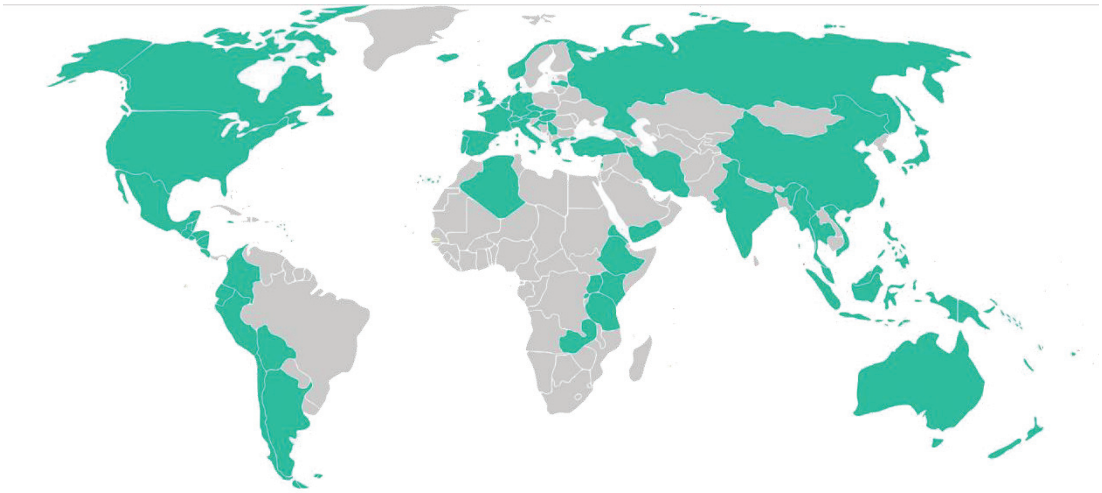

Figure 3.5 World map of geothermal power countries installed and developing (Source: GEA Annual Report 2015[29])

And Volcanic Belt: It is located on the west coast of South America, this belt includes Venezuela, Colombia, Ecuador, Peru, Bolivia, Chile and Argentina. Because of the large number of active volcanoes, high-temperature geothermal systems have been developed. However, the existing geothermal areas have not been evaluated much yet.

Alp-Himalaya belt: This geothermal belt, formed by the impact of the Indian plateau and the Eurasian Plateau, is among the giant geothermal belt in the world. It has150 km wide and 3000 km long. This generation includes Italy, Yugoslavia, Greece, Turkey, Iran, Pakistan, India, Tibet, China, Myanmar and Thailand.

East African Rift System: Active system includes countries such as Zambia, Malawi, Tanzania, Uganda, Kenya, Ethiopia, Djishuti. Active volcanism is in Kenya, Ethiopia and Tanzania.

Caribbean islands: There is a significant potential in the region where active volcanism dominates these islands.

Central America Volcanic Belt: This belt that affects Guatemala, El Salvador, Nicaragua, Costa Rica and Panama has led to the formation of many active geothermal systems.

Other: Canada, the United States, Japan, East China, Philippines, Indonesia, New Zealand, Iceland, Mexico, North and East Europe and the Commonwealth of Independent States have geothermal sites that are influenced by different tectonic formations.

3.3.1.4 The Potential of Geothermal Energy in The World and Its Main Applications

Geothermal energy has been used for the first time in history by the Romans and the Chinese for bathing, heating and cooking purposes. Geothermal energy is used in Europe at the beginning of the 1200s. The first generation of electricity from the steam obtained from geothermal sources was opened in the city of Larderella, Italy in 1904. The first turbo-generator was installed in 1912. While it was used for heating in Iceland in 1930, drilling works were done to provide hot water to a touristic hotel in the New Zealand, Waireakei area in 1940, and then the works were continued to obtain electricity. In 1954, a power plant with a capacity of 200MWe was established. The use of geothermal energy in electricity production spread worldwide In the United States in 1960, in Mexico in 1961 and Japan in 1966 [30].

The use of geothermal energy can be expressed in two ways: electricity and heat generation. The worldwide, the USA, the Philippines, Indonesia, Turkey and New Zealand are ranked as the first five countries to generate electricity from geothermal energy. Geothermal energy is the use of electricity 70.329MW and the world's first five countries in direct use applications in China, the United States, Sweden, Turkey and Iceland are emerging as [31].

3.3.1.5 Potential and Applications of Geothermal Energy in Turkey

Turkey is located on the active Alpine-Himalayan belt, due to its geological and geographical position. This line is an essential geothermal energy region with high potential. Before the 1960s, geothermal resources were used by nations who lived in these lands for cooking, health and bathing purposes. The Mining Research and Exploration Institute (MTA) was established in 1935. Geologic research was started, and international cooperation projects were started in the 1960s. Inventory of mineral and hot water has been renewed [32].

- The first geothermal well survey was carried out in İzmir-Balçova in 1963.
- The first 1000 m^2 greenhouse facility was established in Denizli-Kızıldere with a capacity of 0.5MWe in 1974.
- The first draft of the geothermal law was prepared by MTA in 1979 and was included in the mining law in 1982.
- In 1983, the first geothermal heating system with heat exchanger was established in İzmir-Balçova.
- In 1984, the first geothermal power plant in Denizli-Kızıldere was opened by one.
- In 1987, the first geothermal district heating system was started in Balıkesir-Gönen.
- Afyon, Kırşehir, İzmir (Balçova, Narlıdere) and Edremit, Bigadiç, Salihli, Sandıklı, Kızılcahamam, Sarayköy, Simav, Sorgun, Kozaklı, and Diyadin started to use district heating systems in 1990s [33].

The works about the operation, financing and investment continue by MTA, municipalities, governorates in order to use and expand geothermal energy. According to data of October 2017, the potential of geothermal energy which is significant as one of Turkey's domestic energy sources is evaluated as 31500MW. 10% of geothermal energy resources that are distributed such as 78% in western Anatolia, 9% in central Anatolia, 7% in the Marmara region, 5% in eastern Anatolia and 1% in other regions are eligible for electricity generation. Geothermal energy and housing heating figures increased nearly three times from 30 thousand houses in 2002 to 114567 houses in 2017[31].

There are 140 geothermal sites in Turkey that contain over 40°C of geothermal fluid. Hot water resources and installed geothermal sites are shown in

Figure 3.6. Aydın-Germencik, Aydın-Salavatlı, Denizli-Kızıldere, Çanakkale-Tuzla fields are suitable for electricity production. Other fields are suitable for direct usage such as heating and industrial use with low temperature.

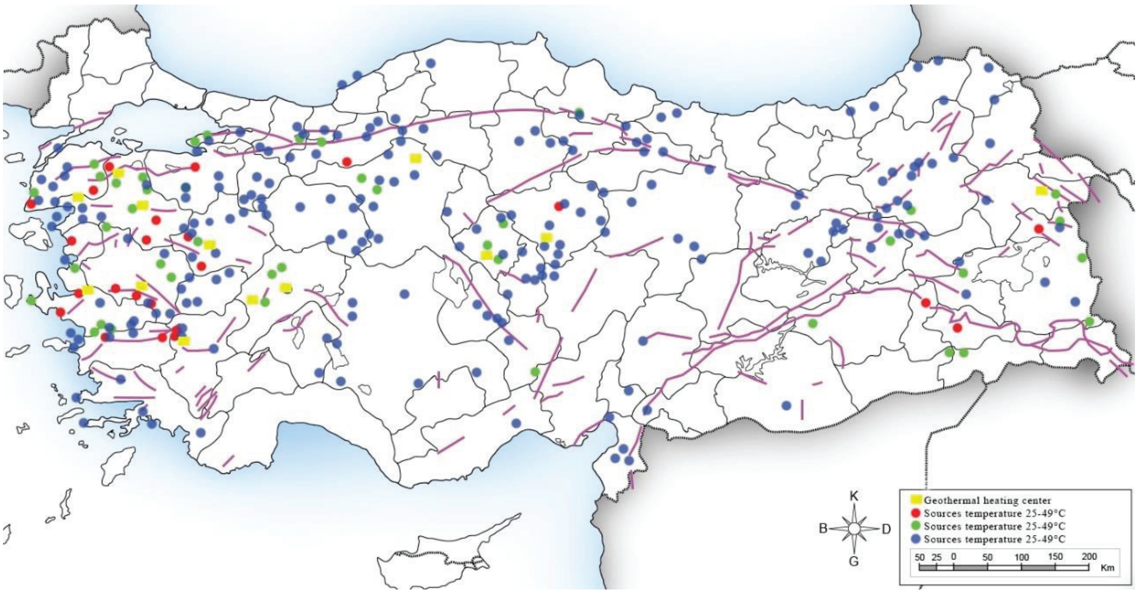

Figure 3.6 Hot water resources and installed geothermal fields in Turkey [34]

CHAPTER 4

CENTRAL AND DISTRICT HEATING SYSTEMS

The heat exchange between the human body and the surrounding environment and the necessity for heating is required to provide thermal comfort in the built environment. Thermal comfort conditions are essential in terms of efficient work and health. The systems to raise one or more volumes to the desired temperature and stabilise them at this temperature is called the heating systems considering cold outside environment. In general, heating systems are collected in four main groups as central heating, individual heating, regional heating and hot air heating. This chapter focuses on central and district heating systems in residential buildings.

4.1 Central Heating Systems

The heat generated in a heating centre is called central heating which is carried out by sending the heat produced to the internal units placed in the environments where it is desired to be heated through a carried fluid. Central heating systems are generally applied in large building groups such as hospitals, barracks, housing sites, university campuses, industrial production facilities. An independent boiler room can be defined for each building and also it is possible to heat from a single centre outside from these buildings on the sites where a few buildings come together. The primary purpose of the heating system is to keep the environment at the desired temperature. That is to meet the heat loss to the external environment.

To heat the desired environment with wafting the hot fluid prepared in a heating plant is a known technique since the ancient Romans and it also is used today [17]. In ancient Rome, the hot flue gas obtained from fuel burned in a furnace were passed through the canals under the floor or inside the walls and used for heating the places especially in the public baths. This method is still used in the Far East and some Turkish baths. The difference in the heating and cooling systems from this old method is the type of energy transfer fluids and the size of the systems. Today hybrid systems are used in combination with more than one of these fluids are water, steam, air, oil, refractory. In addition to this, decentralised mechanical systems like different types of fuel or electricity used in the stove, and radiant heaters are also available such another solution. In terms of the size of the system are classified like individual, central and regional systems. Different heating elements such as a radiator, convection, floor or wall heating can be diversified applications in all these systems.

The system includes a central boiler or heater to heat the fluid to be used, the piping for distribution of the heated fluid and the radiators to transfer the heat to the ambient air. Radiators are usually assembled on the wall. However, there are also central heating installations that are heating from the ground by embedding specific pipes under the ground without using the radiator. All systems have water circulating pump in the system to deliver heat to all radiators. Heating elements are placed in the area where the room is most likely to have heat loss. The hot water prepared in the boiler room in the building is sent to each unit separately. In most of these systems, solid, liquid or gas fuels can be used as the primary energy sources. The use of fossil fuels such as natural gas, coal and petroleum products is one of the most preferred energy sources in our country and the world. There may be various pros or cons to the systems and the fuels compared to each other. For this reason, engineering and economic analysis must be carried out in order to use the appropriate heater fluid and a heater element in each system. The selected heating system is determined with ±1ºC precision and must have a quick and effective adjustment mechanism. In order to be a suitable system, it must be economical and efficient in terms of plant, operation and maintenance costs and must be carried out with a simple operating system [35].

Advantages of the central heating systems from individual heating systems can be listed as follows:

- Provides the opportunity to combine various energy resources.
- Heat losses are less than the chimney.
- Boilers take up less space.
- There is no problem transporting fuel to the building.
- Heating is clean and easy.
- It is less polluting the environment.
- Operating cost is low.
- The risk of fire is less.
- It provides healthier and comfortable heating.

- Since it is possible to control room temperatures and combustion automatically, fuel waste is prevented.

Disadvantages of the central heating systems can be listed as follows:

- The construction cost of the galleries, pipes, insulation and consoles is high.
- There are heat losses from pipes in the galleries. Dampness, rotting of insulations and control difficulties due to the isolation over time will deteriorate.
- Water volume in pipes increases expansion tank volume.
- The risk of crustaceans increases in the system, due to water losses during the breakdown.
- The water volume of the pipes in the gallery delays the heating time of the system.

Especially in developing countries, the increase in energy consumption is increasing in parallel to the population. If the definition of energy efficiency is taken into consideration in building, it is understood as a result of the necessity of saving energy without compromising the comfort conditions and reducing the energy consumption costs. Therefore, whatever fuel is used, the aim is to heat the water in the boiler and distribute it to heating elements such as radiators, fan coil, air conditioning plant and hot air apparatus, and to ensure that the volume where these elements are located reach the desired temperatures.

4.1.1 Components of Central Heating System

A hot water system generally consists of a hot water boiler, water carrier pipes, heater elements, circulation pump, expansion container and various intermediate components. Hot water produced in hot water boiler is transported to heating elements with insulated pipes. The water loses its heat and returns to the boiler. While the circulation of water is provided naturally in the old systems, it is provided by circulation pumps because it is more economical and comfortable. Heated water is collected in a storage tank called expansion container. In modern systems, electronic panel systems operate according to the external air temperature is used.

i. Heating Boiler

The required heat in the system is provided either by an independent heating boiler or by using a heat exchanger if there is hot water, boiling water or steam ready in the system. Boilers can be classified as solid fuel, liquid fuel and gas fuel according to fuel type. According to material, they can be separated steel and cast. Boiler type is determined according to the fuel type and heat required to be used in the heater installation.

- Boilers with as much thermal efficiency and heating surface value as possible should be preferred during boiler selection.
- Generally, heating boilers are standard productions. If the calculated required heat capacity or heating surface value remains between the two standard production values, the upper value should be chosen.
- The thermal capacity of hand-fed coal-fired boilers should not exceed 60kW.

Because of the expansion of natural gas usage, one of the atmospheric burners and blown burners can be selected. In addition, due to the feature of natural gas, high efficiency condensing natural gas boiler can also be used in the system.

ii. Burner

They are devices that allow liquid or gas fuel to burn in the boiler. Burners should be selected, placed and adjusted according to type and extent of heat capacity of the boiler, form and scale that the flame does not directly hit the boiler surface. The purchase price of burners is 2-8% of the fuel consumed in a year. Safety, boiler compliance, maintenance and service ease, life, rated and operational efficiency factors are the determining factors in the selection of a burner.

iii. Expansion Tank

While the water temperature decreases, the volume increases in hot water heating systems. Increasing this volume must be balanced within the system. The balancing is achieving through the expansion tanks. Expansion tanks ensure the expansion of water, as well as the system's security by preventing the excessive increase in pressure. When necessary, it also makes the addition of water that is reduced in specific dimensions and the evacuation of the air that may occur in the system.

There are two types of expansion tanks in practice: open and closed. In order to determine the capacity, whatever the type, the total water volume of the boiler, heater and pipes should be calculated in the installation [36].

iv. Boiler

Boilers are devices that produce hot water for use other than heating and are considered to be a heat exchanger. Double-walled and serpentine types are available. They produce water at a temperature of 45-60ºC for use with heating hot water (90-70ºC). In order to save energy, the boiler temperature should not exceed 45ºC.

The use of hot water varies according to the number of people and the size of the housing, as well as the level of life of people, age, system structure and seasonal conditions. Average hot water consumption values required in various buildings and places of need were calculated as simple life level 10-20L.day/person, medium life level 20-40L.day/person and high life level 40-80L.day/person.

The boiler should be selected according to the average usage values of the heater. An instantaneous water heater designed with average power is insufficient during peak water usage hours of the day. Therefore, the larger the storage volume in the water heater, the smaller the required heater power can be kept. Size volumes are determined according to the water requirement. Safety valves should be used in order to prevent the expansion due to water heating. If no outside water is required from the safety valve, a closed expansion tank must be used by the used water in the system.

v. Plumping System

After the heat loss calculation is completed, and the system and heater type are selected, the design of the pipe installation which provides the connection between boiler and heaters should be done. Central heating facilities are usually used in black steel pipes. However, the use of plastic and copper pipes has been increasing in recent years.

After the installation design is completed, pipe diameters should be dimensioned. The pipe diameter should be selected according to the water flow that can transmit the required heat needed by the building. The diameter should be selected as small as possible. When the pipe diameter is reduced, it should be noted that there is no flow sound in the pipes and pressure losses are not too much.

The hot water pipes passing through the non-heated areas need to be insulated to reduce heat losses. Otherwise, heating efficiency is reduced. Pipes outside the building should never be buried in concrete and soil. These pipes are insulated against heat and humidity and are passed through the ducts. However, inside the building pipes can be insulated and buried on the wall. In our country, the thermal insulation thickness of pipes is minimum, and labour is not paid attention. The most economical insulation thickness can be found theoretically by comparing the energy cost of the heat loss in the insulated pipe and the investment costs for this insulation. However, due to the complexity of the heat loss account, tables are usually used for the thickness of the heat insulation prescribed by regulations and standards.

In order not to increase the characteristic values of the pump too much, sharp turns should be avoided especially in the pipe installation. In order to maintain circulation, the pump must be big enough to resistance such as pressure, pipeline, valve, radiator, boiler. Instead of evaluating the height of the building as it is open to the atmosphere in the resistance calculation, zonal losses such as boilers, radiators and valves are calculated as the resistance of pipes.

vi. Circulation Pump

The task of the circulation pump is to overcome the pressure losses in the pipes, take the desired amount of hot water from the boiler and turn it around from the heaters and return it to the boiler again. The circulation pumps used in the heating installations are electrically operated centrifuges. Quiet, long life, small size, economical and stable work has advantages such as. For this reason, centrifugal pumps are widely used in heating installations. The four distinct features of these pumps can be listed as flow rate, pressure, core power and efficiency.

vii. Chimney

It is the equipment used to pull out flue gases or dirty air. The chimneys are divided into two parts, natural-pulled and forced-pulled. A suction fan creates the pull force in the forced-drive shafts. In natural towed chimneys, unwanted air is thrown out as a result of the force created by the density difference caused by the temperature difference.

Each boiler must have a separate smoke chimney, more than one boiler, for whatever reason, should not be connected to the same chimney. Smoke chimneys should not be placed on the exterior wall of the building unless there is a technical requirement. The thickness of the chimney walls should not be less than a brick thickness, and no perforated brick and briquette should be used in the construction of the chimney wall.

viii. Heater Element

Today, flat pipe, flanged pipe, cast, steel or aluminium radiators, panel radiators, fan-coils and convectors or pipes placed inside the wall or ceiling can be used as heaters.

In central heating systems, the most commonly used devices as volume heaters are radiators. In these devices, approximately %70-80 of the total heat transfer is transported, and %30-20 is transmitted by radiation. There are kinds of cast, steel, aluminium and panel.

If the radiator is used, the thermal power of each slice radiator type can be preferred at different internal temperatures by the standard information obtained from the manufacturer catalogues.

The heat given to the volume in the floor heating system is based on the system placed under the floor and passing through the hot water. The pipes must be a long life, easily bent, corrosion resistant and shock resistant at temperatures below freezing point. Pipes are frequently placed in areas where the room is more than heat loss, and rarely in areas where there is less heat loss.

4.2 Geothermal District Heating System

The use of one or more geothermal fluid production sites as a source of heat to provide heat energy to a group of buildings is called a geothermal district heating system. With this system, heating of the building and domestic water use, cooling the building, industrial and thermal tourism applications can be found. In history, the regional heating system has been used in different ways and purposes. For example, during the Roman period, houses, baths and greenhouses are known to be heated by geothermal hot water. Chautes-Aigues Cantal village in France is one of the first planned projects that has been operating since the 14. century when the wooden pipes and geothermal waters were distributed. In Copenhagen in 1903, a waste incinerator was set up, and steam was obtained to heat the hospital, municipal building, children's home and the poor house. Examples are also found in daily usage areas such as home heating, restaurant kitchens and laundry.

Geothermal energy is more suitable than other alternative energy sources in central heating systems. Hot water from the source is used to transport energy in geothermal regional heating systems. For this reason, large pieces of equipment such as boilers, fuel tanks are not needed in the buildings. The heat exchangers placed under the building and the pipe system carrying hot water from the geothermal production area are the main elements.

The most important advantages of using geothermal energy in the regional heating system are to be a domestic and clean energy source, flexible system size, variety of use, modularity, high efficiency, combined ease of use and low operation and maintenance costs can be considered. Many factors are effective except for the general characteristics of the source in the design of geothermal district heating system. These factors can be examined in two groups as limiting and design factors. Considering these factors in the decision and design, energy used by the consumer is checked to stay within the economic and feasible limits.

Limiting factors can be itemised such as the composition of geothermal fluids, the wellhead flow, and temperature of the geothermal source, energy use intensity, the depth of the geothermal resource, the distance between the well and the application area and cost of alternative energy. The selection of wellhead and well-inside units, the system of geothermal system distribution, temperature drop, system load factor and total load, at the same time heaters, user units and the selection of appropriate materials have affected the design. Geothermal district heating systems should also be designed by looking at reservoir performance, fluid chemical properties, and thermophysical characteristics, mass flow rate, pressure and temperature, topographical properties of the region to bite, meteorological conditions, housing layout and building elements such as many different parameters.

4.2.1 Components of Geothermal District Heating System

The first step in the system is to remove the fluid from the geothermal resource to the earth with the help of the geothermal well. Separators at the wellhead provide the separation of steam flow if it is necessary. The pump at the head of the well sends to the systems according to the purpose of the fluid. If the used liquid does not cause any damage; as a result, it is sent back underground.

The fluid used in the central heating system is transferred to the geothermal heat centre by transmission line at the bottom of the well. As a next stop, the fluid coming to plate heat exchangers is evaluated in other areas such as hot spring by re-injection after transferring its heat to circulation water. The heated circulation water is sent to the residences via the public network. The central heating houses have a pump in each of the building entrance and allow the water to circulate in the building. Heat exchangers at the entrance of the building and the heat of the fluid are transferred to the system and used for heating purposes from the natural source. The system's roaming network is schematically illustrated in Figure 4.1. The geothermal central heating system can be examined in six sections:

I. Geothermal well system
II. Transport line
III. Geothermal heat centre
IV. Public heating network
V. Built-in installation
VI. Re-injection system

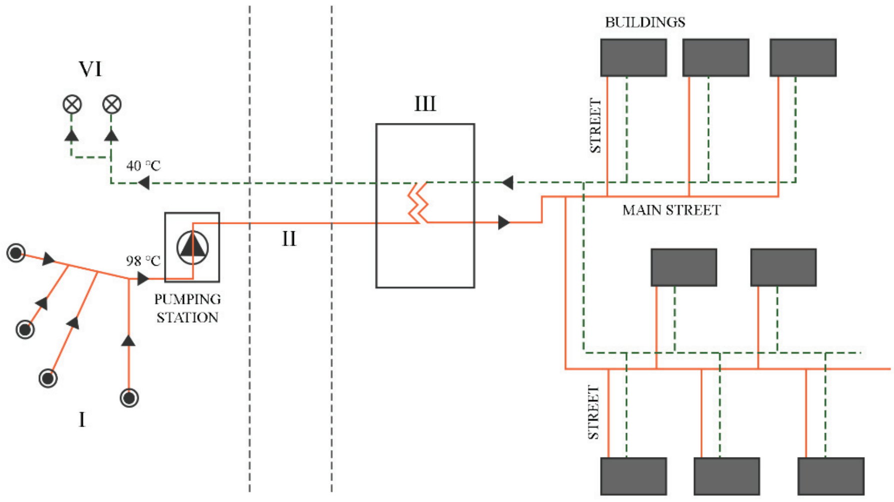

Figure 4.1 General flow diagram of geothermal central heating system

I. Geothermal Well System

A wellhead system is built on the drilling well where the geothermal fluid is produced. This system includes production well, dosage group, pressurisation group and the well pump.

Geothermal production wells are system produces geothermal fluids by naturally or mechanically prepared by opening at a certain depth and appropriate size. The potential of geothermal energy is determined by research in drilling wells. Well-pumps designed with electric pumps and operated in hot water is used for transportation of water to the earth. Two types of pumps come to mind as a well in pump: vertical shaft pumps and submersible pumps. Other types of pumps are not used in geothermal fields because their use and flow rates are limited. The electric motor of the vertical shaft pumps is placed on the drainage cap above the well. The pump located at the end of the column pipes which can reach up to 250 m depth is turned by the help of the mils in the additional parts of the pipes. Submersible pumps are driven by the submersible type electric motor mounted under the pump, which is high-speed, small diameter, high temperature resistant. The energy transmitted to the pump motor is transmitted by special cables that are resistant to high temperature[35]. High-temperature submersible pumps have a long sealing section to prevent the well water from entering the engine from the shaft ends. Phase separation level, equipment plan, temperature, time-flow information, output pressure should be known to determine the flow rate of the well.

Dosage pumps are pumps that push the inhibitor into the well. Compounds in the fluid that flow from pipelines and heat exchanger occur minerals and solid compounds. This crustacean causes a decrease in production and prevents mechanical installation from working. This also decreases energy production because it affects heat transfer negatively. If appropriate measures are not taken, over time, accumulated compounds can block wells and pipelines. Dosage pumps and pump inhibitors to the wells to prevent this negative factor affecting the system.

II. Geothermal Fluid Transportation System – Pipeline

If the region where it was founded of geothermal district heating system is far away from the production wells, geothermal fluid is transported to the system by the pipeline transportation system. Geothermal fluid from production well is cleaned from foreign materials with the help of separators. The fluid transfers its energy to the clean fluid with minimum heat loss. A separate line is sent to the ground with a re-injection well.

Insulated stainless steel pipes carry geothermal fluid with high temperature (>90ºC). There is a polyurethane insulation case around the steel pipe and PVC protective case on the outside. Geothermal fluids at lower temperatures are transported from the bottom of the well to the heat centre with an insulated special packaged pipe. Thus, geothermal fluid can be transported with a loss between 0.1ºC/km to 0.5ºC/km. The transfer of geothermal fluid is also carried out through insulated special package pipes which are buried directly in the soil.

III. Geothermal Heat Centre

The geothermal fluid that is obtained from the geothermal reservoirs is brought to the geothermal heat centre by transport pipeline. It transfers its heat through the heat exchangers to the public circulation water that is clean, without crustation and corrosion. The cooling fluid returns to re-injection wells.

The structure and equipment of the heat centre are as follows:

Geothermal Fluid Pumps

Geothermal fluid is sent to the heat exchanger by geothermal pumps in the heat centre. The difference between these pumps and other circulating pumps is that the fan and shaft of the pump are made of corrosion-resistant materials.

Heat Exchanger

The devices used to transfer the heat of the geothermal fluid to the local cycle, which will not cause crustation or corrosion, are called heat exchangers. Geothermal plate type heat exchangers are preferred in central heating systems. Geothermal plate heat exchangers are the latest design structuring of the most efficient and most widely used geothermal systems. Plate heat exchangers are manufactured from corrosion-resistant materials such as titanium (Figure 4.2). Geothermal heat exchangers have also increased the possibility of using low-temperature geothermal fluids. The difference between inlet and outlet temperature should be 7ºC in the shell and tube heat exchangers. However, this difference is reduced to 2ºC or even 0.2ºC in special cases. This situation reduces the amount of geothermal fluid that needs to be used and the flow of indoor clean urban cycle water [37]. Besides, the overall heat transfer coefficient (U) for plate type heat exchangers is 3 to 4 times higher than the shell and tube units.

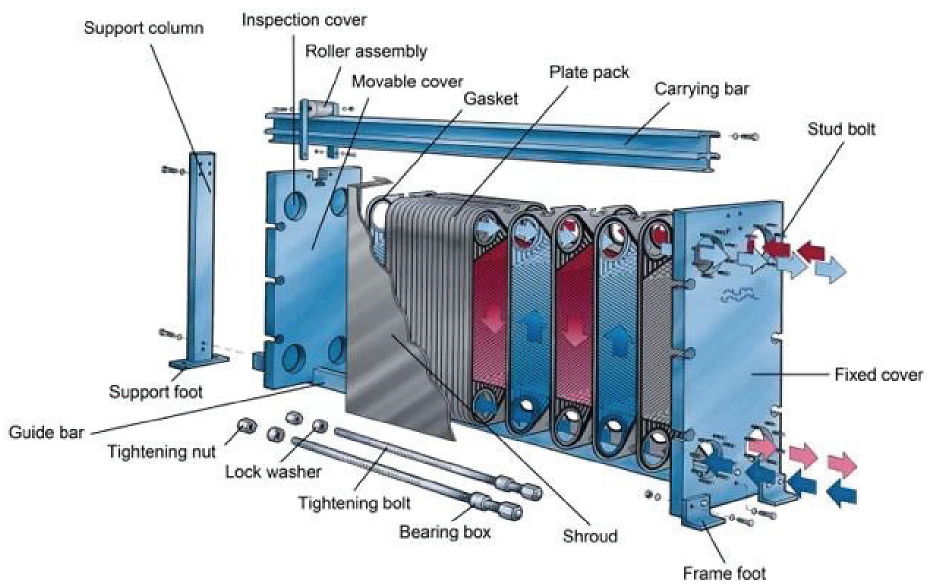

Figure 4.2 A Sample type heat exchanger
(Source: Alfa Laval Company [38])

Plate type heat exchangers are two types that are sealed and soldered. Solder types are not preferred too much because solder seams are sensitive to corrosion. A sealed heat exchanger is used widely because of the high thermal performance, corrosion resistance materials, ease of installation and placement, easy capacity change and its ability to occupy the minimum space according to its capacity. The commonly used sealed plate type heat exchanger and its main parts are shown in Figure 4.2. These plates are the most essential and functional part of the system. The plate heat exchanger consists of a series of individual plates pressed between two heavy covers. All assembly is held together with the help of connection bolts. Each plate is hung from the top carrying rod and directed by the bottom carrying rod. Primary and secondary fluids flow in the opposite direction from both sides of the plates. The placement of plate gaskets controls water flow and circulation. It can be channelled through the water plate by changing the position of the container. Gaskets are mounted in such a way that liquids do not mix. Besides, the outer perimeter of all seals is exposed to the atmosphere and, as a result, a visual indication is provided when a leak occurs.

Automatic Control System

Heat capacity in geothermal central heating systems varies according to the external air temperature.

In the variable temperature heat distribution system, the temperature of the local indoor cycle heating water is changed according to the external air temperature. Flow rate is kept constant. In this system, the time to respond to the demand from consumers is very long. Also, this situation leads to a decrease in the life of the pipe.

Domestic indoor closed cycle heating water flow is changed according to the heat demand from consumers in the variable flow heat distribution system. The temperature is kept stable. The constant temperature difference is working as a variable flow rate according to the external air temperature. Working frequency converters or gradual pumping can achieve this according to critical differential pressure.

Municipal Water Conditioning System

City water conditioning system is used to provide the required fluid in case of loss of water in the circulation system as a result of water losses. If the new fluid entering the city water system is activated without conditioning, corrosion and crustacean events will be seen in the system. The capacity of the city water conditioning system is based on the fact that the system can be filled in 48-72 hours. The city water conditioning system, which is calculated in this way, can quickly meet system leakage. The clean water from the city grid is passed through a smoothing device and is collected in a reinforced concrete tank. The water in the tank is pressurised through a package of pump system. The water pressure is also controlled into the closed expansion tank.

IV. Urban Heating Network

The system that carries the heat from the heat centre to the buildings is called the city heat distribution system. Geothermal central heating systems will provide the necessary heating load, population density and per capita, water usage in consideration of the node points are assumed to pass. In order to provide various pressures within the network, pressure reducing valves are required to be placed in the necessary places. The most critical problem in the distribution of indoor clean cycle water in the city is heat losses. Materials and building technology are used in order to minimise these losses.

The pipes in the geothermal heating system can be laid under the soil without channels. In the ductless pipe system, flexible pipes, polyurethane-hard foam insulated pipes, steel pipes, double polystyrene layer with polyethylene protective layer heating pipes, pre-insulated package heat pipes, glass fibre reinforced pipes can be used.

V. Building Interior Installation

When geothermal central heating systems are planned, the heat requirement of each building is determined and accordingly, control valves are placed under the buildings. These valves prevent more fluid from entering the building than they need. The heater fluid that reaches the building is used to heat the buildings and to prepare hot water.

Interior Heating System

Hot fluid entering the building can be used for heating the building by giving it directly to the radiator. In another method, a heat exchanger can be installed in each building group by grouping the buildings according to the heat requirements. If geothermal central heating systems include multi-storey buildings and more apartments, under each building should be installed a heat exchanger. Thus, the pressure of the fluid pumps in the system prevents the building heating system from being affected.

The heater fluid circulating in the radiators with the help of circulation pump from the heat exchanger ensures that the desired spaces are heated in the buildings. This system is similar to a central heating system. The difference between them is that the geothermal system provides continuous heating while the heating system operates uninterruptedly.

VI. Re-injection

Producing hot water is a very high amount in geothermal reservoirs where the water is effective. While some of the hot water produced is used as hot water directly, the remaining part remains residual water after the heat is removed in central geothermal heating systems. Wastewater must be used in useful areas or eliminated without damaging the environment. The evaluation of waste or residual water is an essential problem in application and field operation. The best solution for this problem is to re-press the unused hot water reservoir. This process is defined as re-injection. As a result of this process, the water reservoir produced will be, and the water balance of the reservoir will not deteriorate, the pressure of the reservoir will be preserved.

4.2.2 Geothermal Heating System Turkey Examples

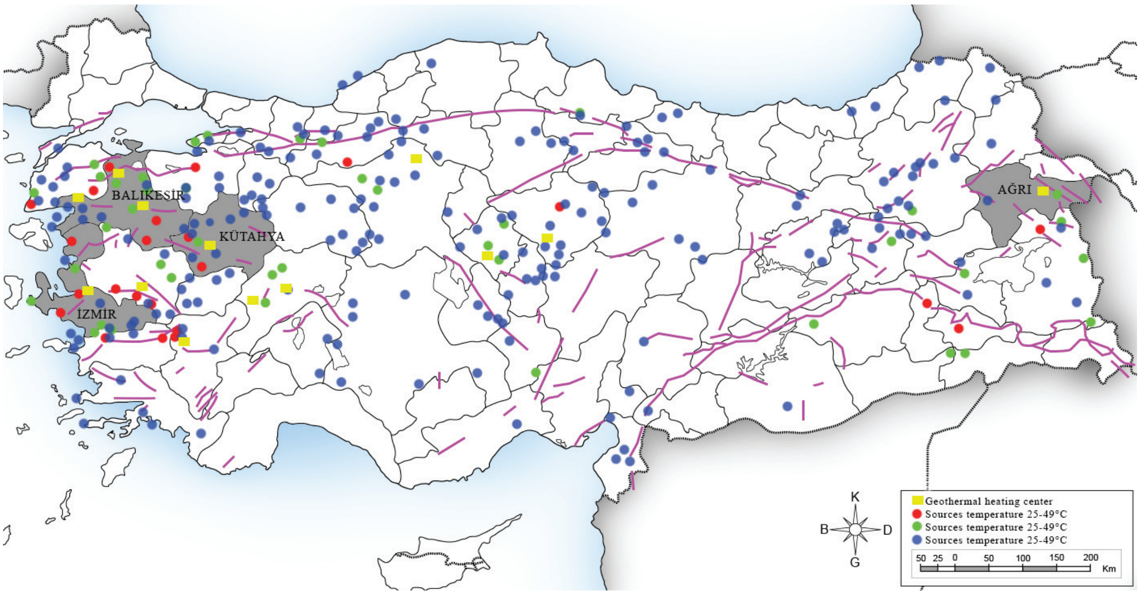

Figure 4. 3 Distribution map of geothermal source [34]

In Turkey, %55 of geothermal areas is used in heating applications. 100 000 homes in 15 residential areas are heated by geothermal energy, and it is becoming more and more widespread[39]. Balçova, Narlıdere, Afyon, Gönen, Simav, Kızılcahamam, Kırşehir, Sandıklı, Kozaklı and Diyadin are the most important ones among them. In this thesis, regional heating systems in Balçova, Gönen, Simav and Diyadin were evaluated respectively (Figure 4. 3).

4.2.2.1 Balçova Geothermal District Heating

Balçova-Narlıdere geothermal region is located on the south-west border of İzmir city centre along the East-West Izmir fault zone. A large portion of the Balçova region and a portion of Narlıdere region are heating using geothermal liquid obtained in this region. The main aim of the establishment of Balçova geothermal regional heating system is to reduce and save the use of other energy sources and fossil fuels that will be more expensive by heating private and public areas such as houses, offices, schools and universities with geothermal energy. Another aim is to contribute to the development of health tourism thanks to the minerals and therapeutic properties of geothermal resources in terms of health.

The exploration and study of geothermal energy in Balçova İzmir began in 1963. The first well produced two phases of liquid at 40m deep and 124°C. After the initial evaluation of geological, geophysical and geochemical data, three exploration wells were opened. Because of the high calcite precipitation problem, the geothermal area found until 1981 could not be developed. The first down-hole heat exchanger application of Turkey was realised in the B-1 well in 1982. This well had a depth of 100m and a temperature of 115°C. The clean water temperature circulating in the cycle was measured at 50-95°C depending on the flow. After this down-hole heat exchanger application, ten separate wells were drilled. These are a maximum of 130°C shallow wells at 200m. The use of geothermal resources in Balçova-Narlıdere has been developing steadily since 1963. In the district of Balçova, 46 wells ranging from 24-1100m have been dug up to date. The temperatures of the wells range from 44-140°C. The thermal energy potential calculated according to the temperature and flow rate of the existing wells is 498MWt [40].

According to the increasing heat demand of the Balçova-Narlıdere geothermal centre heating system, the heat generated from the reservoir is increasing rapidly. Total production capacity was increased from $620m^3/h$ to $1250m^3/h$. Besides, there is another geothermal fluid with a $500m^3/h$ capacity which is cleaned and prepared for reuse.

The installed capacity of the system reached 24500 dwellings in 2007, 30900 dwellings in 2009 and 49500 dwellings in 2013. Today, the heating potential is 71314 units of housing or $26250000m^2$ of greenhouse area. However, most of the current energy is used in heating. According to the latest values, 33500 residences are heated in Balçova. It has been determined that $58450m^2$ greenhouse areas can be heated.

The geothermal pipeline system of Balçova-Narlıdere geothermal centre heating system collects geothermal fluid from 11 production wells and distributes it to 10 heat stations of each sub-system. After transferring the heat to the user, the geothermal fluid is directed to the injection again. Some features such as well temperatures, flow rates and capacities of the production well are shown in Table 4.1 below.

Table 4.1 Hot water wells in İzmir-Balçova
(Source: Arslan E. S.[40])

Production Well	Year	Depth (m)	Temperature (ºC)	Flow (l/h)	Energy Capacity (kcal/h)
B-4	1983	125	104	30	1320000
B-5	1983	109	101	117	4479000
BD-1	1983	120	85	55	1375000
B-10	1987	125	101	220	9020000
BD-2	1995	677	115	130	7150000
BD-4	1998	624	135	209	15675000
BD-5	1999	1100	111	55	2805000
BD-6	1999	606	130	199	13930000
BD-7	1999	700	115	69	3795000
BD-9	2003	772	137	360	27540000
BD-11	2006	716	144	225	18900000
BD-12	2006	830	143	256	21248000
BD-14	2007	716	119	125	7375000

Geothermal power plants and their capacities are connected directly to the system. It is shown in Table 4.2. The number of facilities and residences directly relates to the production and characteristics of wells.

Geothermal fluids pumped from wells connected to different points of the geothermal pipeline are mixed in the geothermal pipeline system. Because geothermal fluids are different in each well, the temperature of the geothermal pipeline system is not constant and depends on the operation of the wells.

Table 4.2 Facilities connected to the system and their capacities of Balçova (Source: Arslan E. S.[40])

Heat Center	Capacity (kcal/h)	Capacity (KE)
Balçova Heat Center	56494821	11097
Teleferik Heat Center	21315671	4187
Özkılıç Heat Center	22909500	4500
Onur Heat Center	35282413	6930
Tuğsuz Heat Center	4410000	866
Narlıdere Heat Center	22620118	4443
GSF Heat Center	8341506	1638
Yenikale Heat Center	14327241	2814
Çetin Emeç Heat Center	22113000	4344
Sahil Evleri Heat Center	7000000	1273
Conservatory	960000	189
GSF Building	2000000	393
Dormitory	2900000	570
Özdilek	4000000	786
DEÜ Hospital	13500000	2652
DEÜ Hospital Annexe	6720000	1320
Balçova Thermal	4000000	786
Ekonomi Üniversitesi	1500000	295
Ekonomi Üniversitesi Annexe	900000	177
TEV Balçova Dormitory	860000	169
School	210000	41
Salih İşgören	350000	69
İJT Facilities	22910	5
Greenhouse	300000	59

Since the geothermal pipeline system is a very complex network, it is essential to monitor and control temperature and pressure throughout the system. The thermodynamic and hydraulic balance of the pipeline system is critical for the system to operate correctly.

Temperature of geothermal fluids changes according to the operation of wells. Inlet temperatures of heat exchanger change between 105-115°C and the re-injection temperature are about 60°C in the system.

Geothermal well pumps of the system are operated according to the constant well pressure strategy. With the help of valves in the system, well pressure is kept constant in 3 bars. Pressure monitoring status is available only in wells.

In Balçova and Narlıdere heat stations, the pressure of the geothermal fluid along the pipeline is the approximately 1.5-2 bar.

4.2.2.2 Gönen Geothermal District Heating

Gönen geothermal site is one of the oldest thermal areas. While the water in this area was used for healing purposes in the past, new installations were built today. Geological, geophysical and geochemical surveys were researched for water supply by the MTA General Directorate. Turkey's first geothermal heating application in 1964. Gönen geothermal regional heating system consists of three parts. In the first part, production and equipment with re-injection wells, balance tanks and well pumps; in the second part there are heat exchangers, circulation pumps, sedimentation and expansion tanks which provide heat transfer and in the third part there are building heating systems.

Stage-I of Gönen geothermal heating system project was started in 1985 and was put into operation in 1987. In 1995, II. Stage of the project has been commissioned. Since 1987, 17 research and production wells have been opened in Balıkesir-Gönen between 133-800m depth. Table 4.3 was given the year, depth and temperature values of the hot water wells in Gönen thermal springs. Four wells in the system are for production purposes, and five wells are for spare production purposes, one well is used for re-injection purposes. The remaining wells have been disabled for several years. Wellhead temperatures range from 50 to 94°C, and flow rates range from about 7 to 26L/s [41].

The geothermal fluid which is produced in wells is used in thermal facilities, for heating the city, housing and industry. In 2017, there are a total of 2500 subscribers which are used in geothermal resources, 500 of them are house and 2000 of them are workplace [41]. Geothermal water is provided to hotels for spa and treatment purposes, during summer and winter periods. With the change of the system, geothermal water at the desired temperature and flow rate are provided. The clean water circulating in the closed circuit to the residences is kept active for 12 months by working at different levels, heating and hot water during winter months, and in summer, for use in hot water.

The monthly heating cost for the year 2019 was TL140/100m^2 for the residences and TL88/30m^2 for the businesses. TL1.40/m^2 increase is made for units in houses that are larger than 100m^2 and in businesses that are larger than 30m^2 [42].

Table 4.3 Hot water wells in Gönen [42]

Production Well	Year	Depth (m)	Temperature (ºC)	Flow (l/s)	Situation
G-1	1976	133	82	14,7	not used since 1990
G-2	1976	534,6	82	20	not used since 2002
G-3	1985	308,25	79	20	used as a reinjection well since 2002
G-4	1990	432,5	75	15	not used since 2002
G-5	1993	332	77	13,45	not used since 1997
G-6		385			no production
G-7	1995	325	62	30	backup production well
G-8	1996	280	62	20	backup production well
G-9	1998	560	94	8	backup production well
G-10	1998	265	69	20	backup production well
G-11	1999	816	89	8	no production due to low pressure
G-12	2002	502	72		production well
G-13	2002	356	71	20	production well
G-14	2002	325	70		no production due to low pressure
G-15	2001	188			backup production well
G-16	2003	216,3	84	25	production well
G-17	2004	230	70	20	production well

4.2.2.3 Simav Geothermal District Heating

In the vicinity of Simav, there are three hot springs. These are Eynal, Çitgöl and Naşa spas. Simav-Eynal thermal springs are one of the significant geothermal fields in

Turkey. In 1987, the hotel in Eynal thermal spring was first heated with a well heat exchanger system with a temperature of 160ºC at 725m depth in wells opened by MTA General Directorate after 1985. Current sources in the field are established for spa tourism, central heating and greenhouse farming in Simav.

Geothermal studies started in 1990 with two wells, and today 13 wells continue to work. The year, depth and temperature values of hot water wells in Eynal hot springs are given in Table 4.4 [43].

Table 4.4 Eynel hot water wells in Simav
(Source: Özkaya, M. Galip; Variyenli, Halil İbrahim; Yonar, G. [43])

Production Well	Year	Depth (m)	Temperature (ºC)	Flow (l/s)	Situation
E-1	1985	68.60	142.5	-	Artesian
E-2	1985	149.50	158	-	Artesian
E-3	1985	150	149	50	Artesian
EJ-1	1987	725.20	162.4	72	Artesian
EJ-2	1990	958	157.47	1	Artesian
E-4	1994	220	98	1	Artesian
E-5	1994	300	97	6	Artesian
E-6	1994	196.6	157	60-80	Artesian
E-7	1997	58	58	0.3	Artesian
E-8	1997	161	161	50	Artesian
EJ-3	1997	151	151	40-60	Artesian
E-9	2005	98	98	60	Artesian
E-10	2005	108	108	80-100	Artesian

The water vapour above 120°C-160°C from the wells in Eynal hot spring is delivered to the Simav heat exchanger centre under the ground with 1°C temperature drop by pumps after gas and vapours extraction in separator tanks and reduced to 98°C. The heat of geothermal hot water is transferred to clean hot water using exchangers and again transferred to the city with special package steel pipes. The subscribers are given hot water again through the inside of the heat exchanger and boilers. Hot water in 50°C coming out of the central heat exchanger building is sent back to Eynal Hot Springs for reinjection. Geothermal fluid produced in wells is used for heating 95% of buildings in the district. These buildings comprise houses, schools and public buildings with a total number of 15000. Hot water taken from heat exchangers returns to Eynal region at 48ºC. Some of this water feeds the system, and the rest is distributed to meet the hot water needs of the aqua park, baths and laundry facilities. The temperature of the hot water going to the buildings is about 65-70°C, the temperature of the water used in the kitchen and bathroom is 40-50°C [43].

4.2.2.4 Diyadin Geothermal District Heating

Diyadin is a tectonic collapse where is rich in the energy deposits. Studies show a significant relationship with the active tectonic structure of the region. The location of the geothermal field is south and 5-7km far from the city centre of Diyadin. The potential of this geothermal field is up to 750L/s. There are seven wells with a total volume flow rate of 750L/s, and the average well discharge temperature is 78°C.

In 1997, the MTA started to search for geothermal energy. Diyadin geothermal system was established in 1998 with the participation of Diyadin Municipality and Ağrı particular provincial administration. Two wells, MT98-1 and MT98-2, were opened. MT98-1 is at a depth of 129m. When the well reaches this depth, it became artesian and gave 150 liter water per second. MT98-2 well was opened the only 77m. Between 70 and 800°C water was obtained from these wells. After these wells, four more wells were opened by the MTA and about 70–80°C hot water was obtained from these wells. However, these wells can be opened up to 215m. Besides, it can be said that the depth of these drilling holes is inadequate considering that this temperature increases 2-3°C at every meter in the weak zones, which is more than 1°C at every meter as the reservoir rocks descend into the deep [44].

There are one heat centre, one promotion centre and three geothermal wells within the company. One of the production wells is heating the greenhouse with 40 decares, and the other wells are heating the district of Diyadin. The heating system project in Diyadin district was started in 1998 with the idea of 400 residential heating, and it was put into the service in 1999. In the first place, 150 houses were heated, and the system could not be continued. Today, around 150 houses are still heating. Although it has more water temperature than the water temperature obtained in many residential areas in Turkey, the number of houses benefiting from the least is seen in Diyadin. This shows that the region does not benefit from the central heating system.

CHAPTER 5

METHODOLOGY

The pre-project report is the first step in calculating the size of mechanical areas that will be involved in the architectural design of a building. As a result of this report, the system to be implemented is finalized based on the joint decisions taken with the architect and investor. Economic, environmental and spatial sizes should be taken into account as a result of system selection. In this section, depending on the choice of heating system, the methods that are used to calculate the heating loss of buildings, the amount of fuel used by different systems to meet this heat loss, the amount of CO_2 thrown into the atmosphere and the spatial requirement of the systems have been explained and formulated. A typical housing structure designed based on different climatic conditions was evaluated using these methods.

5.1 Heat Loss Calculation

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. The equipment to meet the heating energy needs are also designed according to the optimum capacity. The TS2164 calculation method was used to determine the capacity of the heating system [4].

The requirement for heating energy in a building is the minimum energy required for the heating system to be kept at the comfort temperature specified in the heating season. There are two different approaches for heating energy calculations: Dynamic methods and Static methods.

<u>Dynamic Methods:</u> It considers the time-dependent change of the thermal mass of the building. It is a method of calculating heat stored in the building mass and released from this mass to the environment. The data of internal and external temperature values, solar

energy values, air condition, heating and cooling system working status are evaluated, and the data of calculations are performed. They are sophisticated methods that take into account the immediate or hourly change of energy transfer in the building.

Static Methods: It is the method in which experimental dynamic effects are determined by using standardised average values and heat gain and losses are taken into account. It is widely used because of practical and usable calculations.

Two different calculation methods stand out in the static approach method being followed. These are the methods in which heat losses and gains are calculated using the degree-day method and the average external ambient temperature. These methods are discussed monthly and seasonal heat loss calculations.

5.1.1 TS 2164 Calculation Method

In the design phase of the heating systems established to meet the heat requirements of buildings, net heat loss is determined if necessary, for the environment to be heated. Concerning the design of the heating system, the "Heating System Design in Buildings" standard (TS2164) is used [4]. For the specified standardised values, constant conditions are accepted every day of the year, and heat losses and heat gain are obtained in the structure. These heat losses are based on the determination of the capacity of the steam boiler.

The heat requirement value for the heating environments is calculated by collecting the increased heat requirement values (Qi) and the infiltration heat requirement values (Qs) [4].

$$Q_h = Q_i + Q_s \tag{5.1}$$

5.1.1.1 No Incremental Heat Requirement Calculation

Required heat value is essential in the design phase of the heating systems determined to meet the heat requirement in buildings. It is calculated with Newton's Law of cooling and Fourier heat transfer equation. The thermal radiation effect in

TS2164 is considered as indirect only in orientation increases. Heat conduction is a heat transfer mechanism in which there is a continuous transition of kinetic energy between groups of particles at the atomic level. As a consequence of the second law of thermodynamics, heat transfer occurs in the direction of decreasing temperature. Heat conduction is expressed by the following Fourier equation ((5.2).

$$\dot{Q}_{cond} = -k.A.\frac{dT}{dx} \tag{5.2}$$

where k is the conduction heat transfer coefficient in W/mK, A is the surface area perpendicular to the heat transfer, and dT/dx is the temperature gradient in K/m.

Heat convection is the mode of heat transfer between a solid surface and the adjacent liquid or gas that is in motion, and it involves the combined effects of conduction and fluid motion that is expressed by the following equation ((5.3) [4].

$$\dot{Q}_{conv} = h.\mathrm{A}.(T_s - T_\infty) \tag{5.3}$$

where h is the *convection heat transfer coefficient* in W/m^2·K, A is the surface area through which convection heat transfer takes place, T_s is the surface temperature, and T_∞ is the temperature of the fluid sufficiently far from the surface.

Heat transfer problems with convection and conduction can be calculated by the thermal resistance approach in a one-dimensional steady-state analysis. In terms of energy efficiency, conductive thermal resistances (R_{cond}) of all the components from 1 to n and heat convection resistance values at the outside and inside surfaces (R_o and R_i) are determined by using following equation (5.4).

$$\begin{gathered} R_{cond} = \frac{L_1}{k_1} + \frac{L_2}{k_2} + \frac{L_3}{k_3} \dots \dots . . + \frac{L_n}{k} \\ R_o = \frac{1}{h_o} \\ R_i = \frac{1}{h_i} \end{gathered} \tag{5.4}$$

Where, L is the thickness of the material (m), and R is the thermal resistance coefficient (m^{2}K/W). Thus, the overall heat transfer coefficient, (U) value of the structural shell is calculated as in equation (5.5)

$$U = \frac{1}{R_o + R_{cond} + R_i} \tag{5.5}$$

The values of R_i and R_o gave in the table mentioned in TS825 [45] should be used for the values of convective thermal resistance on the inner and outer surfaces of the structural elements (APPENDIX).

Table 5. 1 that is prepared by TS825 shows the recommended U value according to the thermal insulation regions of Turkey [45]. During the design phase of new buildings, the energy requirement is calculated by selecting the material, the size of the elements and the specific solutions.

Table 5. 1 The recommended max u-values according to districts [45]

	U_{Wall}	$U_{Ceiling}$	$U_{Basement}$	U_{Window}
District 1	0.70	0.45	0.70	2.4
District 2	0.60	0.40	0.60	2.4
District 3	0.50	0.30	0.45	2.4
District 4	0.40	0.25	0.40	2.4

Some factors such as the environment of the building, the direction it looks at, the status of the environment structures, the working conditions of the heating system change the theoretical temperature requirement value. The incremental heat requirement is determined by equation (5.6). Total heat loss from each component such as external wall surrounding the environment, window, door, ceiling, and the floor gives the incremental heat requirement for the environment to be heated.

$$Q_o = \sum U.A.(T_\mathrm{i} - T_O) \tag{5.6}$$

Indoor temperature T_i and outdoor temperature T_o are determined based on the meteorological data from previous years [36]. T_i is assumed to be constant at 20°C.

The temperature values that are adjacent to the unheated buildings and environments required heating are shown in Table 5.2 depend on the exterior temperature values. It is essential to choose the correct temperature values of the roof and soil contact surfaces for projecting.

Table 5.2 Projected temperature values for unheated area [45]

<table>
<tr><td rowspan="2">Roof Overall Heat Transfer Coefficient U (W/m^{2}K)</td><td colspan="14">Outdoor Temperature (°C)</td></tr>
<tr><td>3</td><td>0</td><td>-3</td><td>-5</td><td>-9</td><td>-10</td><td>-12</td><td>-15</td><td>-18</td><td>-20</td><td>-21</td><td>-24</td><td>-25</td><td>-27</td></tr>
<tr><td>$U_d<2.3$</td><td>12</td><td>9</td><td>6</td><td>3</td><td>0</td><td>-1</td><td>-3</td><td>-6</td><td>-9</td><td>-10</td><td>-12</td><td>-12</td><td>-14</td><td>-15</td></tr>
<tr><td>$2.3<U_d<5.8$</td><td>9</td><td>6</td><td>3</td><td>0</td><td>-3</td><td>-4</td><td>-6</td><td>-9</td><td>-12</td><td>-13</td><td>-15</td><td>-15</td><td>-17</td><td>-18</td></tr>
<tr><td>$U_d|>5.8$</td><td>6</td><td>3</td><td>0</td><td>-3</td><td>-6</td><td>-7</td><td>-9</td><td>-12</td><td>-15</td><td>-16</td><td>-18</td><td>-18</td><td>-20</td><td>-22</td></tr>
<tr><td>If the unheated volume is connected to the outside air</td><td>15</td><td colspan="2">12</td><td>10</td><td colspan="2">9</td><td colspan="2">6</td><td colspan="3">3</td><td colspan="3">0</td></tr>
<tr><td>If the unheated volume is limited to the outside air and opens to a volume</td><td>9</td><td colspan="2">6</td><td colspan="3">3</td><td colspan="2">0</td><td colspan="3">-3</td><td colspan="3">-6</td></tr>
<tr><td rowspan="2">Soil Under Flooring
Soil Adjacent to Outer
Wall up to 2 m Depth</td><td colspan="3">9</td><td colspan="5">6</td><td colspan="5">3</td><td>0</td></tr>
<tr><td colspan="3">3</td><td colspan="5">0</td><td colspan="5">-3</td><td>-6</td></tr>
<tr><td>Unheated Volume Temperature Surrounded by Cabin-Heated Volumes</td><td colspan="14">15</td></tr>
<tr><td>Unheated Volume Temperature Surrounded by Stove-Heated Volumes</td><td colspan="14">10</td></tr>
<tr><td>Boiler Room</td><td colspan="14">between 15-20</td></tr>
</table>

5.1.1.2 Incremental Heat Requirement Calculations

The calculated no incremental heat requirement value is increased by a specific increase coefficient depending on the conditions of the environment where it is located. The incremental heat requirement (Q_i) determines the value required for the determination of the heating system. Incremental heat requirement is calculated by using equation 5.7.

$$Q_i = Q_o(1 + Z_D + Z_H + Z_W) \tag{5.7}$$

These incremental coefficients given by TS2164 are selected from the relevant tables as combined increase coefficient (Z_D), direction increase coefficient (Z_H) and high-fold increase coefficient (Z_W) [4].

i. Combined Increase Coefficient (Z_D)

Table 5.3 Combined increase coefficient (Z_D) [4]

Operating Condition	**% Z_D**			
I. Operation*	7	7	7	7
II. Operation**	20	15	15	15
III. Operation***	30	25	20	15
*) Installation works continuously, and the boiler fire is extinguished only at night. (Residential use) **) Boiler fever is extinguished completely every day for 10 hours. ***) Fire is completely extinguished every day for 14 hours or longer.				

The combined increase coefficient is equal to the sum of the cold outer surface heat loss increase (Z_A) and intermittent heating regime increase (Z_U). The value of Z_A is a coefficient that is determined to meet the heat transfer from ambient air to the surrounding cold external surfaces of the heated environment. The value of Z_U is taken into consideration to increase the cooling components to their old temperatures in a short time after reducing the heating load in the system and stopping the operation for a while. The combined increase coefficients Z_D were regulated in Table 5.3.

ii. Direction Increase Coefficient (Z_H)

Table 5.4 Direction increase coefficient (Z_H) [4]

Direction	**S**	**SW**	**W**	**NW**	**N**	**NE**	**E**	**SE**
%Z_H	-5	-5	0	5	5	5	0	-5

The sunlight can be affected depend on the location of the environment to be heated in the building. Direction increase coefficient given in Table 5. 4 is taken into consideration for rooms with outer walls, no direction increase is required in internal volumes.

iii. High-fold Increase Coefficient (Z_W)

Table 5.5 Increase in Suggested Floor Heights (Z_W) [4]

	Total Number of Floors												Z_W %
	4	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	
Floor Number	3,2,1	3,2,1	3,2,1	3,2,1	3,2,1	3,2,1	3,2,1	3,2,1	3,2,1	3,2,1	4,3,2,1	5,4,3,2,1	0
	4	4	5,4	5,4	5,4	6,5,4	6,5,4	6,5,4	6,5,4	6,5,4	7,6,5	8,7,6	5%
		5	6	6	7,6	8,7	9,8,7	9,8,7	9,8,7	9,87	10,9,8	11,10,9	10%
				7	8	9	10	10	11,1	12,11,10	13,12,11	14,13,12	15%
								11	12	13	14	15	20%

Another factor that affects the heat loss from the building is the wind speed on the outer surfaces. As the wind speed will increase with the elevation above ground level, the heat transfer resistance of the upper floors of the buildings decreases and the heat losses increase accordingly. Also, due to the lack of insulation in the installation columns, heating water is cooled a little until it reaches high floors (Table 5. 5). For these reasons, the high-fold increase is added to the heat requirement value.

The air temperature in the heating environments is not the same at all points. The temperature differences between air temperatures also increase while the floor height of the environment increases. Considering the situation explained before, %5 increase margin can be applied for each 1m height in volume with floor height is more than 4m.

5.1.1.3 Infiltration Heat Loss Calculation

Air leakages can be occurred by the pressure differences between the outer and inner environment from gaps of building components such as windows and doors that are opened and closed in a heated environment. In order to meet this low yield, additional heat should be given to the indoor environment. The heat requirement can be calculated approximately by equation ((5.8).

$$Q_i = \sum(aL).R.H.\Delta T.Z_e \tag{5.8}$$

a : Air leakage coefficient (m^3/mh) (Table 5. 6)

L : Fuga length (m)

R : Room state coefficient

H : Structural status coefficient(Wh/m^3 °C)

ΔT : Internal and external air temperature difference (°C)

Z_e : Constant coefficient (1.2 for environments with a window on both outer walls, and 1 in other cases is taken)

Table 5.6 Air leak coefficient (m^3/mh)

Material	Shape of Window and Door	a
Wood	Single Window	3
	Double Glazed Window	2,5
	Double Window	2
Plastic Frame	Single- or Double-Glazed Window	2
Steel or Metal Frame	Single Window	1.5
	Double Glazed Window	1.5
	Double Window	1.2
Interior Door	Non-threshold Door	40
	Threshold Door	15
Window values are assumed for exterior doors.		

Air leak coefficient values is given according to material and shape of window and door in Table 5. 6.

Room state coefficient R shows the resistance of the room against the air leaking from the window and escaping from the interior doors. The R coefficient calculation cannot be fully calculated. Therefore, R is considered to be 0.9 for rooms that have a window and door with standard size and R is considered to be 0.7 for rooms that have big windows and only one door.

The building status coefficient H is related to environment and wind conditions in the area where the building is located. The coefficient is selected according to the conditions specified in Table 5.7.

Table 5.7 Coefficient of state of the building H (Wh/m^3 ^{o}C)

State of the Region	State of the Building	H Coefficient	
		Row Housing	Discrete Housing
Normal Region	Protected	0.279	0.396
	Free	0.477	0.675
	Fully Free	0.700	0.977
Windy Region	Protected	0.477	0.675
	Free	0.700	0.977
	Fully Free	0.95	1.314

5.1.2 Degree-Day (DD) Method

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.

Annual heat loss from the unit surface area of the wall is calculated by equation (5.9).

$$\dot{q}_{year} = 86400.k.\mathrm{HDD}.U \tag{5.9}$$

q_{year} : Annual heat loss from the unit surface of the wall (W/m^2)

HDD: The sum of the differences between internal and external ambient temperatures in the days of yearly heating (°C.day)

1 day: 86400 seconds

k: Surface multiplication coefficient

Because of the heat loss from the unit surface of the external wall, the annual amount of energy required for heating E_{year} is calculated by dividing the annual heat loss by the efficiency of the heating system.

$$E_{year} = 86400.k.\mathrm{HDD}.U/\eta \tag{5.10}$$

E_{year} : Annual energy required for unit surface area (J/m^2)
η: Efficiency of heating system

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

$$Q_{year} = 24.k.\mathrm{HDD}.U.A \tag{5. 11}$$

Q_{year}: Annual Heat Loss (Wh)
A: Area of Calculation (m^2)
1 day: 24 h

k is the surface multiplication coefficient and is given in TS 825. This value is equal to 1 for external walls and terraced roofs, which are in contact with the outside air, while it is equal to 0.8 and 0.5 for ceilings (with pitched roof) and floors (ground floors), respectively. The change of k value is due to the change of outside air temperature used in calculations [45].

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. Researches show that people need to warm up at temperatures below 18.3°C. In the literature, it is accepted that the difference in temperature between indoor and outdoor environments is 3°C and it is stated that the balance temperature for heating can be obtained at 15°C for outdoor environments in general [46].

Many countries use different definitions for degree-day calculation. The European Community Statistical Office (Eurostat) recommends the method for HDD given in equation (5.12) to create a comparable and common use [47].

$$\begin{gathered} HDD = (18°C - T_m)value \quad T_m \leq 15°C\ (heating\ threshold) \\ HDD = 0 \quad if \quad T_m > 15°C \end{gathered} \tag{5.12}$$

T_m = Average daily temperature

Similarly, cooling degree day (CDD) explains the severity of the temperature taking into calculation for the temperature of the external environment and room at a given time. Although it is not officially designated temperature, the threshold temperature is 22°C in the energy management practices for the construction sector[47].

$$CDD = (T_m - 22°C)\ value \quad T_m > 22°C\ (cooling\ threshold) \qquad (5.13)$$
$$CDD = 0 \quad if \quad T_m \leq 22°C$$

Calculations are done daily. Monthly and daily warmth are obtained by collecting daily results. According to Turkey's degree-day (DG) values, it is divided into four heat insulation zones as shown in

Figure 5.1. The provinces with the lowest DD value are in the first region, and the provinces with the highest DD values are in the fourth region.

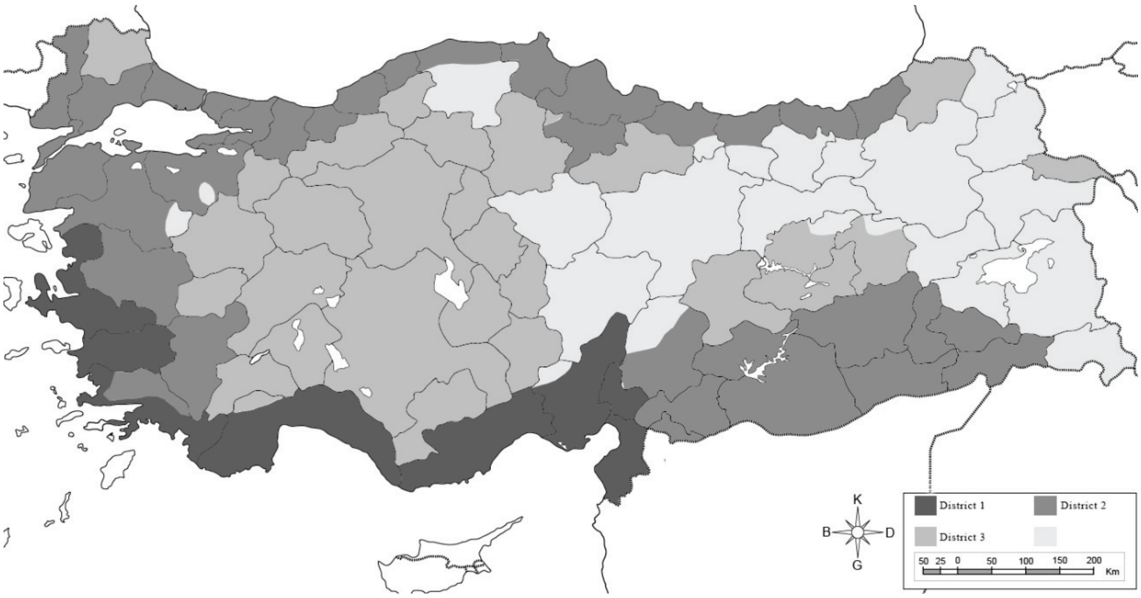

Figure 5.1 Thermal insulation area map for Turkey [45]

5.2 Cost Calculation

The system that will meet the heating energy needs of the building has different economic parameters such as fuel consumption, investment cost, m^2-based values of the parts that are allocated to the system.

5.2.1 Annual Fuel Consumption and Cost Calculation

The annual heating energy requirement is the energy necessary in which the building is at a constant ambient temperature of 20°C during the heating season. During the heating season, the heating system does not run continuously. When buildings are used in low capacity or not used at all, a controlled heating system provides significant energy savings. Therefore, the annual fuel consumption of the building is calculated considering the need for annual heating energy [36].

$$B_y = \frac{Q_{Year}}{H_u \cdot \eta_k} \tag{5.14}$$

B_y : Annual fuel amount (kg or m^3)
H_u : Lower heat value of the fuel used (kJ/kg or kJ/m^3)
η_b: Efficiency of the heating system

Information about the lower heat value of the fuels and efficiency of boilers used in central heating systems is given in Table 5.8 [45]. The rated capacity and the operation of the boiler at full load is a decisive criterion in determining the boiler efficiency. When annual fuel consumption is calculated, the average boiler efficiency which is considered to be the efficiency of the heating system includes some error margin. The margin of this error was neglected in this study.

Table 5.8 Approximate lower heating value of the fuels and boiler efficiency [45]

Fuel Type	Lower heat value H_u	Efficiency of the boiler, η_b
Lignite coal	10 000 kJ/kg	0.60
Manisa/Soma coal	20 000 kJ/kg	0.65
Zonguldak coal	29 000 kJ/kg	0.65
Fuel oil	41 600 kJ/kg	0.75
Natural gas	34 485 kJ/kg	0.75

Cost analysis is also fundamental in heating system selection. Because, a serious budget is allocated for heating, especially in cold climates. The annual fuel cost per year of heating energy requirement is calculated from the following equation (5.15);

$$M_y = B_y C_{source} \tag{5.15}$$

M_y: Annual fuel cost (TL)
B_y: Annual fuel amount (m^3 or kg)
C_{source}: Fuel unit price (TL/m^3 or TL/kg)

Table 5.9 shows the unit prices of the fuels. TKİ (Turkish coal administration) was based on sales prices in April 2019 (APPENDIX). Unit prices for fuel oil and natural gas were determined for April 2019 by Tesisat Journal (APPENDIX). Unit prices for geothermal resources vary based on provinces. The base unit prices were determined as TL0.00997/kWh for İzmir,TL 0.0792/kWh for Simav. Prices are fixed for Gönen and Diyadin. While paying 140TL per month in Simav district for 100 m^2 housing, and 30TL per m^2 is paid for the heating period accepted on October 15-May 15 in 2019 in Diyadin district.

Table 5.9 Unit price of the fuel types

Fuel Type	**Price**
Coal	TL0.503/kg [48]
Fuel oil	TL4,42/kg [48]
Natural gas	TL1.32/m^3 [48]
Geothermal	TL0.0997/kWh for Balçoca TL0,0790/kWh for Simav

*1 m^3 natural gas = 0.67 kg natural gas

5.2.2 Investment Cost Calculation

A building needs the necessary equipment; connect components and storage areas for the HVAC system chosen to meet the heating requirements. There is a unique area called a mechanical room inside the building for the installation and operation of this system. The size of the allocated area varies according to the selected system. Because of the equipment used in HVAC systems such as boiler, pump, as well as fuel system to operate according to the type of storage space is emerging.

The selected purchase costs of all the elements used in the system are taken into account in the calculation of the initial investment costs of building heating systems. Besides, installation costs and annual repair and maintenance fees can be assessed depending on the system and fuel type.

Storage area or equipment is needed in different systems depending on the type of fuel storage. In the system that is working with fuel oil or coal, the fuel must be stored. However, there is no need for storage in natural gas and geothermal district heating systems. The size of the fuel tank is chosen by determining the climate conditions of the building area and transportation facilities, the way the building is used, and how often the fuel will be stored according to the storage characteristics. The fuel tank should be large enough to meet the fuel requirement of the facility for at least 20 days. The storage space required for solid-fuel systems is calculated as in equation (5.16) [36]. When calculating storage for solid fuels, the height of the stack should be taken into account. Coal stack height should not exceed 1.5-2m and width should not exceed 5m.

$$B_{fuel} = \frac{Q_{boiler} Z_d Z_s}{H_u \eta_b}$$

$$A_{coal} = \frac{B_{fuel}}{\rho \cdot h} \tag{5.16}$$

B_{fuel} : Fuel amount for the boiler (kg or m^3)

Z_d : Daily working time (h/day)

Z_s : Monthly working time (day)

H_u : Lower heat value of the fuel used (kJ/kg or kJ/m^3)

η_b: Efficiency of the heating system

A_{coal} : Storage area (m^2)

h: Max storage height (m)

ρ: Fuel density to be stored

Fuel tanks manufactured for storage of liquid fuels are standard and are specified in TS712. After determining the amount of fuel to be stored, the volume of the liquid fuel tank is found by equation (5.17). Depending on the position of the fuel tank upright or bed selection is made.

$$V_{fuel\ oil} = \frac{B_{fuel}}{\rho \cdot D} \tag{5.17}$$

$V_{fuel\ oil}$: Volume of the fuel tank (m^3)
D: Storage load factor (It is assumed to be 1 for all calculations.)

Elements such as boiler, pump, and expansion tank to be selected for the systems are selected from the catalogues of various companies according to the heat requirement of the building.

5.2.3 Area of Utilization and Cost Calculation

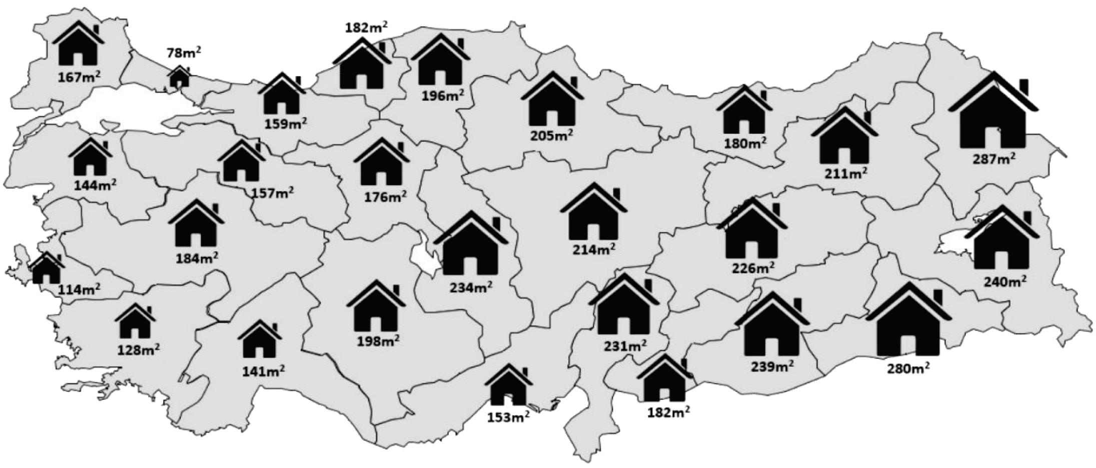

Figure 5.2 Sizes of housing that can be received 300,000 TL in Turkey for 2017 (Source: Central Bank of the Republic of Turkey [49])

There are specially designed volumes within the building depending on the system and fuel selection to be used for heating the building. In addition to the initial investment costs of the systems, there is also the cost of the use of the spaces to be used. The m^2 sizes of the houses of the Central Bank of Turkey which can be purchased for 300000 TL for December 2017 are shown in Figure 5.2 [49]. According to these values, it is stated that in Izmir, 114 m^2 in 300000 TL, 144 m^2 in Balıkesir, 184 m^2 in Kütahya and 287 m^2 in Ağrı.

This report is based on the determination of m^2 prices of the volumes allocated for the heating system. According to the Consumer Price Index calculated by the Turkish Statistical Institute (TSI), unit price conversions for February 2019 are stated in Table 5.10. (1$=5.26 TL)

Table 5.10 Unit prices for house according to cities

CITY	2017 December PRICE (TL/m^2)	2019 February PRICE (TL/m^2)	2019 February PRICE ($/$m^2$)
İZMİR	2631.58	3205.00	609.32
BALIKESİR	2083.33	2537.00	482.32
KÜTAHYA	1630.43	1985.00	377.38
AĞRI	1045.30	1273.00	242.02

The areas obtained from the volumes allocated for heating systems are included in different usage areas within the structure, providing the user with a broader usage area, as well as the economically positive effects of the owners.

5.3 CO_2 Emission Account

CO_2 emissions mean that carbon is released into the atmosphere using the heat machines used in fossil fuels. The impact of global warming and climate change, which has been accelerating in recent years, has become even more pronounced with the increase in CO_2 emissions. 85% of the waste gases released as a result of burning the fuels used in the heating system are CO_2 [7]. Therefore, CO_2 emissions are taken into account as a general approach in calculations. In the regulation on energy performance in buildings published in the Official Gazette, the annual CO_2 emissions of buildings are limited, and global environmental improvements are targeted. Depending on the energy source used (fuel type), 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 5.18 below for fossil sources according to the annual heating energy requirement [7].

$$SEGM_y = 0.278x10^{-3} B_y H_u FSEG \tag{5.18}$$

$SEGM_y$: Annual CO_2 emission amount (kg eqv.CO_2)

FSEG: CO_2 emission conversion coefficient by fuel type (kg eqv.CO_2/kWh)

For geothermal energy CO_2 emission is calculated from equation (5.19, because fuel amount is equal to total heat loss value for a year.

$$SEGM_y = Q_{year}\, FSEG \tag{5.19}$$

Emission conversion coefficients (*FSEG*) depend on the type of fuel to meet energy needs. The conversion coefficients specified in Table 5.11 were used for calculating CO_2 emissions [7].

Table 5.11 CO_2 emission conversion coefficient by fuel type [7]

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

CHAPTER 6

BUILDING DESCRIPTION

6.1 General Information About Reference Building

A reference building was designed to comply with the building and climate standards for use in the calculations. This building is a residential building with four floors. On the first floor which is thought as the entrance floor, there are three apartment units and a mechanical room. There are four apartment units on each floor after the first floor. The properties and size of this field according to system selection are detailed in the following sections. Ground floor spaces were not included, and it was accepted that they would be positioned in the form of a separate system in the structure consisting of totally 15 apartment units. Table 6.1 represents some of the structural and dimensional characteristics of the case study building.

Table 6.1 Architectural and dimensional characteristics of the case study building

Situation	**Feature**
Situation of the building	Discrete order building
Purpose of using	Residence
Number of floors	4 (1 entrance, 3 floors)
Statistical situation	Reinforced concrete carcass
Width	19.00 m
Height	12.00 m
Depth	42,80 m
Height of floor	3.00 m
Windows	Wood profile double glass
Outdoors	Wood & metal profile with heat insulation
Roof	Unused roof

Perspective models of the building is shown in Figure 6. 1 and Figure 6. 2. At the beginning of the study work, a building was designed, and the as-built plans (ground floor, first floor and roof plan) of the reference study building were drawn using Autodesk AutoCAD R2016©. In these drawings, conceptual plans and locations of the selected architectural details can be seen.

Figure 6. 1 1st perspective model of the case study building

Figure 6. 2 2nd perspective model of the case study building

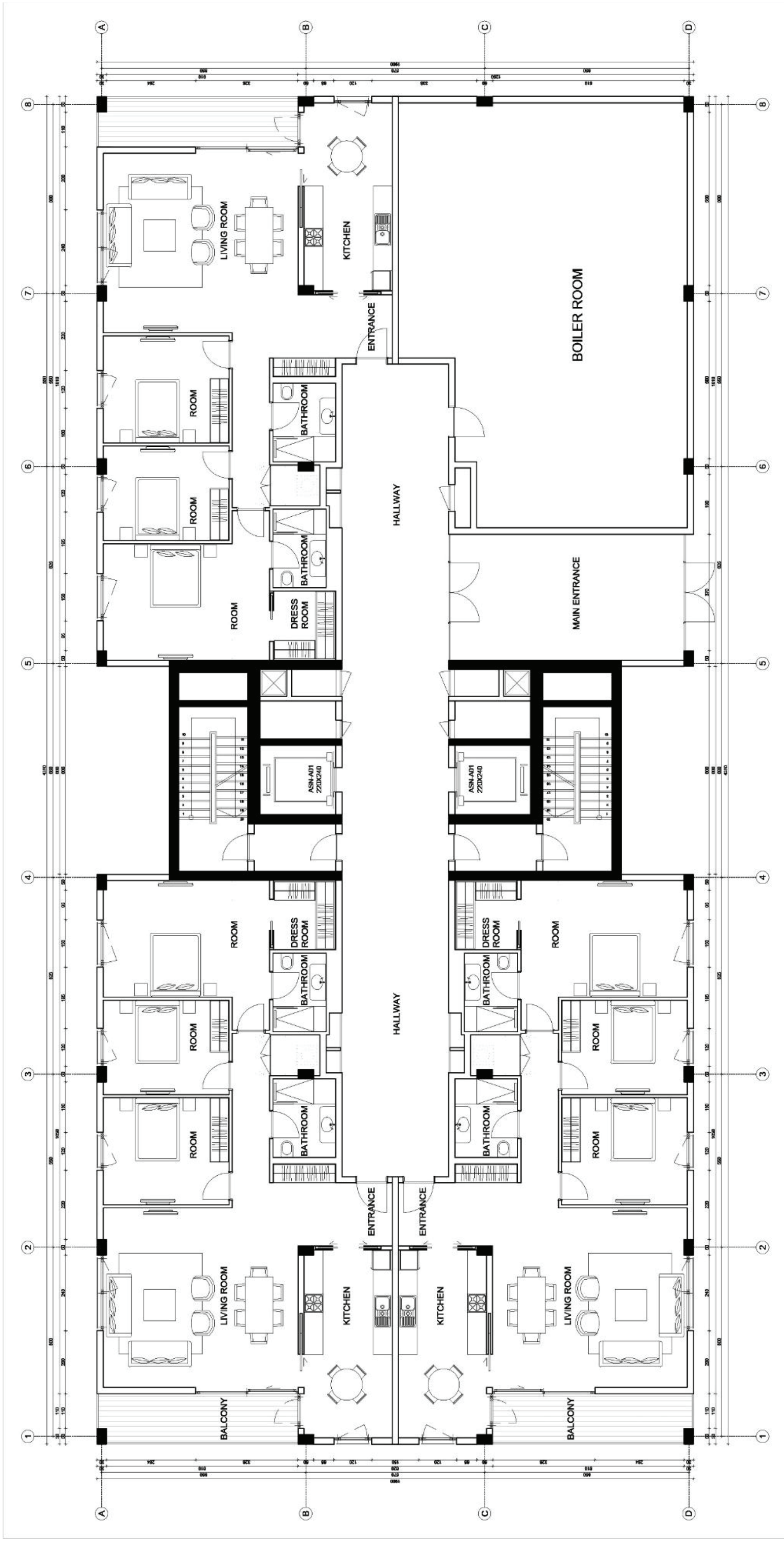

Figure 6.3 Ground floor plan of the study building

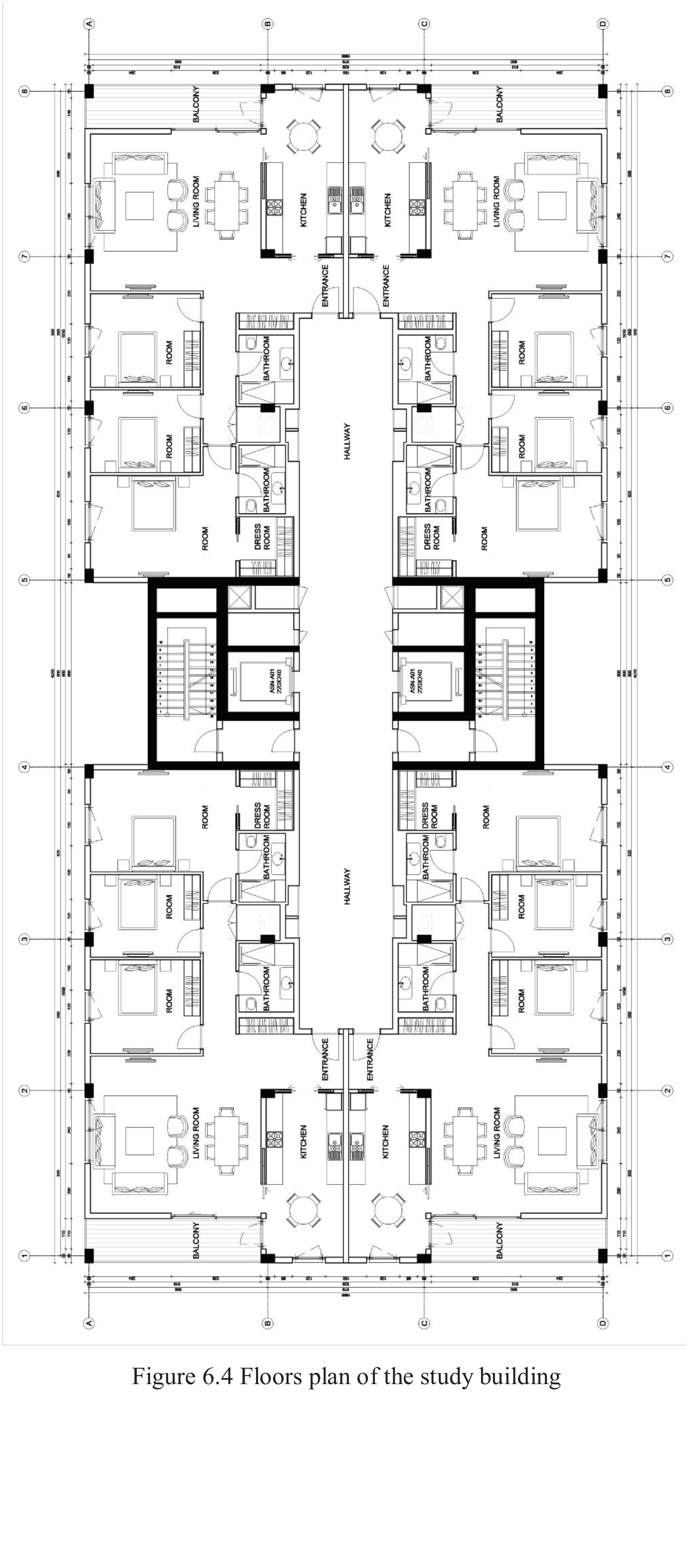

Figure 6.4 Floors plan of the study building

6.2 Location of the Building & Weather Conditions

The designed building was accepted that it was located in four different cities in Turkey. These provinces are İzmir/Balçova, Balıkesir/Gönen, Kütahya/Simav and Ağrı/Diyadin. Each of the four selected provinces represents one of the thermal regions of Turkey. Another point that is considered during the selection phase of the provinces is that the region has geothermal resources and is actively using geothermal district heating systems as shown in Figure 6.5. Geothermal settlements in Turkey are also shown according to different temperature groups, along with cities in four climate heating zones selected in Figure 6.5.

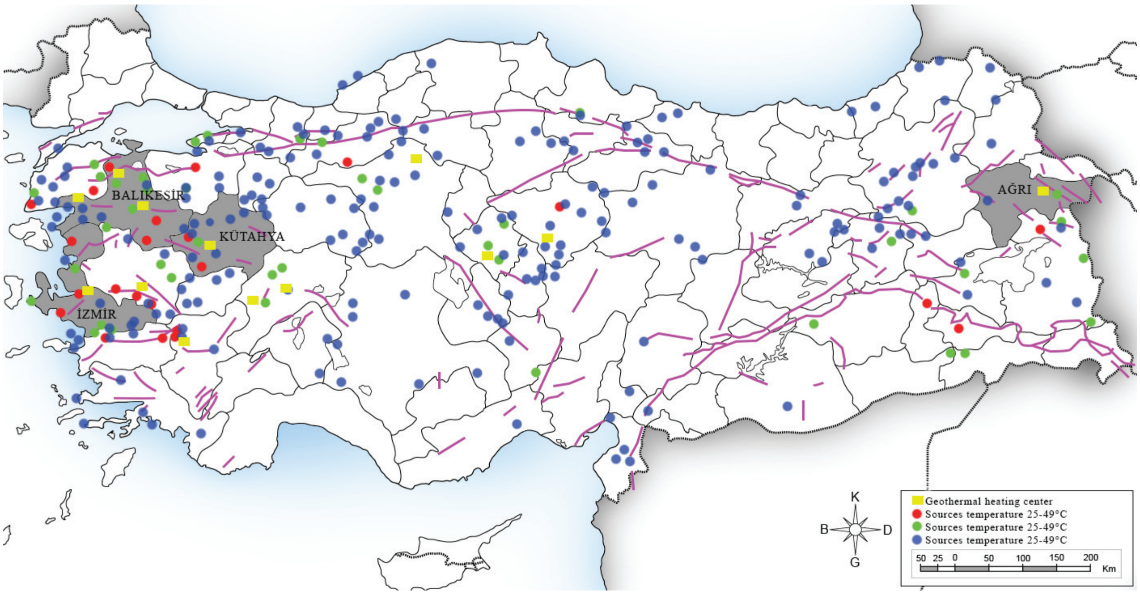

Figure 6.5 Distribution map of geothermal source [34]

Izmir-Balçova (District I): It is one of the coastal shores of the Aegean region located between 38° 24' 45" North latitudes and 27° 8' 18" East longitudes. It is surrounded by the mountains; the east is surrounded by the Aegean Sea extending to the inner parts. The province, which is located in the Mediterranean climate zone, is hot and dry summer with warm and rainy winters. According to the climate data between 1938 to 2017 [47], the lowest average temperature is 5.7°C in January; the highest average temperature is 33.1°C in July. Average hours of sunshine are highest in July and total sunshine time for a year is 96.2 hours [47] (APPENDIX).

Balıkesir -Gönen (District II): Located between 40° 6' 17"northern latitudes and 27° 39' 14" east longitudes, Gönen is a district in the north of Balıkesir, to the south of the Marmara region. The distance from the sea level of the district centre is 33 m. The northeast is covered with plains, the west and south-east part are covered with hilly areas. It is under the influence of the Mediterranean and the Black Sea climate. Since there is no natural obstacle in the north, the effects of the Sea of Marmara reach the inner parts. The summers are hot, and the winters are rainy. The lowest average temperature is 1.3°C in January; the highest average temperature is 31.2°C in July and August. Average hours of sunshine are highest in July and and total sunshine time for a year are 81 hours [47] (APPENDIX).

Kütahya-Simav (District III): 39° 5' 17"North latitudes and 28° 58" 39" east latitudes. It is located to the west of Kütahya and has 800 m height. Due to the distance from the sea and its height, the effects of the transition climate are seen. The lowest average temperature is -3.3°C in January, the highest average temperature is 28.3°C in August. Average hours of sunshine are highest in July and and total sunshine time for a year are 72.2 hours [47] (APPENDIX).

Ağrı-Diyadin (District IV): Located between 39° 43' 8.6" northern latitudes and 43° 3' 2.1" east longitudes, Ağrı is a district in the eastern side of Turkey. The pain that occupies 5 of the ten highest peaks of our country is at an altitude of 1640 m. It is under heavy terrestrial climatic conditions, driven by hard and long winter conditions. The winters are tough and long, and the summers are hot. Snow is very effective from rainfall. The lowest average temperature is -15.7°C in January, the highest average temperature is 30°C in August. Total sunshine time for a year are highest in July and average hours of sunshine are 74 hours [47] (APPENDIX).

The main parameter for the performance of the regional heating system is climate data. Climate effect is mainly due to external air temperature. It is based on below 15°C when heating is required to achieve 20°C internal temperature. If the outdoor temperature is above 22°C, heating is not necessary. The average daily temperature data for 2018 for İzmir, Balıkesir, Kütahya and Ağrı were used in the calculations. Figure 6.6 shows the duration curve of the external temperature values of provinces. According to the graph, the area of 15°C and below gives the required degree-day value for that province. While this graph was created, the average daily temperature data was obtained for each day for a year and obtained by forming a 6th degree polynomial curve line. For example, the HDD (Heating degree day) value was calculated at 803°C.day according to data for İzmir for 2018.

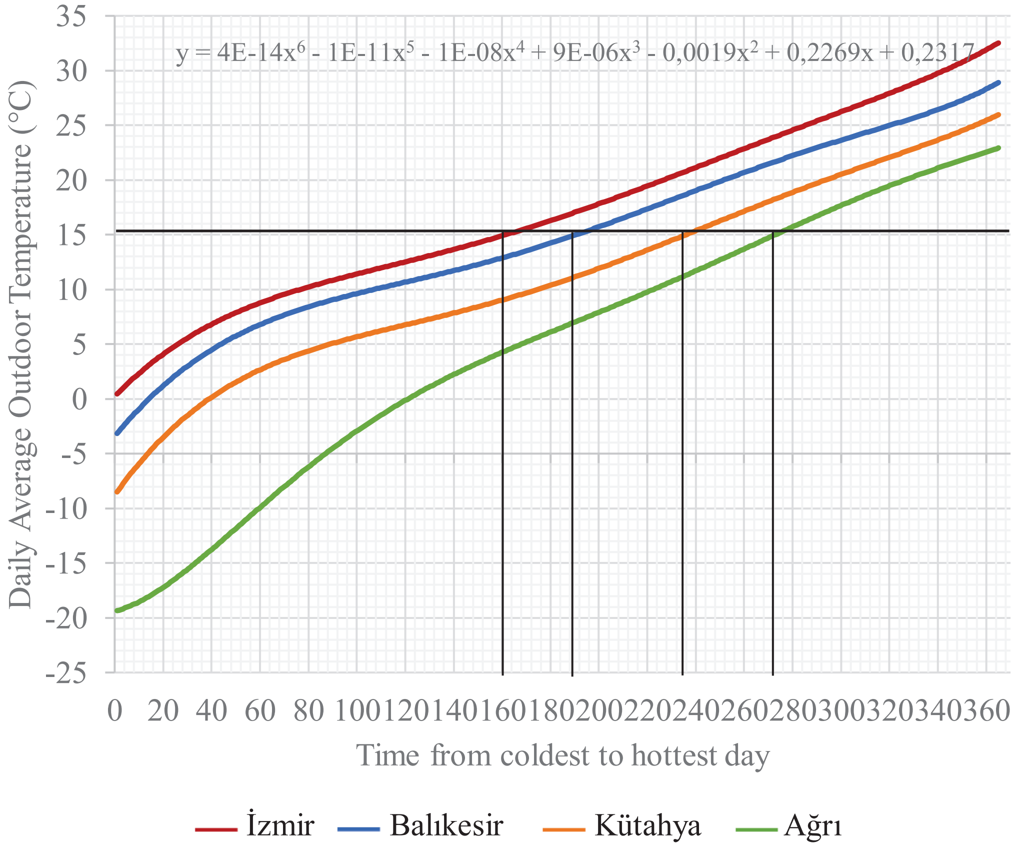

Figure 6.6 Duration curve of outdoor temperature

Table 6.2 Degree day values for 2018 according to the cities

District	District I	District II	District III	District IV
City	İzmir/Merkez	Balıkesir/Gönen	Kütahya/Simav	Ağrı/Merkez
HDD	803	1577	1894	3367
T≤15°C	110	168	188	247
CDD	735	318	78	80
T>22°C	148	97	56	45

Heating degree day and cooling degree day values of the selected cities that are prepared to use for the calculated total annual heat loss of the building from duration curve graph are shown in Table 6.2 in 2018 [47].

6.3 Building Components

The heat transfer coefficient values of the building elements depend on the materials preferred in the design and thermal conductivity of designed materials.

6.3.1 Exterior Walls as Building Component

According to the building survey, there are two types of exterior walls of the reference building. One of them is comprised of solid bricks with the dimension of 19x13.5x19cm [50], heat insulation material (3 cm), cement plaster (3 cm) and gypsum plaster (2 cm). The other wall is comprised of reinforced concrete with a thickness of 25 cm, heat insulation (5 cm), cement plaster (3 cm) and again gypsum plaster (2 cm). The thickness of the insulation material is given for the calculations of İzmir. The walls are bonded by double layers of these solid bricks and cement-based mortar as an adhesive material. The heat insulation material is used from outside of the walls and the overall heat transfer coefficient, U-values change according to the district.

The thermal and physical properties of the wall materials are represented in Figure 6.7 for İzmir as an example. According to this, U values were 0.669W/m^{2}K for a solid brick wall and 0.674W/m^{2}K for a reinforced concrete wall. The thermal and physical values taken for the other three cities are given in APPENDIX . Architectural detail of a typical exterior wall can be seen in Table 6.4.

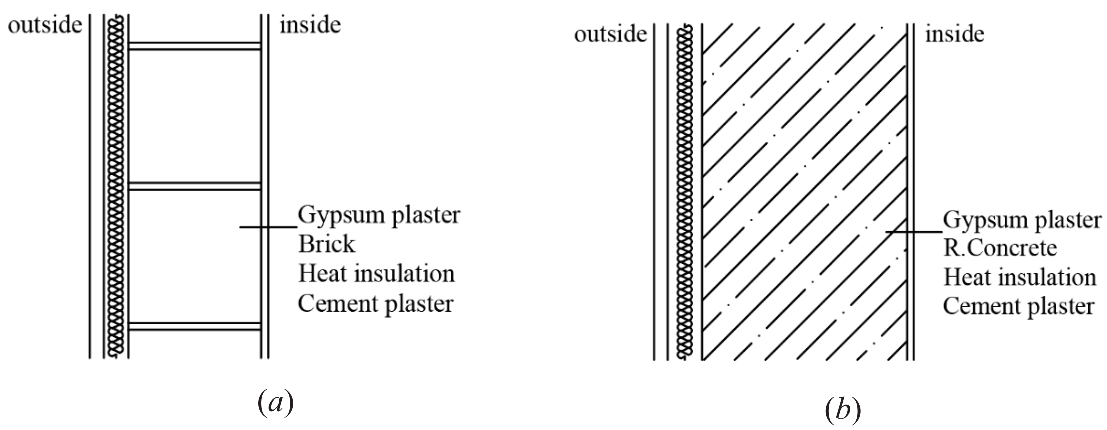

Figure 6.7 Exterior brick wall (*a*) and reinforced concrete wall (*b*) construction

Table 6.3 Overall heat transfer coefficient calculation for exterior brick wall for İzmir

Heat Loss Surface Type	Building Materials	Thickness of Building Materials	Thermal Conductivity	Thermal Resistance	Overall Heat Transfer Coefficient
		L	k	R	U
		(m)	(W/mK)	(m^2K/W)	(W/m^2K)
Outside Wall	R_i			0.13	
	Gypsum Plaster	0.02	0.38	0.053	
	Brick	0.19	0.33	0.576	
	Heat Insulation	0.03	0.045	0.667	
	Cement Plaster	0.03	1	0.030	
	R_o			0.04	
Total				**1.495**	0.669

Table 6.4 Overall heat transfer coefficient calculation for conrete wall for İzmir

Heat Loss Surface Type	Building Materials	Thickness of Building Materials	Thermal Conductivity	Thermal Resistance	Overall Heat Transfer Coefficient
		L	k	R	U
		(m)	(W/mK)	(m^2K/W)	(W/m^2K)
Reinforced Concrete Wall	R_i			0.13	
	Gypsum Plaster	0.02	0.38	0.053	
	Reinforced Concrete	0.3	2.5	0.120	
	Heat Insulation	0.05	0.045	1.111	
	Cement Plaster	0.03	1	0.030	
	R_o			0.04	
Total				**1.484**	0.674

6.3.2 Slabs and Floors as Building Component

The reference building has four floors. In the ground floor, the slab is constructed a reinforced concrete slab; and details and component properties of this floor are represented below in Figure 6.8 and Table 6.5 for İzmir. This floor is composed of a reinforced concrete slab (15 cm), a levelling layer which is a kind of mortar (2 cm), the heat insulation (5 cm), cement-based mortar (3 cm) and the wood floor as the finishing material. The finishing material changes according to the function of the zone except for the wet rooms. A typical detail from the first floor can be seen in Figure 6.8. Thermophysical properties of the materials are shown in Table 6.5. U values of the floor construction are calculated as 0.640 W/m^{2}K for İzmir.

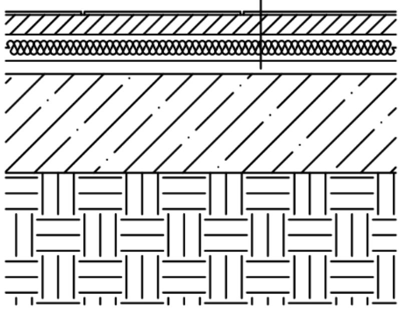

Figure 6.8 Floor construction

Table 6.5 Overall heat transfer coefficient for floor for İzmir

1	2	3	4	5	6
Heat Loss Surface Type	**Building Materials**	**Thickness of Building Materials**	**Heat Conduction Coefficient**	**Thermal Resistance**	**Overall Heat Transfer Coefficient**
		L	**k**	**R**	**U**
		(m)	**(W/mK)**	**(m^{2}K/W)**	**(W/m^{2}K)**
Basement (earth contact)	R_i			0.17	
	Wood Floor	0.005	0.13	0.038	
	Cement Finish	0.03	1.4	0.021	
	Heat Insulation	0.05	0.045	1.111	
	Self-Levelling	0.02	1.4	0.014	
	Concrete	0.15	1.3	0.115	
	Blokaj	0.15	1.65	0.091	
	R_o			0	
Total				**1.562**	0.640

The roof of the reference building is cradle roof. This slab of the roof is composed of a reinforced concrete slab (15 cm), the heat insulation (0.08 cm) and gypsum plaster (0.02 cm). Detail of roof slab can be seen in Figure 6.9, and the thermo physical properties of the materials are given in Table 6.6. U value of the roof construction is calculated 0.426 W/m2K for İzmir.

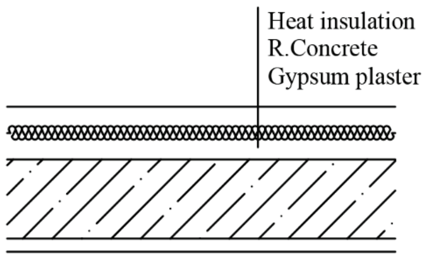

Figure 6.9 Roof construction

Table 6.6 Overall heat transfer coefficient for roof for İzmir

1	2	3	4	5	6
Heat Loss Surface Type	**Building Materials**	**Thickness of Building Materials**	**Thermal Conductivity**	**Thermal Resistance**	**Overall Heat Transfer Coefficient**
		L	**k**	**R**	**U**
		(m)	**(W/mK)**	**(m^2K/W)**	**(W/m^2K)**
Ceiling (with roof)	R_i			0.13	
	Heat Insulation	0.08	0.04	2.000	
	Concrete	0.15	1.3	0.115	
	Gypsyum Plater	0.02	1	0.020	
	R_o			0.08	
Total				**2.345**	0.426

6.3.3 Doors and Windows as Building Components

The reference building has two types of doors. One of them is used for the entrance of the building, and the other one is used for exterior walls of the residences for reaching to the balconies. All the windows and exterior doors are made up of wood profiles and use the same connection details. U values of the door are assumed to be the same value that is 4 W/m^2K and the wood profile windows' U value is 2.2 W/m^2K in all calculation [36].

CHAPTER 7

RESULTS AND DISCUSSION

This section mainly includes the results of the building on total heat loss, fuel consumption, economic analysis and the spatial response to the chosen system and the interpretation of these results. In all calculations, the actual dimensions of the building and the thermophysical properties of the building materials selected within the framework of the TS825 Thermal Insulation Rules[45] in buildings and the one-year average outdoor weather data were used. The building was accepted as a single volume, and the heat loss calculations were made according to this situation. The amount of fuel used for different types and heating systems and annual fuel cost calculations were made under the data obtained. As a result of the analysis, the size of the mechanical room and the economic value of this room were calculated for four different heating systems with suitable capacity for the building. Calculations and results in Microsoft Excel are shown in the following sections in the form of charts and graphs. Detailed charts are included in the appendices section.

7.1 Total Heat Loss Calculation

In order to examine and comment on the situation of the reference building, heat loads of the same type of the building in different heating zones were calculated with the help of the heat loss methods described in Chapter 5. The total heat load found is based on the capacity of the required boiler and the heat exchanger, and the energy consumption of the building is determined for different heating zones by using the degree-day method.

Figure 7.1 shows the distribution of the annual heat loads of the building by provinces according to the HDD values obtained from Table 6.2.

According to the comparison of the other provinces with the lowest HDD value of Izmir located in District 1, annual heat loss, in other words, the energy required to be given to the building was also the lowest. 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.

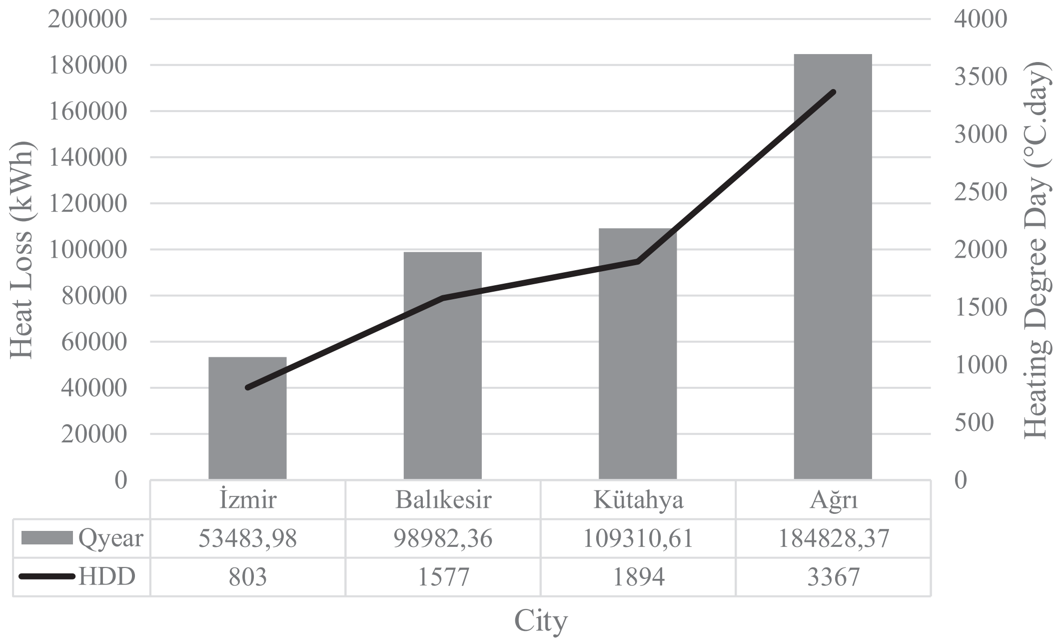

Figure 7.1 Heat loss and HDD values according to cities

7.2 Annual Fuel Consumption Calculation

7.2.1 Fuel Consumption Analysis for Reference Building

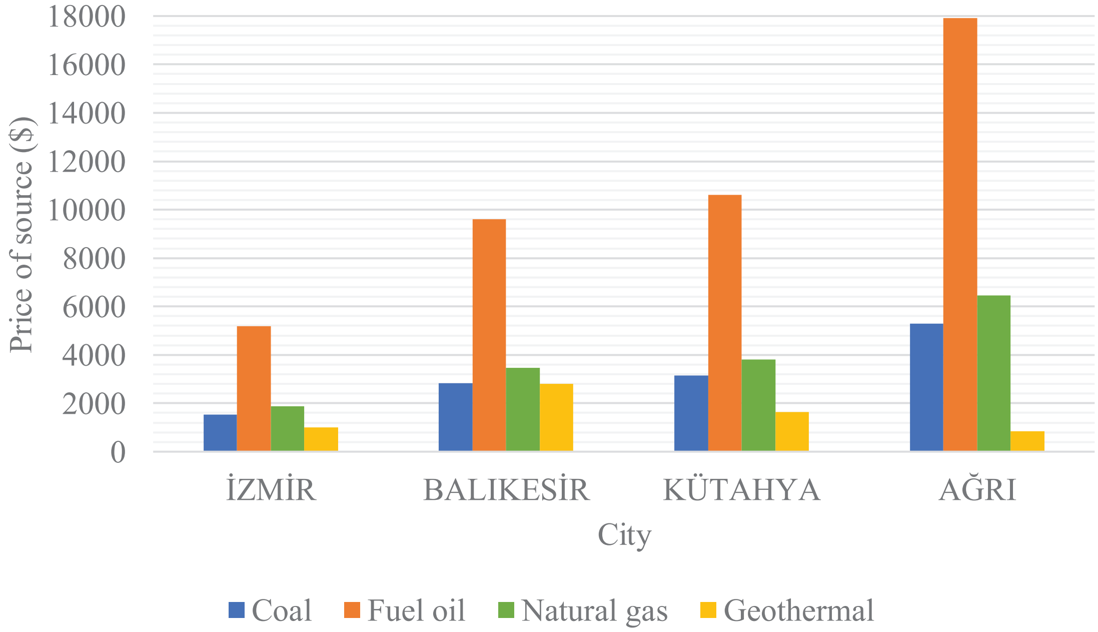

Figure 7.2 Price of used heat sources according to cities

Annual fuel consumption and calculations of the reference building for İzmir, Balıkesir, Kütahya and Ağrı are given in equation (5.14) and (5.15). In line with the information and data provided, the cost comparison of four energy sources based on provinces is shown in Figure 7.2 and Table 7.1.

Table 7.1 Annual price of the energy sources

	City		İZMİR	BALIKESİR	KÜTAHYA	AĞRI
COAL	Q	kWh	53484.0	98982.4	109310.6	184828.4
	H_u	kJ/kg	20000	20000	20000	20000
	η_k	\	0.60	0.60	0.60	0.60
	B_y	kg	16045.2	29694.7	32793.2	55448.5
	C_{source}	TL/kg	0.50	0.50	0.50	0.50
	$Price_{Total}$	TL	8070.73	14936.44	16494.97	27890.60
	$Price_{Total}$	$	1534.4	2839.6	3135.9	5302.4
FUEL OIL	Q	kWh	53484.0	98982.4	109310.6	184828.4
	H_u	kJ/kg	41600	41600	41600	41600
	η_k	\	0.8	0.8	0.8	0.8
	B_y	kg	6171.2	11421.0	12612.8	21326.4
	C_{source}	TL/kg	4.4	4.4	4.4	4.4
	$Price_{Total}$	TL	27276.8	50481.0	55748.4	94262.5
	$Price_{Total}$	$	5185.7	9597.1	10598.6	17920.6
NATURAL GAS	Q	kWh	53484.0	98982.4	109310.6	184828.4
	H_u	kJ/m^3	34485.0	34485.0	34485.0	34485.0
	η_k	\	0.75	0.75	0.75	0.75
	B_y	m3	7444.5	13777.4	15215.0	25726.4
	C_{source}	TL/kg	1.32	1.32	1.32	1.32
	$Price_{Total}$	TL	9826.7	18186.2	20083.9	33958.9
	$Price_{Total}$	$	1868.2	3457.5	3818.2	6456.1
GEO.	Q	kWh	53484.0	98982.4	109310.6	184828.4
	C_{source}	TL/kWh	0.0997		0.0790	
	$Price_{Total}$	TL	5332.4	14700.0	8635.5	4500
	$Price_{Total}$	$	1013.8	2794.7	1641.7	855.5
Average dollar rate for February 2019					**1 $ = 5.26 TL**	

It is seen that the cost of fuel oil from the chosen source to meet the annual energy needs for the building based on region is 5k$ per year for İzmir, 18k$ per year for Ağrı with the highest cost. Natural gas follows the fuel oil. Natural gas and coal provide a saving of half compared to the fuel oil. Geothermal energy is one of the essential sources of energy in the world. Table 7.1 shows the fuel consumption rates and costs of a structure heated by coal, fuel oil, natural gas and geothermal resources in detail. The heat loss values (Q), the lower calorific value (H_u) and the boiler thermal value (n_k) of the fuel are given in Table 7.1. Accordingly, the required amount of fuel (B_y) was calculated and fuel costs for the fuel unit price (C_{source}) were given based on TL and US$. For geothermal energy, on the other hand, the price of direct unit energy has been calculated because there is no boiler. The monthly geothermal heating cost for Balıkesir/Gönen was calculated at the fixed price determined by accepting that it was heated for 7 months. For Ağrı/Diyadin, the seasonal fixed price of 30 TL was applied on m^2 basis for the dates of 15 October-15 May, which is accepted as the heating season. In Balıkesir, the price of coal and geothermal energy and heating is very close, resulting from the constant price application in Gönen district.

7.3 Boiler Room Capacity

The boiler room in which the heating system of the building will be placed is designed by the decisions made during the design stage. Depending on the system, the spatial size and economic data of this area should be evaluated during the construction process.

7.3.1 Boiler Room Size

This course aims to calculate the mechanical chamber sizes of the systems which operate with the fuel base for the reference building. As a general approach, accounts were made according to the size of the tank to meet the 30-day need. The daily working time (Z_d), monthly working time (Z_s), the lower calorific value of coal (H_u) and efficiency of the system working by coal (η_b) are given. Accordingly, the amount of fuel needed (B) has been determined. Coal storage requires a dedicated space in the mechanical chamber instead of special equipment. Depending on the climatic conditions of the area where the building is located, the use of the building, transportation facilities, fuel storage properties are decided. In Table 7.2, the required storage area (A_{coal}) was determined by dividing the coal density (ρ) and maximum storage height (h) following the coal requirement calculated.

Table 7.2 Storage for coal

City	$\dot{Q}$ (kW)	Z_d (h/day)	Z_s (day)	H_u (kJ/kg)	η_b	B (kg)	A_{coal} (m^2)	ρ (kg/m^3)	h (m)
İzmir	58.39	24	30	20000	0.6	12612.14	12.01	700	1.5
Balıkesir	73.61	24	30	20000	0.6	15900.31	15.14	700	1.5
Kütahya	72.72	24	30	20000	0.6	15708.57	14.96	700	1.5
Ağrı	88.64	24	30	20000	0.6	19145.59	18.23	700	1.5

Special equipment is needed for the storage of fuel oil. In Table 7.3, daily working time (Z_d), monthly working time (Z_s), the efficiency of the system working by coal (η_b) and the lower calorific value of coal (H_u) were given as similar to Table 7.2 in order to select the appropriate sizes of the fuel tank. Accordingly, the need for fuel oil (B) and the volume (V) of the tank to be selected were determined. Fuel oil tanks are standard size steel tanks. Liquid fuel tanks can be selected in horizontal or vertical type as specified in TS712 (APPENDIX). In this study, horizontal use of the selected fuel tank was preferred, and the area ($A_{fuel\ oil}$) of the tank which is considered suitable for the reference building was determined from the standard dimensions.

Table 7.3 Storage for fuel oil

City	q (kW)	Z_d (h/day)	Z_s (day)	H_u (kJ/kg)	η_b	B (kg)	$V_{fuel\ oil}$ (m^3)	ρ (kg/m^3)	D	$A_{fuel\ oil}$ (m^2)
İzmir	58.39	24	30	41600	0.75	4850.82	6.93	700	1	4.488
Balıkesir	73.61	24	30	41600	0.75	6115.50	8.74	700	1	4.488
Kütahya	67.48	24	30	41600	0.75	5606.41	8.01	700	1	4.488
Ağrı	88.64	24	30	41600	0.75	7363.69	10.52	700	1	6.42

In the selection of boilers, which are perhaps the most important part of heating systems, the boiler capacity of the building needs to be sufficient to meet the total heat loss. Total heat losses were calculated according to TS2164 [4] as described in Chapter 5. Table 7 4, the total heat loads of the building were calculated, and the outside temperature ($T_{outside}$) that are the non-heated environments, the soil contact floor and the roof; the design temperature values and the increase coefficients were given according to the cities. The temperature values of the environments to be heated are accepted as 20°C constant in each region.

Table 7. 4 Design temperature values [4]

				Projected Temperature (°C)			
City	Z_D	Z_H	Z_W	$T_{Basement}$	$T_{ceiling}$	$T_{outside}$	T_{inside}
İzmir	0.07	*0.05 **-0.05	*0 **0.05	9	9	0	20
Balıkesir				6	3	-6	20
Kütahya				6	-3	-12	20
Ağrı				3	-12	-24	20

*North façade of the building

**South façade of the building

The total heat loss values of a reference building are shown in Table 7. 5. Ağrı city which has the highest heat loss and needs the highest capacity of the boiler at the same time is located in the 4th heat region. Detailed representation of the total heat losses lost from building elements, increment coefficients and infiltration loads is shown in APPENDIX .

Table 7. 5 Heating capacity of the building

City	Capacity	
	Q (KW)	**Q (kcal/h)**
İzmir	58.39	50205.98
Balıkesir	73.61	63295.39
Kütahya	72.72	62532.14
Ağrı	88.64	76214.09

The boilers required for all these systems were selected following the information contained in the product catalogues of the companies working in this field.

The boiler and tank models required for solid, liquid and gas fuels are taken from the product catalogues and price list of Baymak brand (APPENDIX). Load values calculated according to TS2164 described in Chapter 5 were used for boiler capacities. Geothermal energy is used in the system for plate heat exchangers for Alarko brand product, and the price list was used (APPENDIX). The product numbers of the selected boiler and storage tanks are stated in Table 7.6, taking into account the needs of different provinces.

Table 7.6 Prefered type of heating products

City	COAL	FUEL OIL		NATURAL GAS	GEOTHERMAL
	Boiler	Storage	Boiler	Boiler	Boiler
	Model	Model	Model	Model	Model
İzmir	LİNYİT COMFORT 60 AUTO INSTALLATION	MYT 7	YAKUT 6" BOILER	YAKUT 6" BOILER	APE-3-4-22
Balıkesir	LİNYİTOMAT 80 PLUS FANLI (PUMPLESS)	MYT 10	YAKUT 8" BOILER	YAKUT 8" BOILER	APE-3-4-24
Kütahya	LİNYİTOMAT 80 PLUS FAN (PUMPLESS)	MYT 10	YAKUT 8" BOILER	YAKUT 8" BOILER	APE-3-4-24
Ağrı	LİNYİTOMAT 100 SOLID SOURCE FAN (3 ATU)	MYT 13	YAKUT 10" BOILER	YAKUT 10" BOILER	APE-3-4-25

The area occupied by the selected boiler in the room is calculated according to the information contained in the technical data tables from the catalogues. Table 7.7, Table 7.8 and Table 7.9 respectively, information on the boilers selected for coal, fuel oil and natural gas are given for four different provinces. It is observed that Balıkesir which is located in the 2nd heat district, has a higher heating capacity than Kütahya which is located in the 3rd heat district. The reason for this is due to the thickness of the heat insulation materials used in accordance with the U values[45] recommended for these two cities in different climatic regions. Geothermal heat exchangers are used instead of boilers. Table 7.10 gives the dimensions of the heat exchanger to meet the needs of each building in four different cities.

Table 7.7 Boiler for coal

City	Capacity		Boiler Capacity (kcal/h)	Width (m)	Height (m)	Depth (m)	A_{boiler} (m^2)
	Q (W)	Q (kcal/h)					
İzmir	58389.6	50205.98	60000	1.06	1.41	1.3	1.378
Balıkesir	73612.5	63295.39	80000	1.204	1.572	1.26	1.517
Kütahya	67484.6	58026.33	80000	1.204	1.572	1.26	1.517
Ağrı	88637.0	76214.09	100000	1.27	1.51	1.36	1.727

Table 7.8 Boiler for fuel oil

City	Capacity		Boiler Capacity (kcal/h)	Width (m)	Height (m)	Depth (m)	A_{boiler} (m^2)
	Q (W)	Q (kcal/h)					
İzmir	58389.6	50205.98	65000	1.3	0.75	0.865	1.12
Balıkesir	73612.5	63295.39	85000	1.37	0.815	0.9	1.23
Kütahya	67484.6	58026.33	85000	1.37	0.815	0.9	1.23
Ağrı	88637.0	76214.09	100000	1.52	0.815	0.92	1.40

Table 7.9 Boiler for natural gas

City	Capacity		Boiler Capacity (kcal/h)	Width (m)	Height (m)	Depth (m)	A_{boiler} (m^2)
	Q (W)	Q (kcal/h)					
İzmir	58389.6	50205.98	65000	1.3	0.75	0.865	1.12
Balıkesir	73612.5	63295.39	85000	1.37	0.815	0.9	1.23
Kütahya	67484.6	58026.33	85000	1.37	0.815	0.9	1.23
Ağrı	88637.0	76214.09	100000	1.52	0.815	0.92	1.40

Considering the area, they cover, it is clear that coal-fired boilers take up more space than fuel oil and natural gas as fossil sources. Geothermal heat exchangers, selected for the resource, take up 36 times less space than coal boilers.

Table 7.10 Heat exchanger for geothermal

City	Capacity (kW)	Boiler Capacity (kW)	Width (m)	Height (m)	Depth (m)	A_{boiler} (m^2)
İzmir	58.4	60	0.18	0.758	0.112	0.020
Balıkesir	73.6	80	0.18	0.758	0.212	0.038
Kütahya	67.5	80	0.18	0.758	0.212	0.038
Ağrı	88.6	125	0.18	0.758	0.212	0.038

Pipes, pumps, water storage etc. are assumed to be approximately the same for all system. Table 7.11 shows the total size of the area required for the installation of the equipment required for the heating system and the efficient operation of the system. A system that works with solid fuel, geothermal resource, with the need to place in the running system, it is observed that there was no significant difference between space needs.

Table 7.11 Boiler room sizes

City	$A_{c,room}$ (m^2)	$A_{fo,room}$ (m^2)	$A_{ng,room}$ (m^2)	$A_{g,room}$ (m^2)
İzmir	13.39	10.10	1.12	0.02
Balıkesir	16.66	10.21	1.23	0.04
Kütahya	16.48	10.21	1.23	0.04
Ağrı	19.96	14.24	1.40	0.04

Since storage needs require a significant amount of space compared to other systems, a larger space is required for coal-powered systems compared to other resources. Comparison of mechanical fields based on fuel types by provinces shows in Figure 7. 3.

In addition to coal and fuel oil systems, especially geothermal energy systems have little spatial need. Therefore, the spatial response to geothermal energy is not even clear in Figure 7. 3.

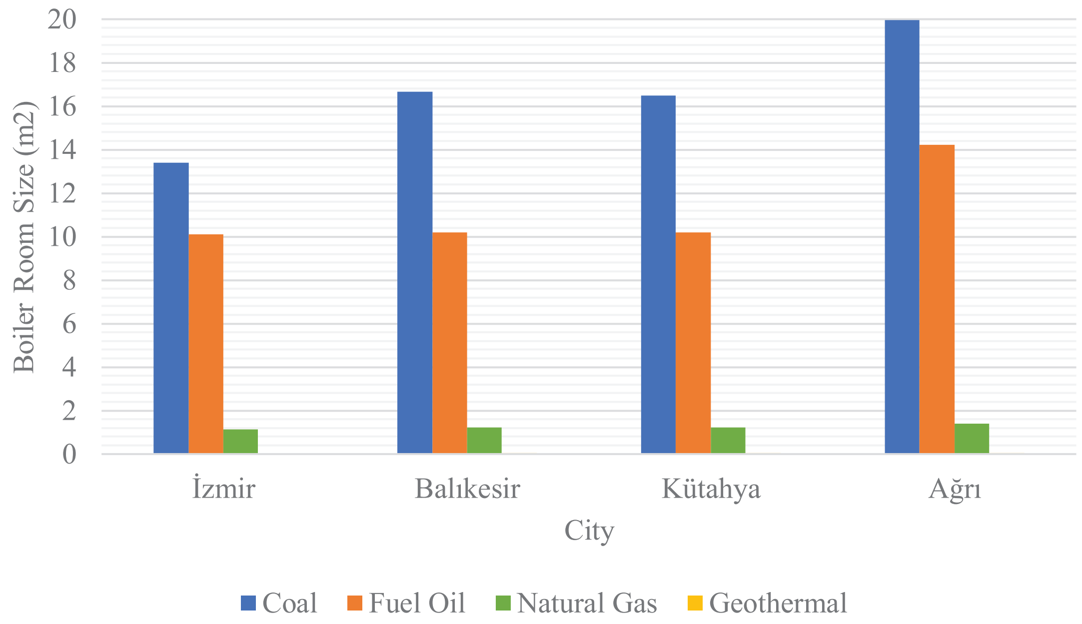

Figure 7. 3 Boiler room sizes according to cities

7.3.2 Boiler Room Economic Analysis

When analysing the cost of a boiler room, taking into consideration the economic values of the vehicles to be used as well as the economic values of the areas where these vehicles will be placed are important originality of this thesis.

7.3.2.1 Price of Heating System

Total investment costs of the boiler and storage products that are required for the central heating system of the building are as shown in Table 7.12, and they are calculated based on the catalogue prices of the products specified in Table 7.6. According to the calculations made independent of the price of the areas allocated to products, the investment required for solid fuel systems is about three times more than geothermal energy. Because geothermal energy does not need storage for fuel and plate heat exchangers have a high capacity in small size.

Table 7.12 Price of preferred type of heating products

City	COAL		FUEL OIL				NATURAL GAS		GEOTHERMAL	
	Boiler		Storage	Boiler	Total Price		Boiler		Boiler	
	Price (TL)	Price ($)	Price (TL)	Price (TL)	Price (TL)	Price ($)	Price (TL)	Price ($)	Price (TL)	Price ($)
İzmir	7034	1337.3	5200	3014	8214	1561.6	3014	573.0	2844	540.7
Balıkesir	6368	1210.6	6510	3431	9941	1889.9	3431	652.3	2988	568.1
Kütahya	6368	1210.6	6510	3431	9941	1889.9	3431	652.3	2988	568.1
Ağrı	10574	2010.3	8450	3878	12328	2343.7	3878	737.3	3060	581.7

1$=5.26 TL

7.3.2.2 Price of Area

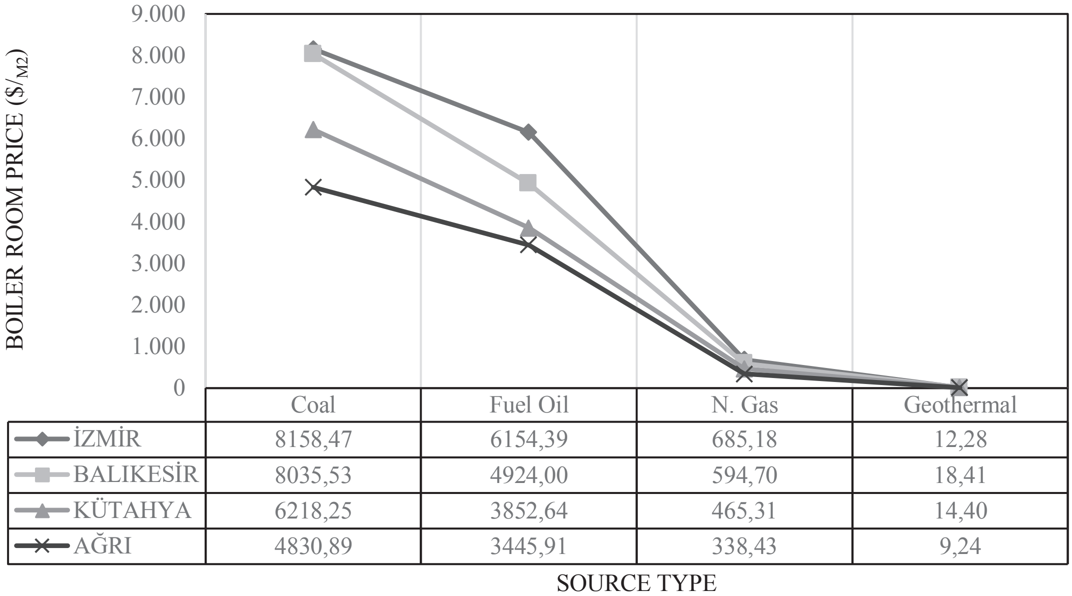

Figure 7. 4 Boiler room prices for energy sources according to cities

Many factors, from the material used in the building to the location, from the social facilities to the front, affect housing prices. One of the most important factors is the size of the house. In this case, if the space allocated for the housing is used for the mechanical room in a building, the price of the housing decreases due to the use of m^2. In Figure 7. 4, using Table 5.10, the prices lost from the mechanical room allocated depending on the heating system selection were determined.

7.4 CO_2 Emission Calculation

According to the types of fuel used for heating in houses, the amount of annual CO_2 emissions (SEGM) are calculated as shown in Table 7.13 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.

Table 7.13 CO_2 emission values for energy sources

	City		İZMİR	BALIKESİR	KÜTAHYA	AĞRI
COAL	By	kg	16045,2	29694,7	32793,2	55448,5
	H_u	kJ/kg	25115,0	25115,0	25115,0	25115,0
	FSEG	kg eqv.CO2 /kWh	0,433	0,433	0,433	0,433
	SEGM	kg eqv.CO2	48507,7	89772,8	99140,1	167631,6
F. OIL	By	kg	6171,2	11421,0	12612,8	21326,4
	H_u	kJ/kg	41860,0	41860,0	41860,0	41860,0
	FSEG	kg eqv.CO2 /kWh	0,3	0,3	0,3	0,3
	SEGM	kg eqv.CO2	23699,0	43859,5	48436,0	81898,2
N. GAS	By	kg or m3	7444,5	13777,4	15215,0	25726,4
	H_u	kJ/m^3	34535,0	34535,0	34535,0	34535,0
	FSEG	kg eqv.CO2 /kWh	0,234	0,234	0,234	0,234
	SEGM	kg eqv.CO2	16724,6	30952,0	34181,7	57796,3
GEOTH	B_y	kWh	53484,0	98982,4	109310,6	184828,4
	FSEG	kg eqv.CO2 /kWh	0,2	0,2	0,2	0,2
	SEGM	kg eqv.CO2	10696,8	19796,5	21862,1	36965,7

As can be seen from Figure 7.5, damage to the surrounding area of coal is much higher compared to other comparative resources. It has been observed that the results of CO_2 emissions from geothermal energy is most environmentally and natural resource, and natural gas follows the geothermal source. Emission value from coal is 4.5 times higher than geothermal energy and 2.9 times higher from natural gas.

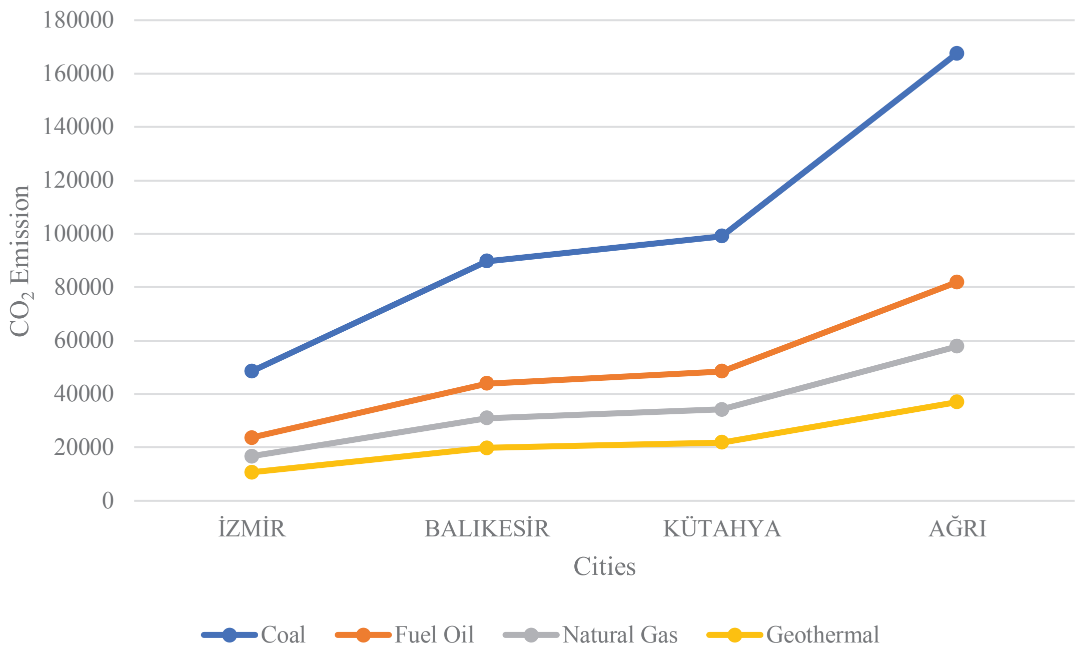

Figure 7.5 Distribution of CO_2 emissions for energy sources

7.5 Life Cycle Cost Calculation

Life cycle cost (LCC) analysis is to define a method to determine the level of economic profitability of a system, taking into account the overall lifecycle of a system. It defines the total cost that occurs during the entire life of the system through all stages such as installation, operation, maintenance, and purchase.

$$LCC = cost_{investment} + \left[\sum_{t=1}^{n} inflation_t \,.\, (cost_{fuel} + cost_{CO2,t}) \right] + R$$

$$cost_{investment} = cost_{area} + cost_{system} \tag{7.1}$$

$$R = cost_{system}(1 + i)$$

In this analysis, it is assumed that there is an increase in rates that take account of cost increases over time. Different solution criteria such as the number of years, money increase value, energy cost is determined in this economic analysis. In the LCC account, investment costs, operating costs, produced CO_2 emissions and renewal costs were taken into consideration. Investment cost ($cost_{investment}$) consists of the cost of the spatial size ($cost_{area}$) required by the system during the installation phase and the cost of the components ($cost_{system}$) required by the system.

Where, R is the cost of renovation of the system. It was decided that the pipes were not added to the calculations as the working life of the pumps is variable depending on the pressure and temperature and the average life of the pipes is assumed as 50 years. The lifetime of four different heating systems for coal, liquid fuels and natural gas is assumed approximately to be 15 years and 30 years for geothermal system. The reference building life for the LCC account was accepted as 30 years. For this reason, the cost of renewable fossil fuels twice during the life of the building must be taken into account.

The most important economic factor affecting variables throughout the building life is inflation rates. The annual average inflation rate for Turkey was calculated as 8.9% with the CAGRR (Compound Annual Growth Rate) method based on the average TÜFE (Consumer Price Index) values from 2008-2018.

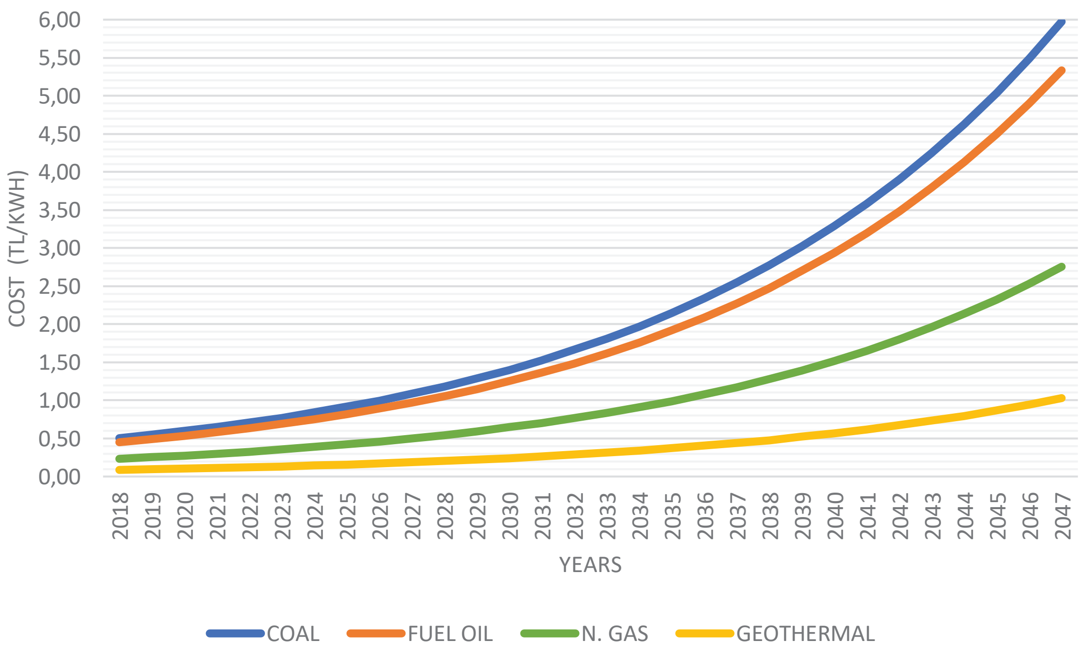

Figure 7.6 Evolution of energy prices

As shown in Figure 7.6, economic projection of different energy sources is expected to change in the coming 30 years; the accuracy is based on energy prices of coal, fuel oil, natural gas and geothermal energy. The overall cost of natural gas, fuel oil and coal are almost 2.5 times, 5.5 times and 6 times higher of geothermal energy cost, respectively. Therefore, this comparison shows that geothermal energy is much cheaper than other energy sources.

LCC includes the cost of CO_2 emissions produced during the years of the building. The observed carbon prices span a wide range, from less than \$1 up to \$140/tCO_2 according to the World Bank carbon pricing dashboard [51]. The carbon price is assumed \$25 per tonne. The annual average inflation rate was calculated as \$1.8. The operation cost can be calculated with the following equation 7.2:

$$cost_{CO2} = \sum_{t=1}^{n} inflation_t \frac{SEGMcost_{CO2}}{1000} \tag{7.2}$$

According to this, the LCC values obtained in thousand TL were given according to the 30-year economic analysis for coal, fuel oil, natural gas and geothermal systems in Table 7.7, Table 7.8, Table 7.9 and Table 7.10 respectively for İzmir.

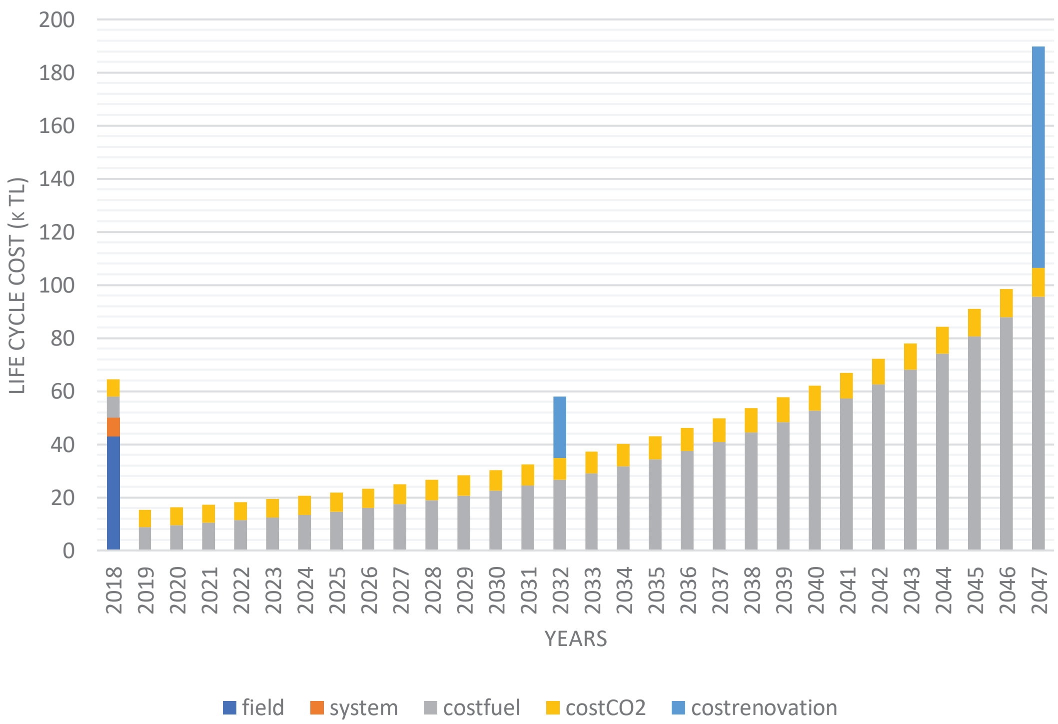

Figure 7.7 LCC for coal in İzmir

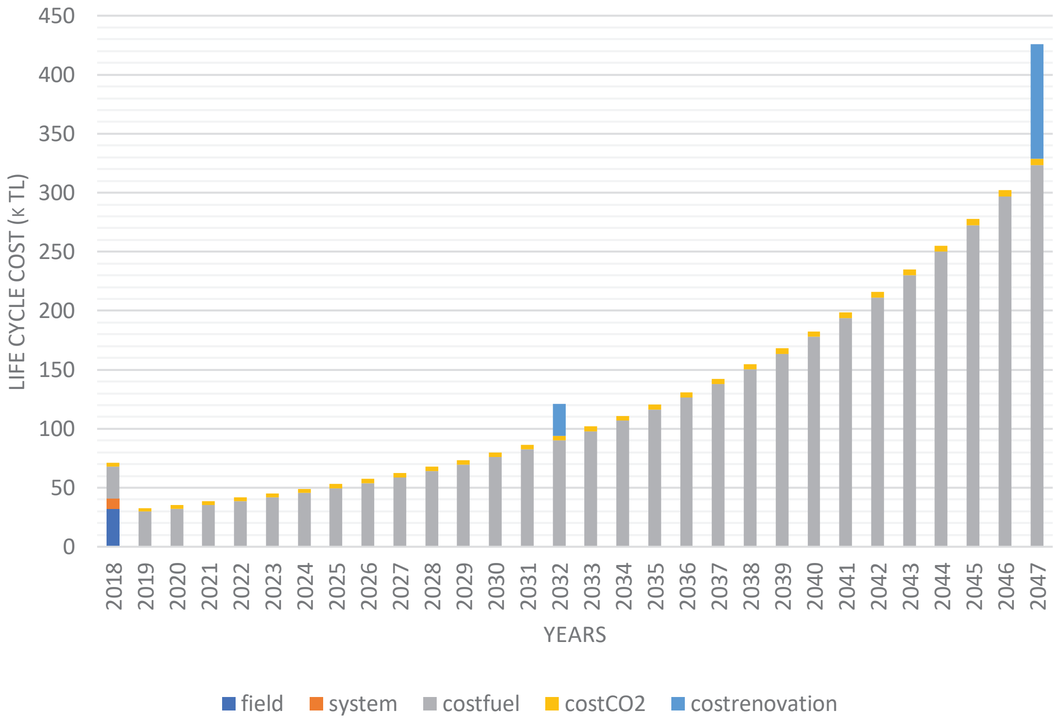

Figure 7.8 LCC for fuel oil in İzmir

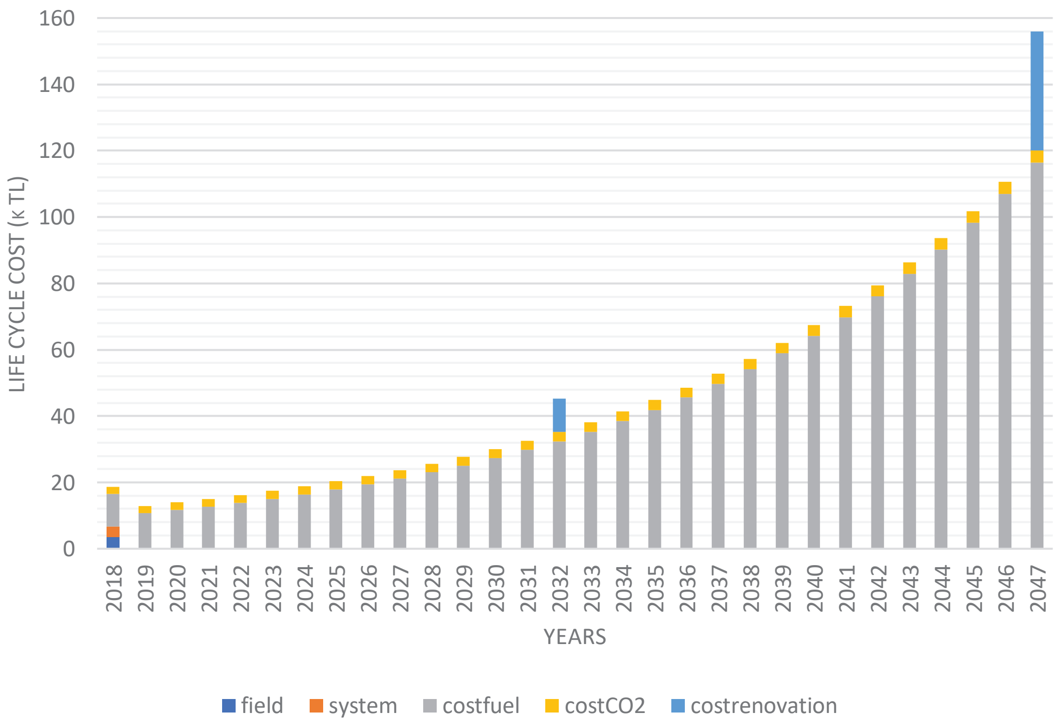

Figure 7.9 LCC for natural gas in İzmir

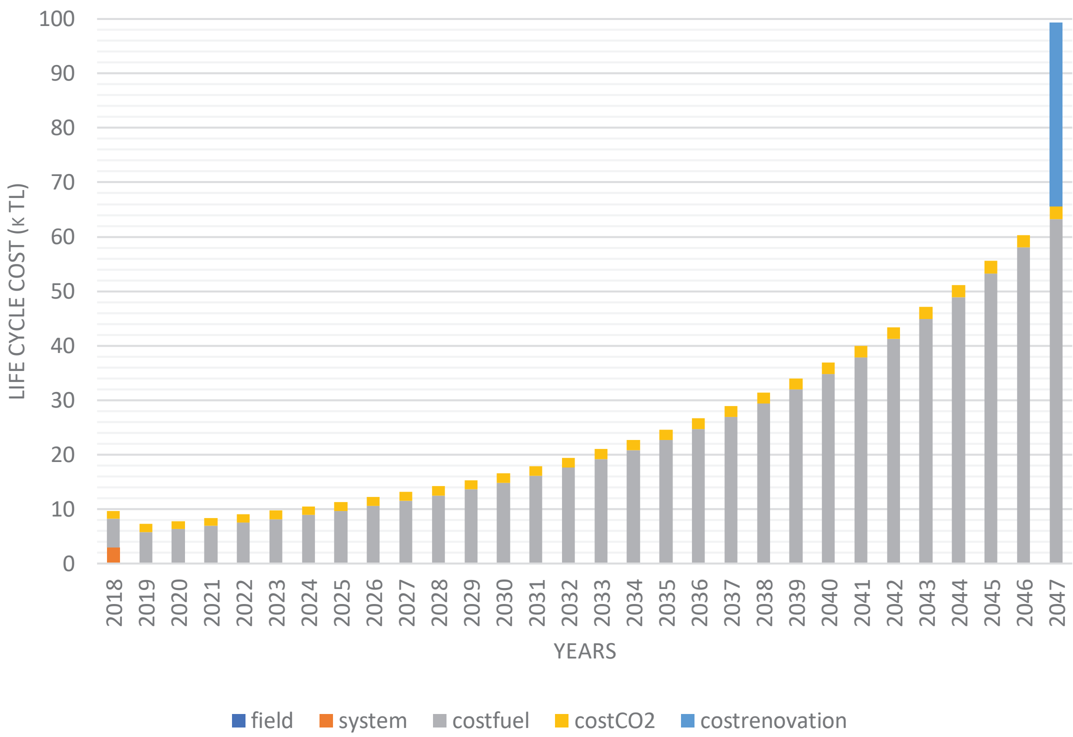

Figure 7.10 LCC for geothermal in İzmir

LCC for buildings selected as a source of geothermal energy for heating is lower than the other three fuel types. The main reasons for this situation are the low initial investment cost, a minimal footprint space, the lower unit price than the other fuels, and no longer life cycle than the systems needed by the other systems. It also proves to be an environmentally sound and renewable energy source because of low CO_2 emissions. The 30-year LCC value of a housing structure heated with geothermal energy in İzmir has proved to be the most economical fuel with $153 compared to its competitors that are natural gas, fuel oil and coal. Respectively, natural gas with $276, coal with $283 and fuel oil with $750 follow the geothermal resource. Although coal is the most economical fossil fuel, it is seen that the damage caused by coal to the environment is quite high in Figure 7.7 with the cost of CO_2 emissions. 16.9% of the lifetime cost of a coal-heated building is due to CO_2 emissions and 15.2% of the area used. In geothermal energy, the share of CO2 emissions is 6.9%, and the share of the required area is 0.042%.

The results of fossil fuels obtained in İzmir province are similar for Balıkesir, Kütahya and Ağrı. However, the unit price differences in geothermal energy in each of these provinces are also useful in the results of the LCC analysis. The cost of fuel consumption represents 90-95% of the LCC value. Therefore, Ağrı that is expected to be the costliest is seen as the most economic region. LCC charts, tables and economic analysis of other provinces, Balıkesir, Kütahya and Ağrı, are given in APPENDIX .

CHAPTER 8

CONCLUSION

This study compares the economic and environmental aspects of different heating systems and energy sources in a residential building. At the same time, the economic evaluation of the system volume and energy source has been discussed. A sample building was assumed to be considered as a design sample to estimate parameters and design conditions as close as possible to real values. The effect of climate condition and economic parameters were investigated to understand their influence and relation with corresponding locations. In addition to the cost of fuel and the installation of economic values, the effect of the heating systems and the areas where the fuel will be placed was evaluated.

Coal, fuel oil, natural gas and geothermal energy sources which are widely being used in Turkey and around the world, were selected to be energy source for the proposed systems. Because geothermal energy is a local resource, the cities selected from 4 climate regions of Turkey have been taken into consideration. The selected cities are İzmir/Balçova, Balıkesir/Gönen, Kütahya/Simav and Ağrı/Diyadin. Overall heat transfer coefficient values specified in the TS825 Thermal Insulation Standards in Buildings, the average temperature data of the external environment and the heating degree day (HDD) values of 2018 were taken into consideration in the calculation of total heat loss depending on the city where the building is located. As a result, the highest heat loss is calculated in Ağrı that has the lowest annual average temperature; by contrast, the lowest heat loss is calculated in İzmir that has the highest annual average temperature.

As a second step, the number of different energy sources and their annual cost was calculated parallel to the annual heating energy consumed by the building. The results show that the most expensive energy source is fuel oil while the most economical energy source is geothermal energy. The results for the selected four provinces are similar. Coal and natural gas follow the geothermal energy source economically. However, the unit prices of the geothermal energy determined for residences vary according to province. Given the amount of fuel consumption, İzmir was expected to be the most economical city. However, due to the differences in unit prices, it was seen that the most economical province was Ağrı.

The required area for heating system installation and their components were compared. It is assumed that they will operate with different energy sources in central system. The spatial requirement for coal and fuel oil should be more, foreseen at the beginning of the study due to their high demand for additional storage unit. Compared to natural gas and geothermal sources the results of the study approved this assumption. While the area needed by a coal-powered system for Izmir is 13.4 m^2, it is 10.1 m^2 for fuel oil, 1.12 m^2 for natural gas and 0.02 m^2 for geothermal. The difference between these areas is about 8000 $ for Izmir. Detailed comparative results were shown in Figure 7. 4.

CO2 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 4.5 times less than coal and 2.7 times less than fuel oil and 1.5 times less than natural gas.

The 30-years LCC analysis was conducted to evaluate effectiveness of every contributing parameter. The results confirm that, geothermal energy is the most economical solution with comparison factors such as system installation cost, the required area for each energy source, cost of consumed energy source, CO_2 emission and renewability related expenses of the resources. Natural gas, fuel oil and coal follow geothermal in this comparison, respectively.

As a result, systems and fuels to be used in building heating should be both easy to use, economical and environmentally friendly, and should not cause large space losses. The study shows that geothermal energy is the best energy source in terms of installation, renovation, fuel consumption and environmentally friendly, and it is a suitable solution for selected settlements in four different climatic regions of Turkey where regional heating. This study is expected to contribute to the academic world in future studies for architects and engineers, and to raise awareness in the energy investment policy of countries and individuals and institutions working in the field of construction.

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APPENDIX A

CALCULATED SURFACE HEAT TRANSFER RESISTANCE VALUES

Table A.1 Calculated surface heat transfer resistance values

<table>
<tr><td rowspan="2"></td><td rowspan="2">Type of Building Components</td><td colspan="2">Thermal Resistance</td></tr>
<tr><td>Ri
(m^2KW)</td><td>Re
(m^2KW)</td></tr>
<tr><td>1</td><td>Outdoor wall</td><td rowspan="4">0.13</td><td>0.04</td></tr>
<tr><td>2</td><td>External walls with rear ventilated façade, heat insulation low walls separating the ceiling</td><td>0.08</td></tr>
<tr><td>3</td><td>Separate walls between the apartments, stair walls, walls separating different use-purpose working rooms, partition the wall adjacent to non-heated areas, low walls adjacent to the heat-insulated roof</td><td>*</td></tr>
<tr><td>4</td><td>Earth contact the outer wall</td><td>0</td></tr>
<tr><td>5</td><td>Horizontal or inclined top (non-ventilated roof) ceiling alternatively, roof that forms the boundary with the outside air of a living space</td><td rowspan="2">0.13</td><td>0.04</td></tr>
<tr><td>6</td><td>A ceiling under an unused ceiling or ventilated room (ventilated roofing shell)</td><td>0.08</td></tr>
<tr><td>7</td><td colspan="3">Separating floor between apartments or floor separating working rooms for different purposes</td></tr>
<tr><td>7.1</td><td colspan="2">In the case of heat flow from top to bottom</td><td>0.13</td></tr>
<tr><td>7.2</td><td colspan="2">In the case of heat flow from top to bottom</td><td>0.17</td></tr>
<tr><td>8</td><td colspan="2">Basement floor ceiling</td><td rowspan="3">0.17</td></tr>
<tr><td>9</td><td colspan="2">Bottom bases forming the boundary with the outside air of a living space</td></tr>
<tr><td>10</td><td colspan="2">A basin sitting on the floor of a living space without a basement</td></tr>
</table>

*If the building component is located indoors, the internal and external surface heat transfer resistance values should be considered the same in the calculations.

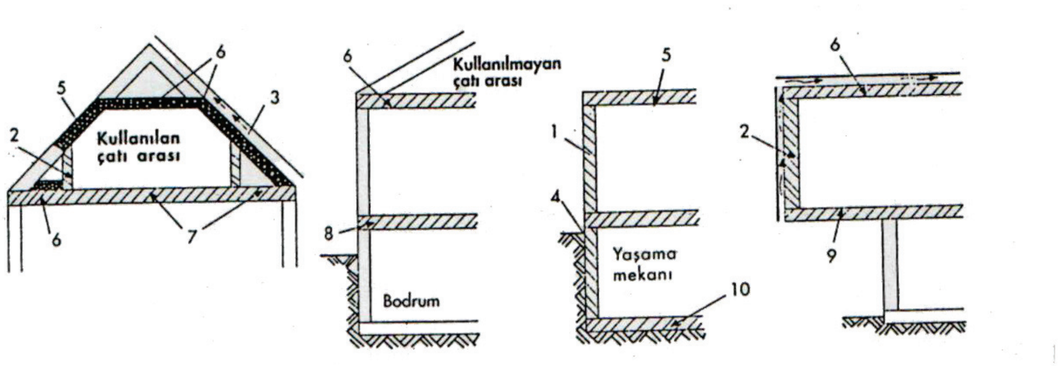

Figure I.1. Design and Layout of Building Components

APPENDIX B

PRICE OF FUELS

Tablo B.1 Sales price of coal produced and sold by the TKİ authority in April 2019

T.K.İ KURUMUNCA ÜRETİLİP SATILAN KÖMÜRLERİN KDV HARİÇ FOB SATIŞ FİYATLARI VE ANALİZ ORTALAMA DEĞERLERİ

	İŞLETME KONTROL MÜDÜRLÜĞÜ	2019 NİSAN TL/TON FİYATI	2019 YILI ANALİZ ORTALAMA DEĞERLERİ (ORJİNAL)							ADRES
			NEM %	KÜL %	UÇUCU MADDE %	SABİT KARBON %	YANAR KÜKÜRT %	TOPLAM KÜKÜRT %	ALT ISI kcal/kg	
KÜTAHYA-TAVŞANLI (GLİ)	Tunçbilek yıkanmış +18 mm	471,00	9,96	24,20	32,47	33,37		2,29	4.965	
	Tunçbilek yıkanmış +18 mm (torbalı)	503,00	11,37	22,86	31,30	34,47		1,83	4.890	Tavşanlı / KÜTAHYA
	Tunçbilek yıkanmış 10-18 mm	471,00	10,79	20,96	32,75	35,50		2,00	5.192	Tel : 0274 614 10 07
	Tunçbilek yıkanmış 10-18 mm (torbalı)	503,00	12,08	19,02	31,21	37,68		1,82	4.959	Tel : 0274 663 32 64
	Tunçbilek yıkanmış 0,5-18 mm arası	328,00	16,12	17,66	30,44	35,78		1,59	4.827	Tel : 0274 663 32 65
KLİ	Keles krible +40 mm (X)	203,00	40,50	13,39	25,35	20,71	0,68	0,98	2.766	KLİ Kontrol Baş.Müh. / KELES
	Keles krible +40 mm (torbalı) (X)	235,00	40,50	13,39	25,35	20,71	0,68	0,98	2.766	Tel : 0224 861 31 44
	Keles krible 0-40 mm (X)	52,00								
										Fax : 0224 861 23 67
MANİSA SOMA (ELİ)	S.Kısrakdere yıkanmış +18 mm	471,00	14,20	10,51	36,48	38,77	0,00	1,41	5.167	Soma / MANİSA
	S.Kısrakdere yıkanmış +18 mm (torbalı)	503,00	14,10	10,52	36,67	38,73	0,00	1,47	5.183	Tel : 0236 613 23 26
	S.Kısrakdere yıkanmış 10-18 mm	471,00	16,20	13,22	34,58	36,03	0,00	1,21	4.753	Tel : 0236 637 10 11
	S.Kısrakdere yıkanmış 10-18 mm (torbalı)	503,00	14,60	12,57	35,89	36,89	0,00	1,52	4.965	Tel : 0236 637 10 12
	S.Kısrakdere yıkanmış 0,5-18 mm arası	328,00	18,20	11,03	33,77	36,98	0,00	1,53	4.841	Fax : 0236 613 20 13
	Briket (torbalı) (X)	436,00	12,73	15,27	39,18	32,81	0,45	0,85	4.363	www.eli.gov.tr
	Kısrakdere krible +20 mm	529,00	17,00	10,64	43,42	45,95	0,72	1,09	4.957	
	Kısrakdere krible +20 mm (torbalı)	561,00	17,10	8,86	35,98	38,09	0,58	0,88	4.949	
	Kısrakdere krible 0-20 mm	202,00	18,60	31,60	34,04	34,36	0,40	0,84	3.443	
	Soma Deniş yıkanmış +18 mm (X)	359,00	23,47	12,73	34,59	29,21	1,13	1,94	3.991	
	Soma Deniş yıkanmış +18 mm (torbalı) (X)	391,00	19,14	15,89	32,17	32,80	0,36	0,72	4.137	
	Soma Deniş krible 0-18 mm (X)	116,00	22,22	26,72	29,47	21,59	0,34	1,24	2.852	
	Soma Deniş yıkanmış 0,5-10 mm (X)	232,00	26,42	12,84	32,64	28,10	1,22	1,94	3.641	
ÇLİ	Çan krible +30 mm	361,00								Çan / ÇANAKKALE
	Çan krible +30 mm (torbalı)	393,00	25,69	12,32	31,60	30,38	6,61	6,76	3.996	Tel : 0286 416 20 01
	Çan krible 10-30 mm	274,00	25,21	19,07	28,85	26,87	3,74	4,16	3.554	
	Çan krible 10-30 mm (torbalı)	306,00								
	Çan krible 0-10 mm toz	153,00	26,19	17,11	29,18	27,54	4,05	4,37	3.622	
	Çan krible 0-30 mm arası	210,00	23,83	17,83	30,55	27,79	6,96	7,52	3.738	Fax: 0286 416 37 00
										www.cli.gov.tr

(X) Bu kömürlerin 2019 yılında üretilmesi durumunda listede belirtilen fiyatlar uygulanacaktır.

Tablo II.2 Fuel prices required for heat needs in residences April 2019

KONUTLARDA 1000 kcal ısı ihtiyacı için gerekli olan **ÇEŞİTLİ YAKITLAR** için **MALİYET KARŞILAŞTIRMA** TABLOSU

(**03 Nisan 2019** tarihinde belirlenmiş **KDV DAHİL** birim fiyatlarla)

Sıra No	Yakıt Çeşidi	İlgili Şirket	Yakıt Alt Isıl Değeri	03 Nisan 2019 Tarihindeki Birim Fiyat	Ortalama İşletme Verim Değeri	03 Nisan2019 Tarihindeki Fiyatlarla TL/1000 kcal		En Ucuza Göre Yakıt Maliyeti İndeksi	02 Nisan 2018 Tarihindeki Birim Fiyatları	03 Nisan 2019 / 02 Nisan 2018 Birim Fiyat Değişimi	Değişim Sırası
1	**100.000.001** m³/yıl ve **üstünde** **Doğalgaz** Tüketimi için	Kocaeli **İZGAZ ENGIE**	8250 kcal/m³	**1,084457** TL/m³	107%	1,084457 x 1000 / 8250 x 0,93	**0,141343**	**100**	**1,065087** TL/m³	**1,8%**	**5**
2	**100.000.001** m³/yıl ve **üstünde** **Doğalgaz** Tüketimi için	Eskişehir **ESGAZ**	8250 kcal/m³	**1,088077** TL/m³	107%	1,088077 x 1000 / 8250 x 0,93	**0,141815**	**100**	**1,116181** TL/m³	**-2,5%**	**2**
3	**10.000.001 - 100.000.000** m³/yıl **Doğalgaz** Tüketimi için	İzmit **İZGAZ ENGIE**	8250 kcal/m³	**1,091085** TL/m³	107%	1,091085 x 1000 / 8250 x 0,93	**0,142207**	**101**	**1,065087** TL/m³	**2,4%**	**6**
4	**10.000.001- 100.000.000** m³/yıl **Doğalgaz** Tüketimi için	Eskişehir **ESGAZ**	8250 kcal/m³	**1,114437** TL/m³	107%	1,114437 x 1000 / 8250 x 0,93	**0,145251**	**103**	**1,116181** TL/m³	**-0,2%**	**3**
5	**1.000.001 - 10.000.000** m³/yıl **Doğalgaz** Tüketimi için	İzmit **İZGAZ ENGIE**	8250 kcal/m³	**1,118808** TL/m³	107%	1,118808x 1000 / 8250 x 0,93	**0,145821**	**103**	**1,065087** TL/m³	**5,0%**	**8**
6	**800.001** m³/yıl **üstünde** **Doğalgaz** Tüketimi için	Ankara **BAŞKENTGAZ**	8250 kcal/m³	**1,126237** TL/m³	107%	1,126237 x 1000 / 8250 x 0,93	**0,146789**	**104**	**1,178301** TL/m³	**-4,4%**	**1**
7	**1.000.001 - 10.000.000** m³/yıl **Doğalgaz** Tüketimi için	Bursa **BURSAGAZ**	8250 kcal/m³	**1,130105** TL/m³	107%	1,130105 x 1000 / 8250 x 0,93	**0,147293**	**104**	**1,067408** TL/m³	**5,9%**	**9**
8	**800.000** m³/yıl ve **üstünde** **Doğalgaz** Tüketimi için	İstanbul **İGDAŞ**	8250 kcal/m³	**1,142803** TL/m³	107%	1,142803 x 1000 / 8250 x 0,93	**0,148948**	**105**	**1,141114** TL/m³	**0,1%**	**4**
9	**100.001 - 1.000.000** m³/yıl **Doğalgaz** Tüketimi için	İzmit **İZGAZ ENGIE**	8250 kcal/m³	**1,157340** TL/m³	107%	1,157340 x 1000 / 8250 x 0,93	**0,150843**	**107**	**1,065087** TL/m³	**8,7%**	**11**
10	**1.000.001- 10.000.000** m³/yıl **Doğalgaz** Tüketimi için	Eskişehir **ESGAZ**	8250 kcal/m³	**1,166077** TL/m³	107%	1,166077 x 1000 / 8250 x 0,93	**0,151981**	**108**	**1,116181** TL/m³	**4,5%**	**7**
11	**100.001 - 300.000** m³/yıl **Doğalgaz** Tüketimi için	Bursa **BURSAGAZ**	8250 kcal/m³	**1,209282** TL/m³	107%	1,209282 x 1000 / 8250 x 0,93	**0,157613**	**112**	**1,067408** TL/m³	**13,3%**	**13**
12	**300.001 - 1.000.000** m³/yıl **Doğalgaz** Tüketimi için	Bursa **BURSAGAZ**	8250 kcal/m³	**1,209282** TL/m³	107%	1,209282 x 1000 / 8250 x 0,93	**0,157613**	**112**	**1,067408** TL/m³	**13,3%**	**13**
13	**100.001 - 1.000.000** m³/yıl **Doğalgaz** Tüketimi için	Eskişehir **ESGAZ**	8250 kcal/m³	**1,213828** TL/m³	107%	1,2123828 x 1000 / 8250 x 0,93	**0,158205**	**112**	**1,116181** TL/m³	**8,7%**	**11**
14	**0 - 100.000** m³/yıl **Doğalgaz** Tüketimi için	İzmit **İZGAZ ENGIE**	8250 kcal/m³	**1,241208** TL/m³	107%	1,241208 x 1000 / 8250 x 0,93	**0,161774**	**114**	**1,065087** TL/m³	**16,5%**	**15**
15	**0 - 100.000** m³/yıl **Doğalgaz** Tüketimi için	Bursa **BURSAGAZ**	8250 kcal/m³	**1,271421** TL/m³	107%	1,271421 x 1000 / 8250 x 0,93	**0,165711**	**117**	**1,067408** TL/m³	**19,1%**	**19**
16	**0 - 100.000** m³/yıl **Doğalgaz** Tüketimi için	Eskişehir **ESGAZ**	8250 kcal/m³	**1,302294** TL/m³	107%	1,302294 x 1000 / 8250 x 0,93	**0,169735**	**120**	**1,116181** TL/m³	**16,7%**	**16**
17	**0 - 800.000** m³/yıl **Doğalgaz** Tüketimi için	İstanbul **İGDAŞ**	8250 kcal/m³	**1,353236** TL/m³	107%	1,353236 x 1000 / 8250 x 0,93	**0,176375**	**125**	**1,141114** TL/m³	**18,6%**	**18**
18	**0 - 800.000** m³/yıl **Doğalgaz** Tüketimi için	Ankara **BAŞKENTGAZ**	8250 kcal/m³	**1,429997** TL/m³	107%	1,429997 x 1000 / 8250 x 0,93	**0,186380**	**132**	**1,178301** TL/m³	**21,4%**	**20**
19	**Yerli Linyit +18 mm** Yıkanmış Parça- Torba	Soma Kısrakdere Manisa - **ELİ**	4731 kcal/kg	**0,860220** TL/kg	65%	0,860220 x 1000 / 4731 x 0,65	**0,279733**	**198**	**0,749300** TL/kg	**14,8%**	**10**
20	**İthal Sibirya Kömürü** Portakal Tipi	İstanbul **HAKAN KÖMÜR**	7000 kcal/kg	**1,640000** TL/kg	65%	1,640000 x 1000 / 7.000 x 0,65	**0,360440**	**255**	**1,190000** TL/kg	**37,8%**	**22**
21	**Fuel-oil No: 4** Kalorifer Yakıtı	İstanbul Avrupa Yakası **SHELL TÜRKİYE**	9875 kcal/kg	**4,420000** TL/kg	80%	4,420000 x 1000 / 9.875 x 0,80	**0,559494**	**396**	**3,280000** TL/kg	**34,8%**	**21**
22	**Elektrik** Konut	Türkiye **TEDAŞ**	860 kcal/kWh	**0,569515** TL/kWh	99%	0,569515 x 1000 / 860 x 0,99	**0,668916**	**473**	**0,488088** TL/kWh	**16,7%**	**16**
23	**Dökmegaz** Konut LPG - **Propan**	İstanbul **İPRAGAZ-AYGAZ**	11100 kcal/kg	**8,445256** TL/kg	106%	8,445256 x 1000 / 11.100 x 1,06	**0,717768**	**508**	**7,324048** TL/kg	**15,3%**	**14**
24	**Motorin** (VP Diesel)	İstanbul Avrupa Yakası **SHELL TÜRKİYE**	10256 kcal/kg	**7,029586** TL/kg	84%	7,029586x 1000 / 10.256 x 0,84	**0,815967**	**577**	**6,236686** TL/kg	**12,7%**	**12**
25	**Elektrik** Ticarethane	Türkiye **TEDAŞ**	860 kcal/kWh	**0,752751** TL/kWh	99%	0,752751 x 1000 / 860 x 0,99	**0,884133**	**626**	**0,491397** TL/kWh	**53,2%**	**23**
26	**LPG 12 kg** Ev Tüpü İstanbul	İstanbul **İPRAGAZ-AYGAZ**	11000 kcal/kg	**8,958333** TL/kg	90%	8,958333 x 1000 / 11.000 x 0,90	**0,904882**	**640**	**7,625000** TL/kg	**17,5%**	**17**

DÖVİZLER	T.C. Merkez Bankası Efektif Satış Fiyatı 03 Nisan **2019** tarihinde	T.C. Merkez Bankası Efektif Satış Fiyatı 03 Nisan **2018** tarihinde	Yıllık **Değişim** Oranı
ABD Doları	**5,6252** TL	**3,9892** TL	**41%**
Avro	**6,3230** TL	**4,9108** TL	**29%**

TESİSAT DERGİSİ - B2B MEDYA - TEKNİK SEKTÖR YAYINCILIĞI

APPENDIX C

GENERAL WEATHER STATISTICAL DATA BETWEEN 1927-2017

Table C.1 General weather statistical data for Izmir between 1927-2017 [47]

İZMİR	T_{avg} (°C)	$T_{max,avg}$ (°C)	$T_{min,avg}$ (°C)	$t_{sun,avg}$ (h)	$D_{rainy,avg}$	Average Monthly Total Rainfall (mm)	T_{max} (° C)	T_{min} (° C)
January	8,7	12,3	5,7	4,2	12,5	133,2	22,4	-8,2
February	9,5	13,5	6,1	5,1	10,6	101,8	27	-5,2
March	11,6	16,1	7,5	6,4	9,2	76,4	30,5	-3,8
April	15,8	20,8	11	7,9	7,9	45,9	32,5	0,6
May	20,7	26	15,3	9,8	5,3	31,2	37,6	4,3
June	25,5	30,5	19,7	11,5	2,1	9,9	41,3	9,5
July	28	33,1	22,3	12,2	0,4	1,7	42,6	15,4
August	27,6	32,9	22,2	11,9	0,5	2,9	43	11,5
September	23,6	29,1	18,5	10,1	1,9	13,7	40,1	10
October	18,7	23,9	14,5	7,5	5,4	43,8	36	3,6
November	14	18,4	10,6	5,5	8,7	93,1	30,3	-2,9
December	10,4	14	7,5	4,1	12,7	143,4	25,2	-4,7
Annual	17,8	22,6	13,4	96,2	77,2	697	43	-8,2

T_{avg} : Average temperature (°C)

$T_{max,avg}$: Average highest temperature (°C)

$T_{min,avg}$: Average lowest temperature (°C)

$t_{sun,avg}$: Average hours of sunshine (hour)

$D_{rainy,avg}$: Average rainy days

T_{max} : Highest temperature (°C)

T_{min} : Lowest temperature (°C)

Table C.2 General weather statistical data for Balıkesir between 1927-2017 [47]

BALIKESİR	T_{avg} (°C)	$T_{max,avg}$ (°C)	$T_{min,avg}$ (°C)	$t_{sun,avg}$ (h)	$D_{rainy,avg}$	Average Monthly Total Rainfall (mm)	T_{max} (° C)	T_{min} (° C)
January	4,8	8,8	1,3	2,9	14,4	85	23,5	-19
February	5,9	10,5	1,9	3,6	11,7	68,9	25,2	-19
March	8,2	13,6	3,3	4,8	11,5	60,8	30,7	-8
April	12,9	19,3	6,9	6,3	9,3	50,1	35,2	-4
May	17,8	24,5	11	8,7	7,6	41,2	38,5	0,6
June	22,4	29,2	15	10,7	4,5	24,8	42,5	4
July	24,8	31,2	17,7	11,6	1,6	8,3	43,2	9,1
August	24,6	31,2	17,9	10,9	1,4	6,1	43,7	6
September	20,7	27,7	14,1	8,6	3,4	21,9	40,3	4
October	15,7	22	10,2	6,2	6,7	45,6	36,4	-2,3
November	10,5	15,9	6	4,2	9,4	75,4	29,9	-7,9
December	6,6	10,6	3,1	2,5	13,7	94,9	26,1	-13
Annual	14,6	20,4	9	81	95,2	583	43,7	-19

Table C.3 General weather statistical data for Kütahya between 1927-2017 [47]

KÜTAHYA	T_{avg} (°C)	$T_{max,avg}$ (°C)	$T_{min,avg}$ (°C)	$t_{sun,avg}$ (h)	$D_{rainy,avg}$	Average Monthly Total Rainfall (mm)	T_{max} (° C)	T_{min} (° C)
January	0,3	4,5	-3,3	2,3	14,6	71,9	17,2	-26
February	1,6	6,5	-2,4	3,4	13,1	59,4	23	-27
March	4,9	10,7	-0,2	4,6	13	57,1	27	-17
April	9,9	16,2	3,8	6,1	11,6	50,9	30,2	-7,8
May	14,5	21,1	7,7	7,6	12	55,7	33,8	-2,8
June	18,2	24,9	10,7	9,4	8	37,6	36,2	0,5
July	20,8	28	13	10,4	3,8	18,4	39,5	2,6
August	20,7	28,3	12,9	9,7	3,2	15,8	38,8	-0,2
September	16,6	24,5	9	7,7	4,6	23,2	36,1	-3,9
October	11,8	18,9	5,5	5,3	8,3	40,4	31,6	-6,9
November	6,8	12,7	1,8	3,6	10	49,6	25,4	-18
December	2,4	6,5	-1,2	2,1	14,1	78	20,5	-28
Annual	10,7	16,9	4,8	72,2	116,3	558	39,5	-28

Table C.4 General weather statistical data for Ağrı between 1927-2017[47]

AĞRI	T_{avg} (°C)	$T_{max,avg}$ (°C)	$T_{min,avg}$ (°C)	$t_{sun,avg}$ (h)	$D_{rainy,avg}$	Average Monthly Total Rainfall (mm)	T_{max} (° C)	T_{min} (° C)
January	-11	-5,5	-15,7	2	11,8	44,4	9,6	-46
February	-9,3	-3,6	-14,6	3	11,5	48,2	13	-43
March	-3,2	1,9	-8	4,3	12,3	50,6	21,5	-40
April	6	11,6	0,6	5,8	14,5	69,5	27,2	-26
May	12,1	18,6	5,2	7,7	15,9	69,4	32,7	-9
June	16,6	24	8,1	9,8	10,2	43,6	39,8	-3
July	21,1	29,2	12	10,3	5,7	21,3	39,8	1,7
August	21,2	30	11,7	10,1	3,8	11,9	39,9	1,2
September	16,2	25,3	6,7	9,1	4,4	17,6	36,2	-4,1
October	9,1	17,1	1,8	6,5	9	56,2	29,2	-20
November	1,6	7,8	-3,5	4,2	8,5	45,6	19,8	-32
December	-6,6	-1,8	-10,9	2,1	10,8	43,4	16	-40
Annual	6,2	12,9	-0,5	74,9	118,4	521,7	39,9	-46

APPENDIX D

OVERALL HEAT TRANSFER COEFFICIENT

Table D.1 Overall heat transfer coefficient for Izmir

1	2	3	4	5	6
Heat Loss Surface Type	**Building Materials**	**Thickness of Building Materials**	**Thermal Conductivity**	**Thermal Resistance**	**Overall Heat Transfer Coefficient**
		L	**k**	**R**	**U**
		(m)	**(W/mK)**	**(m^2K/W)**	**(W/m^2K)**
Outside Wall	R_i			0,13	
	Gypsum Plaster	0,02	0,38	0,053	
	Brick	0,19	0,33	0,576	
	Heat Insulation	0,03	0,045	0,667	
	Cement Plaster	0,03	1	0,030	
	R_o			0,04	
Total				**1,495**	0,669
Reinforced Concrete Wall	R_i			0,13	
	Gypsum Plaster	0,02	0,38	0,053	
	Reinforced Concrete	0,3	2,5	0,120	
	Heat Insulation	0,05	0,045	1,111	
	Cement Plaster	0,03	1	0,030	
	R_o			0,04	
Total				**1,484**	0,674
Basement (earth contact)	R_i			0,17	
	Wood Floor	0,005	0,13	0,038	
	Cement Finish	0,03	1,4	0,021	
	Heat Insulation	0,05	0,045	1,111	
	Self-Levelling	0,02	1,4	0,014	
	Concrete	0,15	1,3	0,115	
	Blokaj	0,15	1,65	0,091	
	R_o			0	
Total				**1,562**	0,640
Ceiling (with roof)	R_i			0,13	
	Heat Insulation	0,08	0,04	2,000	
	Concrete	0,15	1,3	0,115	
	Gypsyum Plater	0,02	1	0,020	
	R_o			0,08	
Total				**2,345**	0,426
Out Door					4
Window					2,2

Table D.2 Overall heat transfer coefficient for Balıkesir

1	2	3	4	5	6
Heat Loss Surface Type	**Building Materials**	**Thickness of Building Materials**	**Thermal Conductivity**	**Thermal Resistance**	**Overall Heat Transfer Coefficient**
		L	**k**	**R**	**U**
		(m)	**(W/mK)**	**(m^2K/W)**	**(W/m^2K)**
Outside Wall	R_i			0,13	
	Gypsum Plaster	0,02	0,38	0,053	
	Brick	0,19	0,33	0,576	
	Heat Insulation	0,03	0,035	0,857	
	Cement Plaster	0,03	1	0,030	
	R_o			0,04	
Total				**1,686**	0,593
Reinforced Concrete Wall	R_i			0,13	
	Gypsum Plaster	0,02	0,38	0,053	
	Reinforced Concrete	0,3	2,5	0,120	
	Heat Insulation	0,05	0,035	1,429	
	Cement Plaster	0,03	1	0,030	
	R_o			0,04	
Total				**1,801**	0,555
Basement (earth contact)	R_i			0,17	
	Wood Floor	0,005	0,13	0,038	
	Cement Finish	0,03	1,4	0,021	
	Heat Insulation	0,05	0,04	1,250	
	Self Levelling	0,02	1,4	0,014	
	Concrete	0,15	1,3	0,115	
	Blokaj	0,15	1,65	0,091	
	R_o			0	
Total				**1,700**	0,588
Ceiling (with roof)	R_i			0,13	
	Heat Insulation	0,1	0,04	2,500	
	Concrete	0,15	1,3	0,115	
	Gypsyum Plater	0,02	1	0,020	
	R_o			0,08	
Total				**2,845**	0,351
Out Door					4
Window					2,2

Table D.3 Overall heat transfer coefficient for Kütahya

1	2	3	4	5	6
Heat Loss Surface Type	**Building Materials**	**Thickness of Building Materials**	**Thermal Conductivity**	**Thermal Resistance**	**Overall Heat Transfer Coefficient**
		L	**k**	**R**	**U**
		(m)	**(W/mK)**	**(m^2K/W)**	**(W/m^2K)**
Outside Wall	R_i			0,13	
	Gypsum Plaster	0,02	0,38	0,053	
	Brick	0,19	0,33	0,576	
	Heat Insulation	0,05	0,035	1,429	
	Cement Plaster	0,03	1	0,030	
	R_o			0,04	
Total				**2,257**	0,443
Reinforced Concrete Wall	R_i			0,13	
	Gypsum Plaster	0,02	0,38	0,053	
	Reinforced Concrete	0,3	2,5	0,120	
	Heat Insulation	0,06	0,035	1,714	
	Cement Plaster	0,03	1	0,030	
	R_o			0,04	
Total				**2,087**	0,479
Basement (earth contact)	R_i			0,17	
	Wood Floor	0,005	0,13	0,038	
	Cement Finish	0,03	1,4	0,021	
	Heat Insulation	0,06	0,035	1,714	
	Self Levelling	0,02	1,4	0,014	
	Concrete	0,15	1	0,150	
	Blokaj	0,15	1,65	0,091	
	R_o			0	
Total				**2,199**	0,455
Ceiling (with roof)	R_i			0,13	
	Heat Insulation	0,11	0,035	3,143	
	Concrete	0,15	1	0,150	
	Gypsyum Plater	0,02	1	0,020	
	R_o			0,08	
Total				**3,523**	0,284
Out Door					4
Window					2,2

Table D.4 Overall heat transfer coefficient for Ağrı

1	2	3	4	5	6
Heat Loss Surface Type	**Building Materials**	**Thickness of Building Materials**	**Thermal conductivity**	**Thermal Resistance**	**Overall Heat Transfer Coefficient**
		L	**k**	**R**	**U**
		(m)	**(W/mK)**	**(m^2K/W)**	**(W/m^2K)**
Outside Wall	R_i			0,13	
	Gypsum Plaster	0,02	0,38	0,053	
	Brick	0,19	0,33	0,576	
	Heat Insulation	0,06	0,035	1,714	
	Cement Plaster	0,03	1	0,030	
	R_o			0,04	
Total				**2,543**	0,393
Reinforced Concrete Wall	R_i			0,13	
	Gypsum Plaster	0,02	0,38	0,053	
	Reinforced Concrete	0,3	2,5	0,120	
	Heat Insulation	0,08	0,035	2,286	
	Cement Plaster	0,03	1	0,030	
	R_o			0,04	
Total				**2,658**	0,376
Basement (earth contact)	R_i			0,17	
	Wood Floor	0,005	0,13	0,038	
	Cement Finish	0,03	1,4	0,021	
	Heat Insulation	0,07	0,035	2,000	
	Self-Levelling	0,02	1,4	0,014	
	Concrete	0,15	1	0,150	
	Blokaj	0,15	1,65	0,091	
	R_o			0	
Total				**2,485**	0,402
Ceiling (with roof)	R_i			0,13	
	Heat Insulation	0,13	0,035	3,714	
	Concrete	0,15	1	0,150	
	Gypsyum Plater	0,02	1	0,020	
	R_o			0,08	
Total				**4,094**	0,244
Out Door					4
Window					2,2

APPENDIX E

DIMENSIONS OF CYLINDRICAL FUEL OIL TANKS [45]

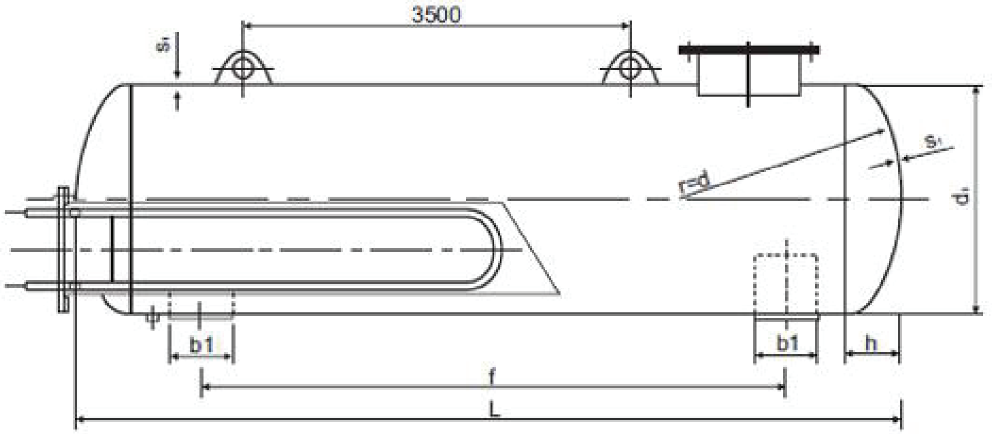

Figure E.1 Dimensions of cylindrical fuel oil tanks

Horizontal Type

Table E.1 Dimensions of cylindrical fuel oil tanks

Volume (m^3)	D (mm)	*l* (mm)	h (mm)	s_1 (mm)	d_2 (mm)	Lift	a_1 (mm)	b_1 (mm)	f (mm)	Weight (kg)
5	1,6	2820	260	5	500	1	1200	350	1770	740
7		3740							2770	930
10		5350							4290	1250
13		6960				2		525	5625	1550
16		8570							7135	1850
20	2000	6960	320	6	600		1800	600	5395	2400
25		8540							7005	2850
30		10120							8615	3400
40	2500	8800	400	7			2200	950	6760	4400
50		10800							8820	5300
60		12800							10880	6300
80	2900	12750	450	9			2600	1350	10295	9500
100		15950							13360	11500

APPENDIX F

HEAT LOSS CALCULATION ACCORDING TO PROVINCES

Table F.1. Heat loss calculation for İzmir-I

HEAT LOSS CALCULATION																	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	19
	AREA CALCULATION						HEAT LOSS CALCULATION										
Building component	Thickness	Length	Height or Width	Total area	Unit	Skip area	Area for calculation	Overall heat transfer coefficient	AxU	T_{inside}	$T_{outside}$	Temperature difference	HEAT LOSS	ZD	ZH	ZW	Qi
							A	U				ΔT	Q_D				
	cm	m	m	m2	number	m2	m2	W/m2°C	W/°C	(°C)	(°C)	°C	W	%	%	%	W
GROUND FLOOR																	
SOUTH																	
Wall	20	31,1	2,6	80,86	1	18,7	62,16	0,669	41,58				831,54				848,17
R.Concrete Wall	30	6,6	3	19,8	1	0	19,8	0,674	13,34				266,89				272,23
Column	30	0,5	3	1,5	8	0	12	0,674	8,09				161,75				164,99
Beam	30	31,1	0,4	12,44	1	0	12,44	0,674	8,38	20	0	20	167,68	0,07	-0,05	0	171,04
Window	\	6,3	1,5	9,45	1	0	9,45	2,200	20,79				415,80				424,12
Door	\	1,1	2,2	2,42	1	0	2,42	4,000	9,68				193,60				197,47
Entrance Door	\	3,7	2,5	9,25	1	0	9,25	4,000	37,00				740,00				754,80
Total									138,86	20	0	20	2777,27	0,07	-0,05	0	**2832,82**
NORTH																	
Wall	20	31,1	2,6	80,86	1	23,74	57,12	0,669	38,21				764,12				855,8128611
R.Concrete Wall	30	6,6	3	19,8	1	0	19,8	0,674	13,34				266,89				298,9197541
Column	30	0,5	3	1,5	8	0	12	0,674	8,09	20	0	20	161,75	0,07	0,05	0	181,1634873
Beam	30	30	0,4	12	1	0	12	0,674	8,09				161,75				181,1634873
Window	\	12,6	1,5	18,9	1	0	18,9	2,200	41,58				831,60				931,392
Door	\	1,1	2,2	2,42	2	0	4,84	4,000	19,36				387,20				433,664
Total									128,67	20	0	20	2573,32	0,07	0,05	0	**2882,12**
EAST																	
Wall	20	17,4	2,6	45,24	1	12,8	32,44	0,669	21,70				433,96				464,3411905
Column	30	1,6	3	4,8	1	0	4,8	0,674	3,24				64,70				69,23033265
Beam	30	11,3	0,4	4,52	1	0	4,52	0,674	3,05	20	0	20	60,93	0,07	0	0	65,19189658
Window	\	1,2	1,5	1,8	1	0	1,8	2,200	3,96				79,20				84,744
Door	\	5	2,2	11	1	0	11	4,000	44,00				880,00				941,6
Total									75,94	20	0	20	1518,79	0,07	0	0	**1625,11**

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Table F.1.(cont)

WEST																	
Wall	20	17,4	2,6	45,24	1	25,6	19,64	0,669	13,14				262,73				281,1239514
Column	30	1,6	3	4,8	1	0	4,8	0,674	3,24				64,70				69,23033265
Beam	30	5,2	0,4	2,08	1	0	2,08	0,674	1,40	20	0	20	28,04	0,07	0	0	29,99981082
Window	\	1,2	1,5	1,8	2	0	3,6	2,200	7,92				158,40				169,488
Door	\	5	2,2	11	2	0	22	4,000	88,00				1760,00				1883,2
Total									113,69	20	0	20	2273,87	0,07	0	0	**2433,04**
BASEMENT																	
Basement	\	\	\	\	\	0	752,12	0,640	481,64	20	9	11	5298,04	0,07	0	0	**5668,91**
1.-2. FLOOR																	
SOUTH-NORTH																	
Wall	20	31,1	2,6	80,86	1	0	80,86	0,669	54,08				1081,70				1103,33
R.Concrete Wall	30	6,6	3	19,8	1	0	19,8	0,674	13,34				266,89				272,23
Column	30	0,5	3	1,5	8	0	12	0,674	8,09	20	0	20	161,75	0,07	-0,05	0	164,99
Beam	30	30	0,4	12	1	0	12	0,674	8,09				161,75				164,99
Window	\	12,6	1,5	18,9	1	0	18,9	2,200	41,58				831,60				848,23
Door	\	1,1	2,2	2,42	2	0	4,84	4,000	19,36				387,20				394,94
Total									144,54	20	0	20	2890,90	0,07	-0,05	0	**2948,72**
NORTH																	
Wall	20	31,1	2,6	80,86	1	0	80,86	0,669	54,08				1081,70				1211,50
R.Concrete Wall	30	6,6	3	19,8	1	0	19,8	0,674	13,34				266,89				298,92
Column	30	0,5	3	1,5	8	0	12	0,674	8,09	20	0	20	161,75	0,07	0,05	0	181,16
Beam	30	30	0,4	12	1	0	12	0,674	8,09				161,75				181,16
Window	\	12,6	1,5	18,9	1	0	18,9	2,200	41,58				831,60				931,39
Door	\	1,1	2,2	2,42	2	0	4,84	4,000	19,36				387,20				433,66
Total									144,54	20	0	20	2890,90	0,07	0,05	0	**3237,81**
EAST																	
Wall	20	17,4	2,6	45,24	1	25,6	19,64	0,640	12,58				251,54				269,15
Column	30	1,6	3	4,8	8	0	38,4	0,674	25,88				517,61				553,84
Beam	30	5,2	0,4	2,08	1	0	2,08	0,674	1,40	20	0	20	28,04	0,07	0	0	30,00
Window	\	1,2	1,5	1,8	2	0	3,6	2,200	7,92				158,40				169,49
Door	\	5	2,2	11	2	0	22	4,000	88,00				1760,00				1883,20
Total									135,78	20	0	20	2715,59	0,07	0	0	**2905,68**
WEST																	
Wall	20	17,4	2,6	45,24	1	25,6	19,64	0,669	13,14				262,73				281,12
Column	30	1,6	3	4,8	8	0	38,4	0,674	25,88				517,61				553,84
Beam	30	5,2	0,4	2,08	1	0	2,08	0,674	1,40	20	0	20	28,04	0,07	0	0	30,00
Window	\	1,2	1,5	1,8	2	0	3,6	2,200	7,92				158,40				169,49
Door	\	5	2,2	11	2	0	22	4,000	88,00				1760,00				1883,20
Total									136,34	20	0	20	2726,78	0,07	0	0	**2917,65**

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Table F.1.(cont)

HEAT LOSS CALCULATION																	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	19
	AREA CALCULATION						HEAT LOSS CALCULATION										
Building component	Thickness	Length	Height or Width	Total area	Unit	Skip area	Area for calculation	Overall heat transfer coefficient	AxU	T_{inside}	$T_{outside}$	Temperature difference	HEAT LOSS	ZD	ZH	ZW	Q
							A	U				ΔT	Q_D				
	cm	m	m	m2	number	m2	m2	W/m2°C	W/°C	(°C)	(°C)	°C	W	%	%	%	W
3. FLOOR																	
SOUTH																	
Wall	20	31,1	2,6	80,86	1	0	80,86	0,669	54,08				1081,70				1157,42
R.Concrete Wall	30	6,6	3	19,8	1	0	19,8	0,674	13,34				266,89				285,58
Column	30	0,5	3	1,5	8	0	12	0,674	8,09	20	0	20	161,75	0,07	-0,05	0,05	173,08
Beam	30	30	0,4	12	1	0	12	0,674	8,09				161,75				173,08
Window	\	12,6	1,5	18,9	1	0	18,9	2,200	41,58				831,60				889,81
Door	\	1,1	2,2	2,42	2	0	4,84	4,000	19,36				387,20				414,30
Total									144,54	20	0	20	2890,90	0,07	-0,05	0,05	**3093,26**
NORTH																	
Wall	20	31,1	2,6	80,86	1	0	80,86	0,669	54,08				1081,70				1265,59
R.Concrete Wall	30	6,6	3	19,8	1	0	19,8	0,674	13,34				266,89				312,26
Column	30	0,5	3	1,5	8	0	12	0,674	8,09	20	0	20	161,75	0,07	0,05	0,05	189,25
Beam	30	30	0,4	12	1	0	12	0,674	8,09				161,75				189,25
Window	\	12,6	1,5	18,9	1	0	18,9	2,200	41,58				831,60				972,97
Door	\	1,1	2,2	2,42	2	0	4,84	4,000	19,36				387,20				453,02
Total									144,54	20	0	20	2890,90	0,07	0,05	0,05	**3382,35**
EAST																	
Wall	20	17,4	2,6	45,24	1	25,6	19,64	0,669	13,14				262,73				307,40
Column	30	1,6	3	4,8	8	0	38,4	0,674	25,88				517,61				605,60
Beam	30	5,2	0,4	2,08	1	0	2,08	0,674	1,40	20	0	20	28,04	0,07	0,05	0,05	32,80
Window	\	1,2	1,5	1,8	2	0	3,6	2,200	7,92				158,40				185,33
Door	\	5	2,2	11	2	0	22	4,000	88,00				1760,00				2059,20
Total									136,34	20	0	20	2726,78	0,07	0,05	0,05	**3190,33**
WEST																	
Wall	20	17,4	2,6	45,24	1	25,6	19,64	0,669	13,14				262,73				307,40
Column	30	1,6	3	4,8	8	0	38,4	0,674	25,88				517,61				605,60
Beam	30	5,2	0,4	2,08	1	0	2,08	0,674	1,40	20	0	20	28,04	0,07	0,05	0,05	32,80
Window	\	1,2	1,5	1,8	2	0	3,6	2,200	7,92				158,40				185,33
Door	\	5	2,2	11	2	0	22	4,000	88,00				1760,00				2059,20
Total									136,34	20	0	20	2726,78	0,07	0,05	0,05	**3190,33**
CEILING																	
Ceiling	\	\	\	\	\	0	752,12	0,426	320,68	20	9	11	3527,49	0,07	0,05	0,05	**4127,16**

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Table F.1.(cont)

Qe=(aL).R.H.ΔT. Ze =(2,5. 459,4).0,9.0,675.20.1 =3435,41 Qe : Enfiltration (W) a:Air leakage coefficient (m3/mh) L:Total lenght of windows and doors (m) R:Room condition coefficient H:Building condition coefficient (Wh/m3 oC) ΔT:Temperature difference (oC)	13954,28
Qtotal (W)	58389,55
Qtotal (kW)	58,39

HEATING DEGREE DAY HEAT LOSS CALCULATION	HDD	*k*	∑U.A	Q_{year} (kWh)
Basement	803	0,5	481,64	4641,08
Ceiling		0,8	320,68	4944,13
Wall		1	1580,14	30452,43
∑Qyear (kWh)				40037,64
Qe (kWh)				13446,34
Qtotal				53483,98

∑Qyear (kWh)

q = U . (Ti - To)
qyear = 86400 . HDD . U
Qyear = (24 . k . HDD . U. A)/1000

Qyear: Annual Heat Loss (kWh)
HDD: Heating Degree Day (°C.day)
U: Overall Heat Transfer Coefficient (W/m2K)
A: Area of Calculation (m2)
1 day: 24 h
k : surface multiplication coefficient

Qe (kWh)

Qe=24[(aL).R.H. HDD. Ze]
=24[(2,5. 459,4).0,9.0,675.HDD.1]/1000
=3435,41

Qe : Enfiltration (kWh)
a:Air leakage coefficient (m3/mh)
L:Total lenght of windows and doors (m)
R:Room condition coefficient
H:Building condition coefficient (Wh/m3 oC)
ΔT:Temperature difference (oC)

Table F.2. Heat loss calculation for Balıkesir-I

HEAT LOSS CALCULATION																	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	19
	AREA CALCULATION						HEAT LOSS CALCULATION										
Building component	Thickness	Length	Height or Width	Total area	Unit	Skip area	Area for calculation	Overall heat transfer coefficient	AxU	T_{inside}	$T_{outside}$	Temperature difference	HEAT LOSS	ZD	ZH	ZW	Qi
							A	U				ΔT	Q_D				
	cm	m	m	m2	number	m2	m2	W/m2°C	W/°C	(°C)	(°C)	°C	W	%	%	%	W
GROUND FLOOR																	
SOUTH																	
Wall	20	31,1	2,6	80,86	1	18,7	62,16	0,593	36,88				958,84				978,02
R.Concrete Wall	30	6,6	3	19,8	1	0	19,8	0,555	10,99				285,81				291,53
Column	30	0,5	3	1,5	8	0	12	0,555	6,66				173,22				176,68
Beam	30	31,1	0,4	12,44	1	0	12,44	0,555	6,91	20	-6	26	179,57	0,07	-0,05	0	183,16
Window	\	6,3	1,5	9,45	1	0	9,45	2,200	20,79				540,54				551,35
Door	\	1,1	2,2	2,42	1	0	2,42	4,000	9,68				251,68				256,71
Entrance Door	\	3,7	2,5	9,25	1	0	9,25	4,000	37,00				962,00				981,24
Total									128,91	20	-6	20	2578,20	0,07	-0,05	0	**2629,76**
NORTH																	
Wall	20	31,1	2,6	80,86	1	23,74	57,12	0,593	33,89				881,10				986,8305012
R.Concrete Wall	30	6,6	3	19,8	1	0	19,8	0,555	10,99				285,81				320,1060611
Column	30	0,5	3	1,5	8	0	12	0,555	6,66	20	-6	26	173,22	0,07	0,05	0	194,0036734
Beam	30	30	0,4	12	1	0	12	0,555	6,66				173,22				194,0036734
Window	\	12,6	1,5	18,9	1	0	18,9	2,200	41,58				1081,08				1210,8096
Door	\	1,1	2,2	2,42	2	0	4,84	4,000	19,36				503,36				563,7632
Total									119,15	20	-6	26	3097,78	0,07	0,05	0	**3469,52**
EAST																	
Wall	20	17,4	2,6	45,24	1	12,8	32,44	0,593	19,25				500,40				535,4278611
Column	30	1,6	3	4,8	1	0	4,8	0,555	2,66				69,29				74,13711805
Beam	30	11,3	0,4	4,52	1	0	4,52	0,555	2,51	20	-6	26	65,25	0,07	0	0	69,81245283
Window	\	1,2	1,5	1,8	1	0	1,8	2,200	3,96				102,96				110,1672
Door	\	5	2,2	11	1	0	11	4,000	44,00				1144,00				1224,08
Total									72,38	20	-6	26	1881,89	0,07	0	0	**2013,62**
WEST																	
Wall	20	17,4	2,6	45,24	1	25,6	19,64	0,593	11,65				302,95				324,1616274
Column	30	1,6	3	4,8	1	0	4,8	0,555	2,66				69,29				74,13711805
Beam	30	5,2	0,4	2,08	1	0	2,08	0,555	1,15	20	-6	26	30,02	0,07	0	0	32,12608449
Window	\	1,2	1,5	1,8	2	0	3,6	2,200	7,92				205,92				220,3344
Door	\	5	2,2	11	2	0	22	4,000	88,00				2288,00				2448,16
Total									111,39	20	-6	26	2896,19	0,07	0	0	**3098,92**
BASEMENT																	
Basement	\	\	\	\	\	0	752,12	0,588	442,30	20	6	14	6192,22	0,07	0	0	**6625,67**

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Table F.2.(cont)

HEAT LOSS CALCULATION																	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	19
	AREA CALCULATION						HEAT LOSS CALCULATION										
Building component	Thickness	Length	Height or Width	Total area	Unit	Skip area	Area for calculation	Overall heat transfer coefficient	AxU	T_{inside}	$T_{outside}$	Temperature difference	HEAT LOSS	ZD	ZH	ZW	Q
							A	U				ΔT	Q_D				
	cm	m	m	m2	number	m2	m2	W/m2°C	W/°C	(°C)	(°C)	°C	W	%	%	%	W
1.-2. FLOOR																	
SOUTH-NORTH																	
Wall	20	31,1	2,6	80,86	1	0	80,86	0,593	47,97				1247,30				1272,24
R.Concrete Wall	30	6,6	3	19,8	1	0	19,8	0,555	10,99				285,81				291,53
Column	30	0,5	3	1,5	8	0	12	0,555	6,66	20	-6	26	173,22	0,07	-0,05	0	176,68
Beam	30	30	0,4	12	1	0	12	0,555	6,66				173,22				176,68
Window	\	12,6	1,5	18,9	1	0	18,9	2,200	41,58				1081,08				1102,70
Door	\	1,1	2,2	2,42	2	0	4,84	4,000	19,36				503,36				513,43
Total									133,23	20	-6	26	3463,98	0,07	-0,05	0	**3533,26**
NORTH																	
Wall	20	31,1	2,6	80,86	1	0	80,86	0,593	47,97				1247,30				1396,97
R.Concrete Wall	30	6,6	3	19,8	1	0	19,8	0,555	10,99				285,81				320,11
Column	30	0,5	3	1,5	8	0	12	0,555	6,66	20	-6	26	173,22	0,07	0,05	0	194,00
Beam	30	30	0,4	12	1	0	12	0,555	6,66				173,22				194,00
Window	\	12,6	1,5	18,9	1	0	18,9	2,200	41,58				1081,08				1210,81
Door	\	1,1	2,2	2,42	2	0	4,84	4,000	19,36				503,36				563,76
Total									133,23	20	-6	26	3463,98	0,07	0,05	0	**3879,66**
EAST																	
Wall	20	17,4	2,6	45,24	1	25,6	19,64	0,593	11,65				302,95				324,16
Column	30	1,6	3	4,8	8	0	38,4	0,555	21,32				554,30				593,10
Beam	30	5,2	0,4	2,08	1	0	2,08	0,555	1,15	20	-6	26	30,02	0,07	0	0	32,13
Window	\	1,2	1,5	1,8	2	0	3,6	2,200	7,92				205,92				220,33
Door	\	5	2,2	11	2	0	22	4,000	88,00				2288,00				2448,16
Total									130,05	20	-6	26	3381,20	0,07	0	0	**3617,88**
WEST																	
Wall	20	17,4	2,6	45,24	1	25,6	19,64	0,593	11,65				302,95				324,16
Column	30	1,6	3	4,8	8	0	38,4	0,555	21,32				554,30				593,10
Beam	30	5,2	0,4	2,08	1	0	2,08	0,555	1,15	20	-6	26	30,02	0,07	0	0	32,13
Window	\	1,2	1,5	1,8	2	0	3,6	2,200	7,92				205,92				220,33
Door	\	5	2,2	11	2	0	22	4,000	88,00				2288,00				2448,16
Total									130,05	20	-6	26	3381,20	0,07	0	0	**3617,88**

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Table F.2.(cont)

HEAT LOSS CALCULATION																	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	19
	AREA CALCULATION						HEAT LOSS CALCULATION										
Building component	Thickness	Length	Height or Width	Total area	Unit	Skip area	Area for calculation	Overall heat transfer coefficient	AxU	T_{inside}	$T_{outside}$	Temperature difference	HEAT LOSS	ZD	ZH	ZW	Q
							A	U				ΔT	Q_D				
	cm	m	m	m2	number	m2	m2	W/m2°C	W/°C	(°C)	(°C)	°C	W	%	%	%	W
3. FLOOR																	
SOUTH																	
Wall	20	31,1	2,6	80,86	1	0	80,86	0,593	47,97	20	-6	26	1247,30	0,07	-0,05	0,05	1334,61
R.Concrete Wall	30	6,6	3	19,8	1	0	19,8	0,555	10,99				285,81				305,82
Column	30	0,5	3	1,5	8	0	12	0,555	6,66				173,22				185,34
Beam	30	30	0,4	12	1	0	12	0,555	6,66				173,22				185,34
Window	\	12,6	1,5	18,9	1	0	18,9	2,200	41,58				1081,08				1156,76
Door	\	1,1	2,2	2,42	2	0	4,84	4,000	19,36				503,36				538,60
Total									133,23	20	-6	26	3463,98	0,07	-0,05	0,05	**3706,46**
NORTH																	
Wall	20	31,1	2,6	80,86	1	0	80,86	0,593	47,97	20	-6	26	1247,30	0,07	0,05	0,05	1459,34
R.Concrete Wall	30	6,6	3	19,8	1	0	19,8	0,555	10,99				285,81				334,40
Column	30	0,5	3	1,5	8	0	12	0,555	6,66				173,22				202,66
Beam	30	30	0,4	12	1	0	12	0,555	6,66				173,22				202,66
Window	\	12,6	1,5	18,9	1	0	18,9	2,200	41,58				1081,08				1264,86
Door	\	1,1	2,2	2,42	2	0	4,84	4,000	19,36				503,36				588,93
Total									133,23	20	-6	26	3463,98	0,07	0,05	0,05	**4052,86**
EAST																	
Wall	20	17,4	2,6	45,24	1	25,6	19,64	0,593	11,65	20	-6	26	302,95	0,07	0,05	0,05	354,46
Column	30	1,6	3	4,8	8	0	38,4	0,555	21,32				554,30				648,53
Beam	30	5,2	0,4	2,08	1	0	2,08	0,555	1,15				30,02				35,13
Window	\	1,2	1,5	1,8	2	0	3,6	2,200	7,92				205,92				240,93
Door	\	5	2,2	11	2	0	22	4,000	88,00				2288,00				2676,96
Total									130,05	20	-6	26	3381,20	0,07	0,05	0,05	**3956,00**
WEST																	
Wall	20	17,4	2,6	45,24	1	25,6	19,64	0,593	11,65	20	-6	26	302,95	0,07	0,05	0,05	354,46
Column	30	1,6	3	4,8	8	0	38,4	0,555	21,32				554,30				648,53
Beam	30	5,2	0,4	2,08	1	0	2,08	0,555	1,15				30,02				35,13
Window	\	1,2	1,5	1,8	2	0	3,6	2,200	7,92				205,92				240,93
Door	\	5	2,2	11	2	0	22	4,000	88,00				2288,00				2676,96
Total									130,05	20	-6	26	3381,20	0,07	0,05	0,05	**3956,00**
CEILING																	
Ceiling	\	\	\	\	\	0	752,12	0,351	264,33	20	3	17	4493,61	0,07	0,05	0,05	**5257,52**

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Table F.2.(cont)

Qe=(aL).R.H.ΔT. Ze =(2,5. 459,4).0,9.0,977.20.1 =3435,41 Qe : Enfiltration (W) a:Air leakage coefficient (m3/mh) L:Total lenght of windows and doors (m) R:Room condition coefficient H:Building condition coefficient (Wh/m3 oC) ΔT:Temperature difference (oC)	**20197,52**
Qtotal (W)	73612,53
Qtotal (kW)	73,61

HEATING DEGREE DAY HEAT LOSS CALCULATION	HDD	*k*	∑U.A	Q_{year} (kWh)
Basement		**0,5**	**442,30**	**8370,11**
Ceiling	**1577**	**0,8**	**264,33**	**8003,48**
Wall		**1**	**1484,93**	**56201,70**
∑Qyear (kWh)				**72575,29**
Qe (kWh)				**26407,07**
Qtotal				**98982,36**

∑Qyear (kWh)

q = U . (Ti - To)
qyear = 86400 . HDD . U
Qyear = (24 . k . HDD . U. A)/1000

Qyear: Annual Heat Loss (kWh)
HDD: Heating Degree Day (°C.day)
U: Overall Heat Transfer Coefficient (W/m2K)
A: Area of Calculation (m2)
1 day: 24 h
k : surface multiplication coefficient

Qe (kWh)

Qe=24[(aL).R.H. HDD. Ze]
=24[(2,5. 459,4).0,9.0,977.HDD.1]/1000
=3435,41

Qe : Enfiltration (kWh)
a:Air leakage coefficient (m3/mh)
L:Total lenght of windows and doors (m)
R:Room condition coefficient
H:Building condition coefficient (Wh/m3 oC)
ΔT:Temperature difference (oC)

Table F.3. Heat loss calculation for Kütahya-I

HEAT LOSS CALCULATION																	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	19
	AREA CALCULATION						HEAT LOSS CALCULATION										
Building component	Thickness	Length	Height or Width	Total area	Unit	Skip area	Area for calculation A	Overall heat transfer coefficient U	AxU	T_{inside}	$T_{outside}$	Temperature difference ΔT	HEAT LOSS Q_D	ZD	ZH	ZW	Qi
	cm	m	m	m2	number	m2	m2	W/m2°C	W/°C	(°C)	(°C)	°C	W	%	%	%	W
GROUND FLOOR																	
SOUTH																	
Wall	20	31,1	2,6	80,86	1	18,7	62,16	0,443	27,54				881,33				898,95
R.Concrete Wall	30	6,6	3	19,8	1	0	19,8	0,479	9,49				303,61				309,68
Column	30	0,5	3	1,5	8	0	12	0,479	5,75				184,00				187,68
Beam	30	31,1	0,4	12,44	1	0	12,44	0,479	5,96	20	-12	32	190,75	0,07	-0,05	0	194,57
Window	\	6,3	1,5	9,45	1	0	9,45	2,200	20,79				665,28				678,59
Door	\	1,1	2,2	2,42	1	0	2,42	4,000	9,68				309,76				315,96
Entrance Door	\	3,7	2,5	9,25	1	0	9,25	4,000	37,00				1184,00				1207,68
Total									116,21	20	-12	32	3718,73	0,07	-0,05	0	**3793,10**
NORTH																	
Wall	20	31,1	2,6	80,86	1	23,74	57,12	0,443	25,31				809,87				907,0520837
R.Concrete Wall	30	6,6	3	19,8	1	0	19,8	0,479	9,49				303,61				340,0383917
Column	30	0,5	3	1,5	8	0	12	0,479	5,75	20	-12	32	184,00	0,07	0,05	0	206,0838738
Beam	30	30	0,4	12	1	0	12	0,479	5,75				184,00				206,0838738
Window	\	12,6	1,5	18,9	1	0	18,9	2,200	41,58				1330,56				1490,2272
Door	\	1,1	2,2	2,42	2	0	4,84	4,000	19,36				619,52				693,8624
Total									107,24	20	-12	32	3431,56	0,07	0,05	0	**3843,35**
EAST																	
Wall	20	17,4	2,6	45,24	1	12,8	32,44	0,443	14,37				459,95				492,1422236
Column	30	1,6	3	4,8	1	0	4,8	0,479	2,30				73,60				78,75348033
Beam	30	11,3	0,4	4,52	1	0	4,52	0,479	2,17	20	-12	32	69,31	0,07	0	0	74,15952731
Window	\	1,2	1,5	1,8	1	0	1,8	2,200	3,96				126,72				135,5904
Door	\	5	2,2	11	1	0	11	4,000	44,00				1408,00				1506,56
Total									66,80	20	-12	32	2137,58	0,07	0	0	**2287,21**
WEST																	
Wall	20	17,4	2,6	45,24	1	25,6	19,64	0,443	8,70				278,46				297,9554029
Column	30	1,6	3	4,8	1	0	4,8	0,479	2,30				73,60				78,75348033
Beam	30	5,2	0,4	2,08	1	0	2,08	0,479	1,00	20	-12	32	31,89	0,07	0	0	34,12650814
Window	\	1,2	1,5	1,8	2	0	3,6	2,200	7,92				253,44				271,1808
Door	\	5	2,2	11	2	0	22	4,000	88,00				2816,00				3013,12
Total									107,92	20	-12	32	3453,40	0,07	0	0	**3695,14**
BASEMENT																	
Basement	\	\	\	\	\	0	752,12	0,455	341,97	20	6	14	4787,59	0,07	0	0	**5122,72**

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Table F.3.(cont)

HEAT LOSS CALCULATION																	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	19
	AREA CALCULATION						HEAT LOSS CALCULATION										
Building component	Thickness	Length	Height or Width	Total area	Unit	Skip area	Area for calculation	Overall heat transfer coefficient	AxU	T_{inside}	$T_{outside}$	Temperature difference	HEAT LOSS	ZD	ZH	ZW	Q
							A	U				ΔT	Q_D				
	cm	m	m	m2	number	m2	m2	W/m2°C	W/°C	(°C)	(°C)	°C	W	%	%	%	W
1.-2. FLOOR																	
SOUTH-NORTH																	
Wall	20	31,1	2,6	80,86	1	0	80,86	0,443	35,83	20	-12	32	1146,46	0,07	-0,05	0	1169,39
R.Concrete Wall	30	6,6	3	19,8	1	0	19,8	0,479	9,49				303,61				309,68
Column	30	0,5	3	1,5	8	0	12	0,479	5,75				184,00				187,68
Beam	30	30	0,4	12	1	0	12	0,479	5,75				184,00				187,68
Window	\	12,6	1,5	18,9	1	0	18,9	2,200	41,58				1330,56				1357,17
Door	\	1,1	2,2	2,42	2	0	4,84	4,000	19,36				619,52				631,91
Total									117,75	20	-12	32	3768,15	0,07	-0,05	0	**3843,52**
NORTH																	
Wall	20	31,1	2,6	80,86	1	0	80,86	0,443	35,83	20	-12	32	1146,46	0,07	0,05	0	1284,04
R.Concrete Wall	30	6,6	3	19,8	1	0	19,8	0,479	9,49				303,61				340,04
Column	30	0,5	3	1,5	8	0	12	0,479	5,75				184,00				206,08
Beam	30	30	0,4	12	1	0	12	0,479	5,75				184,00				206,08
Window	\	12,6	1,5	18,9	1	0	18,9	2,200	41,58				1330,56				1490,23
Door	\	1,1	2,2	2,42	2	0	4,84	4,000	19,36				619,52				693,86
Total									117,75	20	-12	32	3768,15	0,07	0,05	0	**4220,33**
EAST																	
Wall	20	17,4	2,6	45,24	1	25,6	19,64	0,443	8,70	20	-12	32	278,46	0,07	0	0	297,96
Column	30	1,6	3	4,8	8	0	38,4	0,479	18,40				588,81				630,03
Beam	30	5,2	0,4	2,08	1	0	2,08	0,479	1,00				31,89				34,13
Window	\	1,2	1,5	1,8	2	0	3,6	2,200	7,92				253,44				271,18
Door	\	5	2,2	11	2	0	22	4,000	88,00				2816,00				3013,12
Total									124,02	20	-12	32	3968,61	0,07	0	0	**4246,41**
WEST																	
Wall	20	17,4	2,6	45,24	1	25,6	19,64	0,443	8,70	20	-12	32	278,46	0,07	0	0	297,96
Column	30	1,6	3	4,8	8	0	38,4	0,479	18,40				588,81				630,03
Beam	30	5,2	0,4	2,08	1	0	2,08	0,479	1,00				31,89				34,13
Window	\	1,2	1,5	1,8	2	0	3,6	2,200	7,92				253,44				271,18
Door	\	5	2,2	11	2	0	22	4,000	88,00				2816,00				3013,12
Total									124,02	20	-12	32	3968,61	0,07	0	0	**4246,41**

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Table F.3.(cont)

HEAT LOSS CALCULATION																	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	19
	AREA CALCULATION						HEAT LOSS CALCULATION										
Building component	Thickness	Length	Height or Width	Total area	Unit	Skip area	Area for calculation	Overall heat transfer coefficient	AxU	T_{inside}	$T_{outside}$	Temperature difference	HEAT LOSS	ZD	ZH	ZW	Q
							A	U				ΔT	Q_D				
	cm	m	m	m2	number	m2	m2	W/m2°C	W/°C	(°C)	(°C)	°C	W	%	%	%	W
3. FLOOR																	
SOUTH																	
Wall	20	31,1	2,6	80,86	1	0	80,86	0,443	35,83	20	-12	32	1146,46	0,07	-0,05	0,05	1226,71
R.Concrete Wall	30	6,6	3	19,8	1	0	19,8	0,479	9,49				303,61				324,86
Column	30	0,5	3	1,5	8	0	12	0,479	5,75				184,00				196,88
Beam	30	30	0,4	12	1	0	12	0,479	5,75				184,00				196,88
Window	\	12,6	1,5	18,9	1	0	18,9	2,200	41,58				1330,56				1423,70
Door	\	1,1	2,2	2,42	2	0	4,84	4,000	19,36				619,52				662,89
Total									117,75	20	-12	32	3768,15	0,07	-0,05	0,05	**4031,93**
NORTH																	
Wall	20	31,1	2,6	80,86	1	0	80,86	0,443	35,83	20	-12	32	1146,46	0,07	0,05	0,05	1341,36
R.Concrete Wall	30	6,6	3	19,8	1	0	19,8	0,479	9,49				303,61				355,22
Column	30	0,5	3	1,5	8	0	12	0,479	5,75				184,00				215,28
Beam	30	30	0,4	12	1	0	12	0,479	5,75				184,00				215,28
Window	\	12,6	1,5	18,9	1	0	18,9	2,200	41,58				1330,56				1556,76
Door	\	1,1	2,2	2,42	2	0	4,84	4,000	19,36				619,52				724,84
Total									117,75	20	-12	32	3768,15	0,07	0,05	0,05	**4408,74**
EAST																	
Wall	20	17,4	2,6	45,24	1	25,6	19,64	0,443	8,70	20	-12	32	278,46	0,07	0,05	0,05	325,80
Column	30	1,6	3	4,8	8	0	38,4	0,479	18,40				588,81				688,91
Beam	30	5,2	0,4	2,08	1	0	2,08	0,479	1,00				31,89				37,32
Window	\	1,2	1,5	1,8	2	0	3,6	2,200	7,92				253,44				296,52
Door	\	5	2,2	11	2	0	22	4,000	88,00				2816,00				3294,72
Total									124,02	20	-12	32	3968,61	0,07	0,05	0,05	**4643,27**
WEST																	
Wall	20	17,4	2,6	45,24	1	25,6	19,64	0,443	8,70	20	-12	32	278,46	0,07	0,05	0,05	325,80
Column	30	1,6	3	4,8	8	0	38,4	0,479	18,40				588,81				688,91
Beam	30	5,2	0,4	2,08	1	0	2,08	0,479	1,00				31,89				37,32
Window	\	1,2	1,5	1,8	2	0	3,6	2,200	7,92				253,44				296,52
Door	\	5	2,2	11	2	0	22	4,000	88,00				2816,00				3294,72
Total									124,02	20	-12	32	3968,61	0,07	0,05	0,05	**4643,27**
CEILING																	
Ceiling	\	\	\	\	\	0	752,12	0,284	213,50	20	-3	23	4910,43	0,07	0,05	0,05	**5745,21**

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Table F.3.(cont)

Qe=(aL).R.H.ΔT. Ze =(2,5. 459,4).0,9.0,675.20.1 =3435,41 Qe : Enfiltration (W) a:Air leakage coefficient (m3/mh) L:Total lenght of windows and doors (m) R:Room condition coefficient H:Building condition coefficient (Wh/m3 oC) ΔT:Temperature difference (oC)	**13954,28**
Qtotal (W)	72724,87
Qtotal (kW)	72,72

HEATING DEGREE DAY HEAT LOSS CALCULATION	**HDD**	***k***	**∑U.A**	**Q_{year} (kWh)**
Basement		**0,5**	**341,97**	**7772,31**
Ceiling	**1894**	**0,8**	**213,50**	**7763,78**
Wall		**1**	**1365,26**	**62059,25**
∑Qyear (kWh)				**77595,34**
Qe (kWh)				**31715,28**
Qtotal				**109310,61**

∑Qyear (kWh)

q = U . (Ti - To)
qyear = 86400 . HDD . U
Qyear = (24 . k . HDD . U. A)/1000

Qyear: Annual Heat Loss (kWh)
HDD: Heating Degree Day (°C.day)
U: Overall Heat Transfer Coefficient (W/m2K)
A: Area of Calculation (m2)
1 day: 24 h
k : surface multiplication coefficient

Qe (kWh)

Qe=24[(aL).R.H. HDD. Ze]
=24[(2,5. 459,4).0,9.0,675.HDD.1]/1000
=3435,41

Qe : Enfiltration (kWh)
a:Air leakage coefficient (m3/mh)
L:Total lenght of windows and doors (m)
R:Room condition coefficient
H:Building condition coefficient (Wh/m3 oC)
ΔT:Temperature difference (oC)

Table F.4. Heat loss calculation for Ağrı-I

HEAT LOSS CALCULATION																	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	19
	AREA CALCULATION						HEAT LOSS CALCULATION										
Building component	Thickness	Length	Height or Width	Total area	Unit	Skip area	Area for calculation	Overall heat transfer coefficient	AxU	T_{inside}	$T_{outside}$	Temperature difference	HEAT LOSS	ZD	ZH	ZW	Qi
							A	U				ΔT	Q_D				
	cm	m	m	m2	number	m2	m2	W/m2°C	W/°C	(°C)	(°C)	°C	W	%	%	%	W
GROUND FLOOR																	
SOUTH																	
Wall	20	31,1	2,6	80,86	1	18,7	62,16	0,393	24,45				1075,65				1097,17
R.Concrete Wall	30	6,6	3	19,8	1	0	19,8	0,376	7,45				327,72				334,28
Column	30	0,5	3	1,5	8	0	12	0,376	4,51				198,62				202,59
Beam	30	31,1	0,4	12,44	1	0	12,44	0,376	4,68	20	-24	44	205,90	0,07	-0,05	0	210,02
Window	\	6,3	1,5	9,45	1	0	9,45	2,200	20,79				914,76				933,06
Door	\	1,1	2,2	2,42	1	0	2,42	4,000	9,68				425,92				434,44
Entrance Door	\	3,7	2,5	9,25	1	0	9,25	4,000	37,00				1628,00				1660,56
Total									108,56	20	-24	44	4776,58	0,07	-0,05	0	**4872,11**
NORTH																	
Wall	20	31,1	2,6	80,86	1	23,74	57,12	0,393	22,46				988,44				1107,052118
R.Concrete Wall	30	6,6	3	19,8	1	0	19,8	0,376	7,45				327,72				367,0493042
Column	30	0,5	3	1,5	8	0	12	0,376	4,51	20	-24	44	198,62	0,07	0,05	0	222,4541238
Beam	30	30	0,4	12	1	0	12	0,376	4,51				198,62				222,4541238
Window	\	12,6	1,5	18,9	1	0	18,9	2,200	41,58				1829,52				2049,0624
Door	\	1,1	2,2	2,42	2	0	4,84	4,000	19,36				851,84				954,0608
Total									99,88	20	-24	44	4394,76	0,07	0,05	0	**4922,13**
EAST																	
Wall	20	17,4	2,6	45,24	1	12,8	32,44	0,393	12,76				561,36				600,6568982
Column	30	1,6	3	4,8	1	0	4,8	0,376	1,81				79,45				85,00925444
Beam	30	11,3	0,4	4,52	1	0	4,52	0,376	1,70	20	-24	44	74,81	0,07	0	0	80,05038126
Window	\	1,2	1,5	1,8	1	0	1,8	2,200	3,96				174,24				186,4368
Door	\	5	2,2	11	1	0	11	4,000	44,00				1936,00				2071,52
Total									64,22	20	-24	44	2825,86	0,07	0	0	**3023,67**
WEST																	
Wall	20	17,4	2,6	45,24	1	25,6	19,64	0,393	7,72				339,86				363,6529433
Column	30	1,6	3	4,8	1	0	4,8	0,376	1,81				79,45				85,00925444
Beam	30	5,2	0,4	2,08	1	0	2,08	0,376	0,78	20	-24	44	34,43	0,07	0	0	36,83734359
Window	\	1,2	1,5	1,8	2	0	3,6	2,200	7,92				348,48				372,8736
Door	\	5	2,2	11	2	0	22	4,000	88,00				3872,00				4143,04
Total									106,23	20	-24	44	4674,22	0,07	0	0	**5001,41**
BASEMENT																	
Basement	\	\	\	\	\	0	752,12	0,402	302,65	20	3	17	5145,11	0,07	0	0	**5505,27**

(cont. on next page)

Table F.4.(cont)

HEAT LOSS CALCULATION																	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	19
	AREA CALCULATION						HEAT LOSS CALCULATION										
Building component	Thickness	Length	Height or Width	Total area	Unit	Skip area	Area for calculation	Overall heat transfer coefficient	AxU	T_{inside}	$T_{outside}$	Temperature difference	HEAT LOSS	ZD	ZH	ZW	Q
							A	U				ΔT	Q_D				
	cm	m	m	m2	number	m2	m2	W/m2°C	W/°C	(°C)	(°C)	°C	W	%	%	%	W
1.-2. FLOOR																	
SOUTH-NORTH																	
Wall	20	31,1	2,6	80,86	1	0	80,86	0,393	31,80				1399,25				1427,24
R.Concrete Wall	30	6,6	3	19,8	1	0	19,8	0,376	7,45				327,72				334,28
Column	30	0,5	3	1,5	8	0	12	0,376	4,51	20	-24	44	198,62	0,07	-0,05	0	202,59
Beam	30	30	0,4	12	1	0	12	0,376	4,51				198,62				202,59
Window	\	12,6	1,5	18,9	1	0	18,9	2,200	41,58				1829,52				1866,11
Door	\	1,1	2,2	2,42	2	0	4,84	4,000	19,36				851,84				868,88
Total									109,22	20	-24	44	4805,57	0,07	-0,05	0	**4901,68**
NORTH																	
Wall	20	31,1	2,6	80,86	1	0	80,86	0,393	31,80				1399,25				1567,16
R.Concrete Wall	30	6,6	3	19,8	1	0	19,8	0,376	7,45				327,72				367,05
Column	30	0,5	3	1,5	8	0	12	0,376	4,51	20	-24	44	198,62	0,07	0,05	0	222,45
Beam	30	30	0,4	12	1	0	12	0,376	4,51				198,62				222,45
Window	\	12,6	1,5	18,9	1	0	18,9	2,200	41,58				1829,52				2049,06
Door	\	1,1	2,2	2,42	2	0	4,84	4,000	19,36				851,84				954,06
Total									109,22	20	-24	44	4805,57	0,07	0,05	0	**5382,24**
EAST																	
Wall	20	17,4	2,6	45,24	1	25,6	19,64	0,393	7,72				339,86				363,65
Column	30	1,6	3	4,8	8	0	38,4	0,376	14,45				635,58				680,07
Beam	30	5,2	0,4	2,08	1	0	2,08	0,376	0,78	20	-24	44	34,43	0,07	0	0	36,84
Window	\	1,2	1,5	1,8	2	0	3,6	2,200	7,92				348,48				372,87
Door	\	5	2,2	11	2	0	22	4,000	88,00				3872,00				4143,04
Total									118,87	20	-24	44	5230,35	0,07	0	0	**5596,48**
WEST																	
Wall	20	17,4	2,6	45,24	1	25,6	19,64	0,393	7,72				339,86				363,65
Column	30	1,6	3	4,8	8	0	38,4	0,376	14,45				635,58				680,07
Beam	30	5,2	0,4	2,08	1	0	2,08	0,376	0,78	20	-24	44	34,43	0,07	0	0	36,84
Window	\	1,2	1,5	1,8	2	0	3,6	2,200	7,92				348,48				372,87
Door	\	5	2,2	11	2	0	22	4,000	88,00				3872,00				4143,04
Total									118,87	20	-24	44	5230,35	0,07	0	0	**5596,48**

(cont. on next page)

Table F.4.(cont)

HEAT LOSS CALCULATION																	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	19
Building component	AREA CALCULATION						HEAT LOSS CALCULATION										
	Thickness	Length	Height or Width	Total area	Unit	Skip area	Area for calculation	Overall heat transfer coefficient	AxU	T_{inside}	$T_{outside}$	Temperature difference	HEAT LOSS	ZD	ZH	ZW	Q
							A	U				ΔT	Q_D				
	cm	m	m	m2	number	m2	m2	W/m2°C	W/°C	(°C)	(°C)	°C	W	%	%	%	W
3. FLOOR																	
SOUTH																	
Wall	20	31,1	2,6	80,86	1	0	80,86	0,393	31,80	20	-24	44	1399,25	0,07	-0,05	0,05	1497,20
R.Concrete Wall	30	6,6	3	19,8	1	0	19,8	0,376	7,45				327,72				350,66
Column	30	0,5	3	1,5	8	0	12	0,376	4,51				198,62				212,52
Beam	30	30	0,4	12	1	0	12	0,376	4,51				198,62				212,52
Window	\	12,6	1,5	18,9	1	0	18,9	2,200	41,58				1829,52				1957,59
Door	\	1,1	2,2	2,42	2	0	4,84	4,000	19,36				851,84				911,47
Total									109,22	20	-24	44	4805,57	0,07	-0,05	0,05	**5141,96**
NORTH																	
Wall	20	31,1	2,6	80,86	1	0	80,86	0,393	31,80	20	-24	44	1399,25	0,07	0,05	0,05	1637,12
R.Concrete Wall	30	6,6	3	19,8	1	0	19,8	0,376	7,45				327,72				383,44
Column	30	0,5	3	1,5	8	0	12	0,376	4,51				198,62				232,39
Beam	30	30	0,4	12	1	0	12	0,376	4,51				198,62				232,39
Window	\	12,6	1,5	18,9	1	0	18,9	2,200	41,58				1829,52				2140,54
Door	\	1,1	2,2	2,42	2	0	4,84	4,000	19,36				851,84				996,65
Total									109,22	20	-24	44	4805,57	0,07	0,05	0,05	**5622,52**
EAST																	
Wall	20	17,4	2,6	45,24	1	25,6	19,64	0,393	7,72	20	-24	44	339,86	0,07	0,05	0,05	397,64
Column	30	1,6	3	4,8	8	0	38,4	0,376	14,45				635,58				743,63
Beam	30	5,2	0,4	2,08	1	0	2,08	0,376	0,78				34,43				40,28
Window	\	1,2	1,5	1,8	2	0	3,6	2,200	7,92				348,48				407,72
Door	\	5	2,2	11	2	0	22	4,000	88,00				3872,00				4530,24
Total									118,87	20	-24	44	5230,35	0,07	0,05	0,05	**6119,51**
WEST																	
Wall	20	17,4	2,6	45,24	1	25,6	19,64	0,393	7,72	20	-24	44	339,86	0,07	0,05	0,05	397,64
Column	30	1,6	3	4,8	8	0	38,4	0,376	14,45				635,58				743,63
Beam	30	5,2	0,4	2,08	1	0	2,08	0,376	0,78				34,43				40,28
Window	\	1,2	1,5	1,8	2	0	3,6	2,200	7,92				348,48				407,72
Door	\	5	2,2	11	2	0	22	4,000	88,00				3872,00				4530,24
Total									118,87	20	-24	44	5230,35	0,07	0,05	0,05	**6119,51**
CEILING																	
Ceiling	\	\	\	\	\	0	752,12	0,244	183,70	20	-12	32	5878,40	0,07	0,05	0,05	**6877,73**

(cont. on next page)

Table F.4.(cont)

Qe=(aL).R.H.ΔT. Ze =(2,5. 459,4).0,9.0,675.20.1 =3435,41 Qe : Enfiltration (W) a:Air leakage coefficient (m3/mh) L:Total lenght of windows and doors (m) R:Room condition coefficient H:Building condition coefficient (Wh/m3 oC) ΔT:Temperature difference (oC)				13954,28
Qtotal (W)				**88636,99**
Qtotal (kW)				**88,64**
HEATING DEGREE DAY HEAT LOSS CALCULATION	**HDD**	***k***	**∑U.A**	**Q_{year} (kWh)**
Basement	**3367**	**0,5**	**302,65**	**12228,42**
Ceiling		**0,8**	**183,70**	**11875,54**
Wall		**1**	**1291,25**	**104343,56**
∑Qyear (kWh)				**128447,52**
Qe (kWh)				**56380,85**
Qtotal				**184828,37**

∑Qyear (kWh)

q = U . (Ti - To)
qyear = 86400 . HDD . U
Qyear = (24 . k . HDD . U. A)/1000

Qyear: Annual Heat Loss (kWh)
HDD: Heating Degree Day (°C.day)
U: Overall Heat Transfer Coefficient (W/m2K)
A: Area of Calculation (m2)
1 day: 24 h
k : surface multiplication coefficient

Qe (kWh)

Qe=24[(aL).R.H. HDD. Ze]
=24[(2,5. 459,4).0,9.0,675.HDD.1]/1000
=3435,41

Qe : Enfiltration (kWh)
a:Air leakage coefficient (m3/mh)
L:Total lenght of windows and doors (m)
R:Room condition coefficient
H:Building condition coefficient (Wh/m3 oC)
ΔT:Temperature difference (oC)

APPENDIX G

MODELS AND PRICES OF BOILERS

Table G.1 Boiler models of Baymak for coal (Model: Stokerli Linyit Comfort Plus Series / Solid-Fuel Steel Floor Heater)

Teknik Veri Tablosu

Modeller		LİNYİT COMFORT 20 STOKERLİ	LİNYİT COMFORT 40 STOKERLİ	LİNYİT COMFORT 60 STOKERLİ	LİNYİT COMFORT 80 STOKERLİ
Anma Gücü	kcal/h	20.000	40.000	60.000	80.000
Anma Gücü	kW	23	46	70	93
Güç Aralığı	kW	18-23	32-46	50-70	70-93
Kazan Max. işletme basıncı	bar	3	3	3	3
Kazan test basıncı	bar	4,5	4,5	4,5	4,5
Maximum çalışma sıcaklığı	°C	90	90	90	90
Limit termostat kesme sıcaklığı	°C	100	100	100	100
Su hacmi	l	65	92	122	188
Kazan ağırlığı	kg	276	347	512	576
Kazan genleşme tankı (Opsiyonel)	l	50	100	100	100
Sirkülasyon pompası (DAB) (Opsiyonel)	Model	EVOSTA 40-70/130	EVOSTA 40-70/130	EVOPLUS 60/180.XM	EVOPLUS 60/180.XM
Baca bağlantı kanalı çapı	mm	Ø150	Ø185	Ø185	Ø185
Kömür Hacmi	kg	85	125	145	145
Genişlik (kaplamalı)	mm	933	1007	1007	1100
Yükseklik (kaplamalı)	mm	1291	1365	1445	1575
Derinlik (kaplamalı)	mm	1115	1230	1445	1480
Tesisat Giriş	Ø	1"	1"	1"	1"
Tesisat Çıkış	Ø	1"	1"	1"	1"
İmbisat Giriş	Ø	1"	1"	1"	1"
İmbisat Çıkış	Ø	1"	1"	1"	1"
Doldurma Boşaltma	Ø	1/2"	1/2"	1/2"	1/2"
Kazan Su Hacmi	l	65	92	122	188

baymak
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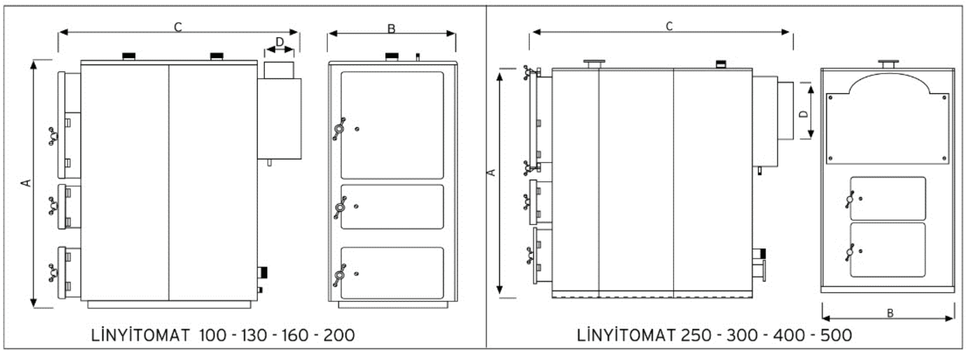
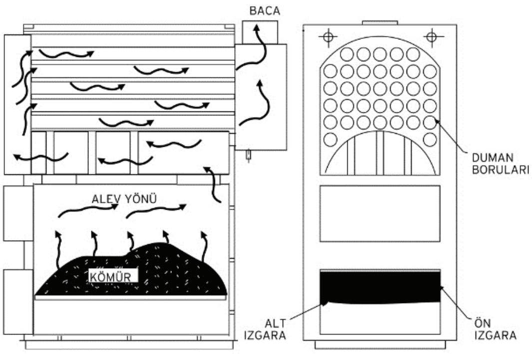
Table G.2 Boiler models of Baymak for coal (Model: Linyomat Series / 3 Solid-Fuel Full-Pass Boiler

Kazan Teknik Ölçüleri





Teknik Veri Tablosu

KAPASİTE Kcal/h	A Yükseklik (mm)	B Genişlik (mm)	C Derinlik (mm)	D Baca Çapı (Ø)	Tesisat Giriş (Ø)	Tesisat Çıkış (Ø)	İmbisat Giriş (Ø)	İmbisat Çıkış (Ø)	Doldurma Boşaltma (Ø)	Kazan Su Hacmi (l)	İmbisat Tankı (l) (Opsiyonel)	Sirkülasyon Pompası (Opsiyonel)	Çalışma Basıncı (Bar)	Test Basıncı (Bar)	Ağırlık (kg)
100.000	1510	870	1360	220	2"	2"	1 1/4"	1 1/4"	3/4"	285	110	EVOPLUS B 80/250.40 M	3	4,5	860
130.000	1680	880	1500	220	2 1/2"	2 1/2"	1 1/2"	1 1/2"	3/4"	356	200	EVOPLUS B 80/250.40 M	3	4,5	960
160.000	1890	880	1500	220	2 1/2"	2 1/2"	1 1/2"	1 1/2"	3/4"	413	200	EVOPLUS B 80/250.40 M	3	4,5	1030
200.000	1890	880	1640	220	3"	3"	1 1/2"	1 1/2"	3/4"	463	300	EVOPLUS B 60/220.40 M	3	4,5	1190
250.000	2000	1100	2160	300	3"	3"	2"	2"	3/4"	626	300	EVOPLUS B 120/250.40 M	3	4,5	1850
300.000	2000	1100	2430	300	3"	3"	2"	2"	3/4"	847	500	EVOPLUS B 60/240.50 M	3	4,5	2200
400.000	2280	1400	2870	550	DN 100	DN 100	3"	3"	1"	1700	500	EVOPLUS B 60/240.50 M	3	4,5	3900
500.000	2500	1500	3100	550	DN 100	DN 100	3"	3"	1"	2480	750	EVOPLUS B 120/280.50 M	3	4,5	4700

baymak

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Table G.3 Price of boiler models of Baymak for coal

YÜRÜRLÜĞE GİRİŞ TARİHİ :01/02/2018
(2018/02 FİYAT LİSTEMİZ BAZ ALINMIŞTIR.)
KDV HARİÇ TAVSİYE EDİLEN PERAKENDE SATIŞ FİYAT LİSTESİ
BU FİYATLARA NAKLİYE ÜCRETLERİ DAHİL DEĞİLDİR, NAKLİYE ÜCRETLERİ VE UYGULAMALARI AYRICA İLA
KREDİ KARTI FİYATLARI YALNIZCA ANLAŞMALI BANKALARDA GEÇERLİDİR.

BAYMAK LİNYİT COMFORT KATI YAKITLI KAZANLAR
PERAKENDE SATIŞ FİYATLARI

	ÜRÜN KODU	ÜRÜN ADI	KAPASİTE Kcal/h	ÇALIŞMA BASINCI (Atü)	NAKİT
TL	05090400	LİNYİT COMFORT 20 MANUEL	20.000	3	3.310
TL	05090401	LİNYİT COMFORT 40 MANUEL	40.000	3	3.977
TL	100020782	LİNYİT COMFORT 60 MANUEL	60.000	3	4.643

Linyit Comfort serisi kazanlara pompa dahil değildir.

BAYMAK LİNYİT COMFORT OTOMATİK YÜKLEMELİ KATI YAKITLI KAZANLAR
PERAKENDE SATIŞ FİYATLARI

	ÜRÜN KODU	ÜRÜN ADI	KAPASİTE Kcal/h	ÇALIŞMA BASINCI (Atü)	NAKİT
TL	05090410	LİNYİT COMFORT 20 OTOMATİK YÜKLEMELİ	20.000	3	5.614
TL	05090411	LİNYİT COMFORT 40 OTOMATİK YÜKLEMELİ	40.000	3	6.543
TL	100020742	LİNYİT COMFORT 60 OTOMATİK YÜKLEMELİ	60.000	3	7.034

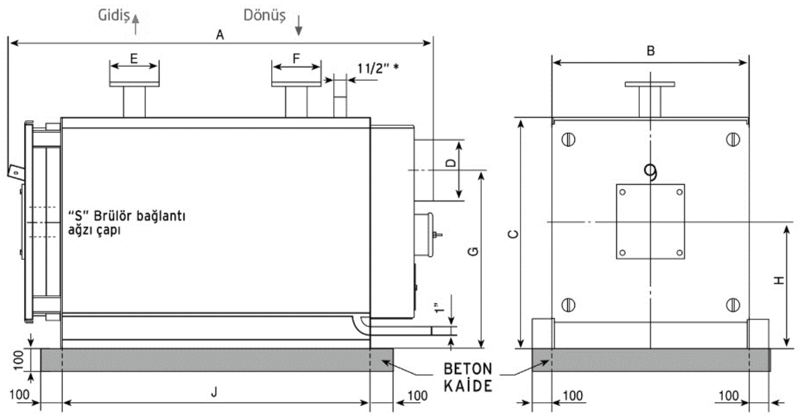
Linyit Comfort serisi kazanlara pompa dahil değildir.

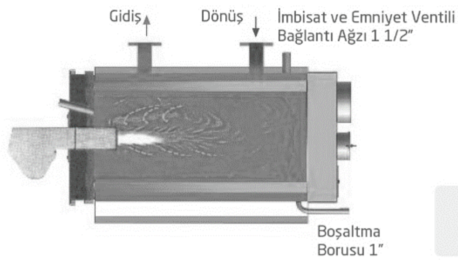
SİRKÜLASYON POMPASIZ
BAYMAK LİNYİTOMAT KATI YAKITLI KAZANLAR
PERAKENDE SATIŞ FİYATLARI

	ÜRÜN KODU	ÜRÜN ADI	KAPASİTE Kcal/h	ÇALIŞMA BASINCI (Atü)	NAKİT
TL	05090192	LİNYİTOMAT 80 PLUS FANLI (POMPASIZ)	80.000	3	6.368
TL	05090153	LİNYİTOMAT 100 KATI YAKITLI FANLI (3 ATU)	100.000	3	10.574
TL	05090154	LİNYİTOMAT 130 KATI YAKITLI FANLI (3 ATU)	130.000	3	12.832
TL	05090155	LİNYİTOMAT 160 KATI YAKITLI FANLI (3 ATU)	160.000	3	13.753
TL	05090156	LİNYİTOMAT 200 KATI YAKITLI FANLI (3 ATU)	200.000	3	14.922
TL	05090157	LİNYİTOMAT 250 KATI YAKITLI FANLI (3 ATU)	250.000	3	20.707
TL	05090158	LİNYİTOMAT 300 KATI YAKITLI FANLI (3 ATU)	300.000	3	23.298
TL	05090159	LİNYİTOMAT 400 KATI YAKITLI FANLI (3 ATU)	400.000	3	39.998
TL	05090160	LİNYİTOMAT 500 KATI YAKITLI FANLI (3 ATU)	500.000	3	47.987

Table G.4 Boiler models of Baymak for fuel oil and natural gas (Model: Yakut Series / 2 Rolling Counter-Pressure Steel Boiler

Kazan Teknik Özellikleri





Özel yanma odası konstrüksiyonu sayesinde yumuşak devreye girme ve sessiz çalışma sağlanmıştır

Teknik Veri Tablosu

Kazan Tipi Yakut	KAPASİTE Kcal/h	KAPASİTE kW	A mm	B mm	C mm	D mm	E mm	F mm	G mm	H mm	J mm	Su hacmi *l*	Yaklaşık Kazan Ağırlığı kg
6	65.000	75	1300	665	750	197	R 1 1/2"	R 1 1/2"	540	415	808	100	260
8	85.000	99	1370	700	815	217	R 1 1/2"	R 1 1/2"	605	440	845	105	350
10	100.000	115	1520	720	815	247	65	65	605	440	990	120	420
12	125.000	145	1520	720	815	247	65	65	605	440	990	120	420
15	150.000	175	1550	740	890	247	65	65	670	500	1030	186	465
18	180.000	205	1550	740	890	247	65	65	670	500	1030	186	465
20	200.000	235	1760	800	930	247	80	80	725	512	1210	250	560
25	250.000	290	1760	800	930	247	80	80	725	512	1210	250	560
30	300.000	350	1995	850	950	296	80	80	745	510	1460	320	675
35	350.000	410	1995	850	950	296	80	80	745	510	1460	320	675
40	400.000	465	2070	1020	1105	296	80	80	850	595	1487	565	1087
50	500.000	580	2070	1125	1200	346	100	100	890	640	1487	635	1087
60	600.000	700	2070	1125	1200	346	100	100	890	640	1487	635	1087
70	700.000	815	2350	1125	1200	346	100	100	890	640	1725	690	1339
80	800.000	930	2350	1125	1200	346	100	100	890	640	1725	690	1339

- Teknik bilgilerde değişiklik hakkımız saklıdır.
- Yakut 6-8 kazanda tüm bağlantılar dişlidir. İmbisat bağlantısı R 1 1/4" tir.
- Yakut 6 için S=145 mm, Yakut 8-35 arasında S=175 mm, Yakut 40-80 arasında S=245 mm'dir.
- Kazan kontrol panoları opsiyoneldir.

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Table G.5 Price of boiler models of Baymak for fuel oil and natural gas (Model: Yakut Series / 2 Rolling Counter-Pressure Steel Boiler)

YÜRÜRLÜĞE GİRİŞ TARİHİ :01/02/2018
(2018/02 FİYAT LİSTEMİZ BAZ ALINMIŞTIR.)
YENİ YAKUT KAZANLAR
PERAKENDE SATIŞ FİYATLARI

DÖVİZ CİNSİ	ÜRÜN KODU	ÜRÜN ADI	ÇALIŞMA BASINCI	KAPASİTE KCAL/H	Adet	NAKİT
	Ürün Kodu	**YAKUT 6" KAZAN**	**3 ATÜ**	**65.000**		
TL	06190800	YAKUT 6" KAPLAMA			1	345
TL	06190400	YAKUT 6" KAZAN			1	2.669
		Paket Fiyatı - TL				**3.014**
					Adet	
	Ürün Kodu	**YAKUT 8" KAZAN**	**3 ATÜ**	**85.000**		
TL	06190801	YAKUT 8" KAPLAMA			1	360
TL	06190401	YAKUT 8" KAZAN			1	3.071
		Paket Fiyatı - TL				**3.431**
					Adet	
	Ürün Kodu	**YAKUT 10" KAZAN**	**3 ATÜ**	**100.000**		
TL	06190814	YAKUT 10-12" KAPLAMA (KIRMIZI)			1	291
TL	06190402	YAKUT 10" KAZAN GOVDE			1	3.587
		Paket Fiyatı - TL				**3.878**
					Adet	
	Ürün Kodu	**YAKUT 12" KAZAN**	**3 ATÜ**	**125.000**		
TL	06190814	YAKUT 10-12" KAPLAMA (KIRMIZI)			1	291
TL	06190403	YAKUT 12" KAZAN GOVDE			1	3.657
		Paket Fiyatı - TL				**3.948**
					Adet	
	Ürün Kodu	**YAKUT 15" KAZAN**	**3 ATÜ**	**150.000**		
TL	06190815	YAKUT 15-18" KAPLAMA (KIRMIZI)			1	316
TL	06190404	YAKUT 15" KAZAN GOVDE			1	3.902
		Paket Fiyatı - TL				**4.218**
					Adet	
	Ürün Kodu	**YAKUT 18" KAZAN**	**3 ATÜ**	**180.000**		

APPENDIX H

MODELS AND PRICES OF HEAT EXCHANGER

Table H.1 Alarko heat exchanger models

Tablo 1: Radyatörlü Isıtma, Devre Kırıcı (Primer 60-40°C, Sekonder 30-50°C)

Tip	Kapasite (Kw)	Primer Devre Basınç Kaybı (mSS)	Sekonder Devre Basınç Kaybı (mSS)	Primer ve sekonder devrelerdeki toplam su hacmi (litre)	Bağlantı çapı	Yükseklik (mm)	Genişlik (mm)	Derinlik (mm)	Susuz ağırlık (kg)
APE 3-4-12	20	0,7	0,9	2	DN32	758	180	112	36
APE 3-4-14	30	1	1,3	3	DN32	758	180	112	37
APE 3-4-16	40	1,3	1,6	3	DN32	758	180	112	38
APE 3-4-18	50	1,5	1,8	4	DN32	758	180	112	39
APE 3-4-20	60	1,8	2,1	4	DN32	758	180	112	40
APE 3-4-22	70	1,9	2,2	5	DN32	758	180	212	42
APE 3-4-24	80	2,1	2,4	5	DN32	758	180	212	43
APE 3-4-25	90	2,5	2,9	5	DN32	758	180	212	43
APE 3-4-26	100	2,7	3	5	DN32	758	180	212	44
APE 3-4-30	125	3,1	3,4	6	DN32	758	180	212	45
APE 3-4-34	150	3,4	3,8	7	DN32	758	180	212	47
APE 3-4-40	175	3,5	3,7	8	DN32	758	180	212	50
APE 3-4-44	200	3,8	4	9	DN32	758	180	262	52
APE 5-3-25	225	4,2	4,2	8	DN50	896	283	437	134
APE 5-3-27	250	4,5	4,4	9	DN50	896	283	437	136
APE 5-3-29	275	4,7	4,6	10	DN50	896	283	437	137
APE 5-3-31	300	4,8	4,7	10	DN50	896	283	437	138
APE 5-3-36	350	4,7	4,7	12	DN50	896	283	437	142
APE 5-3-40	400	5	4,9	13	DN50	896	283	537	146
APE 5-3-45	450	4,8	4,8	15	DN50	896	283	537	150
APE 6-1-31	500	5	5	18	DN65	946	395	438	205
APE 6-1-34	550	5	4,9	20	DN65	946	395	438	208
APE 6-1-37	600	4,9	4,8	22	DN65	946	395	438	211
APE 6-1-40	650	4,9	4,9	23	DN65	946	395	438	214
APE 6-1-43	700	4,9	4,9	25	DN65	946	395	438	216
APE 6-1-46	750	4,9	4,9	27	DN65	946	395	438	219
APE 6-1-49	800	4,9	4,9	29	DN65	946	395	438	222
APE 6-1-52	850	4,9	4,9	31	DN65	946	395	438	225
APE 6-1-55	900	4,9	4,9	32	DN65	946	395	438	227
APE 6-1-58	950	5	4,9	34	DN65	946	395	438	230
APE 6-1-61	1000	5	5	36	DN65	946	395	538	234

Tablo 2: Radyatörlü Isıtma Devre Kırıcı (Primer 80-60°C, Sekonder 50-70°C)

Tip	Kapasite (Kw)	Primer Devre Basınç Kaybı (mSS)	Sekonder Devre Basınç Kaybı (mSS)	Primer ve sekonder devrelerdeki toplam su hacmi (litre)	Bağlantı çapı	Yükseklik (mm)	Genişlik (mm)	Derinlik (mm)	Susuz ağırlık (kg)
APE 2-4-18	20	0,2	0,2	3	DN32	483	180	112	24
APE 2-4-24	30	0,2	0,2	4	DN32	483	180	212	27
APE 2-4-30	40	0,3	0,2	5	DN32	483	180	212	28
APE 3-4-18	50	1,9	1,5	4	DN32	758	180	112	39
APE 3-4-20	60	2,1	1,8	4	DN32	758	180	112	40
APE 3-4-22	70	2,3	1,9	5	DN32	758	180	212	42
APE 3-4-24	80	2,4	2,1	5	DN32	758	180	212	43
APE 3-4-24	90	2,9	2,6	5	DN32	758	180	212	43
APE 3-4-26	100	3,1	2,7	5	DN32	758	180	212	44
APE 3-4-30	125	3,5	3,1	6	DN32	758	180	212	45
APE 3-4-36	150	3,5	3,2	8	DN32	758	180	212	48
APE 3-4-40	175	3,8	3,5	8	DN32	758	180	212	50
APE 5-3-22	200	3,9	3,8	7	DN50	896	283	437	132
APE 5-3-24	225	4,1	4,1	8	DN50	896	283	437	134
APE 5-3-26	250	4,3	4,3	9	DN50	896	283	437	135
APE 5-3-28	275	4,5	4,5	9	DN50	896	283	437	136
APE 5-3-30	300	4,6	4,6	10	DN50	896	283	437	138
APE 5-3-35	350	4,6	4,5	12	DN50	896	283	437	141
APE 5-3-39	400	4,7	4,7	13	DN50	896	283	437	144
APE 5-3-43	450	4,9	4,8	15	DN50	896	283	537	148
APE 5-3-47	500	5,1	5	16	DN50	896	283	537	151
APE 5-3-52	550	5	5	18	DN50	896	283	537	154
APE 5-3-57	600	5	5	19	DN50	896	283	537	158
APE 6-1-37	650	4,8	4,8	22	DN65	946	395	438	211
APE 6-1-39	700	5	5	23	DN65	946	395	438	213
APE 6-1-42	750	5	4,9	25	DN65	946	395	438	215
APE 6-1-45	800	4,9	4,8	26	DN65	946	395	438	218
APE 6-1-47	850	5,1	5	28	DN65	946	395	438	220
APE 6-1-50	900	5	4,9	29	DN65	946	395	438	223
APE 6-1-53	950	4,9	4,9	31	DN65	946	395	438	225
APE 6-1-55	1000	5,1	5,1	32	DN65	946	395	438	227

Table H.2 Alarko heat exchanger price of models December 2018

ALARKO

Carrier

ALARKO CARRIER
SANAYİ VE TİCARET A.Ş.

PLAKALI EŞANJÖR

Liste No : S/18-04
Sayfa No : 1
Tarih : 31.12.2018

ADANA-TEL : (322) 457 62 23
ANKARA-TEL : (312) 409 52 00
ANTALYA-TEL : (242) 322 00 29
İSTANBUL-TEL : (262) 648 60 00
İZMİR-TEL : (232) 483 25 60

ÖNERİLEN BAYİ SATIŞ FİYAT LİSTESİ
TÜM FİYATLARA **KDV** DAHİLDİR

Bu Liste, 15.11.2018 Tarihli Liste Yerine Geçer

ÜRÜN KODU	ÜRÜN TİPİ	TEKNİK ÖZELLİKLER	FİYATLAR (€)				ÜRETİM YERİ
		Kapasite kW	Peşin	1 Peşin 4 Taksit	1 Peşin 6 Taksit	1 Peşin 10 Taksit	
Radyatörlü Isıtma, Devre Kırıcı (Primer 60-40 °C, Sekonder 30-50 °C)							
09.16.002.0024	APE 3-4-12	20	353	367	374	388	
09.16.002.0025	APE 3-4-14	30	377	392	400	415	
09.16.002.0026	APE 3-4-16	40	401	417	425	441	
09.16.002.0027	APE 3-4-18	50	425	442	451	468	
09.16.002.0028	APE 3-4-20	60	450	468	477	495	
09.16.002.0029	APE 3-4-22	70	474	493	502	521	
09.16.002.0030	APE 3-4-24	80	498	518	528	548	
09.16.002.0031	APE 3-4-25	90	510	530	541	561	
09.16.002.0032	APE 3-4-26	100	522	543	553	574	
09.16.002.0033	APE 3-4-30	125	571	594	605	628	
09.16.002.0034	APE 3-4-34	150	619	644	656	681	
09.16.002.0035	APE 3-4-40	175	692	720	734	761	
09.16.002.0036	APE 3-4-44	200	740	770	784	814	
09.16.002.0066	APE 5-3-25	225	809	841	858	890	
09.16.002.0068	APE 5-3-27	250	845	879	896	930	
09.16.002.0070	APE 5-3-29	275	880	915	933	968	TÜRKİYE YERLİ ÜRETİM
09.16.002.0071	APE 5-3-31	300	915	952	970	1.007	
09.16.002.0074	APE 5-3-36	350	1.004	1.044	1.064	1.104	
09.16.002.0075	APE 5-3-40	400	1.074	1.117	1.138	1.181	
09.16.002.0078	APE 5-3-45	450	1.163	1.210	1.233	1.279	
09.16.002.0105	APE 6-1-31	500	1.174	1.221	1.244	1.291	
09.16.002.0106	APE 6-1-34	550	1.230	1.279	1.304	1.353	
09.16.002.0108	APE 6-1-37	600	1.286	1.337	1.363	1.415	
09.16.002.0110	APE 6-1-40	650	1.342	1.396	1.423	1.476	
09.16.002.0111	APE 6-1-43	700	1.398	1.454	1.482	1.538	
09.16.002.0112	APE 6-1-46	750	1.454	1.512	1.541	1.599	
09.16.002.0114	APE 6-1-49	800	1.510	1.570	1.601	1.661	
09.16.002.0115	APE 6-1-52	850	1.565	1.628	1.659	1.722	
09.16.002.0116	APE 6-1-55	900	1.621	1.686	1.718	1.783	
09.16.002.0118	APE 6-1-58	950	1.677	1.744	1.778	1.845	
09.16.002.0119	APE 6-1-61	1000	1.733	1.802	1.837	1.906	

NOT

1- Fiyatlarımıza % 18 KDV dahildir.
2- Fiyatlarımız AVRO/adet cinsinden verilmiştir. Ödemelerde teslim tarihindeki T.C.M.B. Avro efektif satış kuru geçerlidir.
3- Ürünlerimizin teslim yeri ACST yetkili satıcı depolarıdır
4- Cihazların tesliminden önce gelebilecek yeni vergiler ve vergi artışları aynı oranda fiyatlara yansıtılacaktır.

APPENDIX I

LIFE CYCLE COST CALCULATION

Table I.1 Life cycle cost calculation for coal in İzmir

İZMİR/COAL										
year	**inflation (%) (TL)**	**inflation (%) ($)**	**cost$_{investment}$**		**cost$_{fuel}$**	**cost$_{CO2}$**		**cost$_{renovation}$**	LCC (TL)	LCC ($)
			field	system		**$**	**TL**			
2018	8,9	1,8	42,91	7,03	8,07	1,21	6,38	0	64,40	12,24
2019			0	0	8,79	1,23	6,49	0	15,28	2,91
2020			0	0	9,57	1,26	6,61	0	16,18	3,08
2021			0	0	10,42	1,28	6,73	0	17,15	3,26
2022			0	0	11,35	1,30	6,85	0	18,20	3,46
2023			0	0	12,36	1,33	6,97	0	19,33	3,68
2024			0	0	13,46	1,35	7,10	0	20,56	3,91
2025			0	0	14,66	1,37	7,23	0	21,89	4,16
2026			0	0	15,96	1,40	7,36	0	23,32	4,43
2027			0	0	17,38	1,42	7,49	0	24,87	4,73
2028			0	0	18,93	1,45	7,62	0	26,56	5,05
2029			0	0	20,62	1,48	7,76	0	28,38	5,40
2030			0	0	22,45	1,50	7,90	0	30,35	5,77
2031			0	0	24,45	1,53	8,04	0	32,49	6,18
2032			0	0	26,63	1,56	8,19	23,21	58,02	11,03
2033			0	0	29,00	1,58	8,34	0	37,33	7,10
2034			0	0	31,58	1,61	8,49	0	40,06	7,62
2035			0	0	34,39	1,64	8,64	0	43,03	8,18
2036			0	0	37,45	1,67	8,79	0	46,24	8,79
2037			0	0	40,78	1,70	8,95	0	49,73	9,45
2038			0	0	44,41	1,73	9,11	0	53,52	10,18
2039			0	0	48,36	1,76	9,28	0	57,64	10,96
2040			0	0	52,67	1,80	9,44	0	62,11	11,81
2041			0	0	57,35	1,83	9,61	0	66,97	12,73
2042			0	0	62,46	1,86	9,79	0	72,24	13,73
2043			0	0	68,02	1,89	9,96	0	77,98	14,83
2044			0	0	74,07	1,93	10,14	0	84,21	16,01
2045			0	0	80,66	1,96	10,33	0	90,99	17,30
2046			0	0	87,84	2,00	10,51	0	98,35	18,70
2047			0	0	95,66	2,03	10,70	83,370	189,73	36,07
TOTAL LCC									1487.13	282.72

Table I.2 Life cycle cost calculation for fuel oil in İzmir

İZMİR/FUEL OIL										
year	inflation (%) (TL)	inflation (%) ($)	$cost_{investment}$		$cost_{fuel}$	$cost_{CO2}$		$cost_{renovation}$	LCC (TL)	LCC ($)
			field	system		$	TL			
2018	8,9	1,8	32,37	8,21	27,28	0,59	3,12	0	70,98	13,49
2019			0	0	29,70	0,60	3,17	0	32,88	6,25
2020			0	0	32,35	0,61	3,23	0	35,58	6,76
2021			0	0	35,23	0,63	3,29	0	38,51	7,32
2022			0	0	38,36	0,64	3,35	0	41,71	7,93
2023			0	0	41,78	0,65	3,41	0	45,18	8,59
2024			0	0	45,49	0,66	3,47	0	48,96	9,31
2025			0	0	49,54	0,67	3,53	0	53,07	10,09
2026			0	0	53,95	0,68	3,59	0	57,55	10,94
2027			0	0	58,75	0,70	3,66	0	62,41	11,87
2028			0	0	63,98	0,71	3,73	0	67,71	12,87
2029			0	0	69,68	0,72	3,79	0	73,47	13,97
2030			0	0	75,88	0,73	3,86	0	79,74	15,16
2031			0	0	82,63	0,75	3,93	0	86,56	16,46
2032			0	0	89,99	0,76	4,00	27,10	121,09	23,02
2033			0	0	98,00	0,77	4,07	0	102,07	19,40
2034			0	0	106,72	0,79	4,15	0	110,86	21,08
2035			0	0	116,22	0,80	4,22	0	120,44	22,90
2036			0	0	126,56	0,82	4,30	0	130,86	24,88
2037			0	0	137,82	0,83	4,37	0	142,20	27,03
2038			0	0	150,09	0,85	4,45	0	154,54	29,38
2039			0	0	163,45	0,86	4,53	0	167,98	31,94
2040			0	0	177,99	0,88	4,61	0	182,61	34,72
2041			0	0	193,84	0,89	4,70	0	198,53	37,74
2042			0	0	211,09	0,91	4,78	0	215,87	41,04
2043			0	0	229,87	0,93	4,87	0	234,74	44,63
2044			0	0	250,33	0,94	4,96	0	255,29	48,53
2045			0	0	272,61	0,96	5,04	0	277,66	52,79
2046			0	0	296,88	0,98	5,14	0	302,01	57,42
2047			0	0	323,30	0,99	5,23	97,36	425,88	80,97
								TOTAL LCC	3936,96	748,47

Table I.3 Life cycle cost calculation for natural gas in İzmir

İZMİR/NATURAL GAS										
year	**inflation (%) (TL)**	**inflation (%) ($)**	**$cost_{investment}$**		**$cost_{fuel}$**	**$cost_{CO2}$**		**$cost_{renovation}$**	LCC (TL)	LCC ($)
			field	system		**$**	**TL**			
2018	8,9	1,8	3,60	3,01	9,83	0,42	2,20	0	18,64	3,54
2019			0	0	10,70	0,43	2,24	0	12,94	2,46
2020			0	0	11,65	0,43	2,28	0	13,93	2,65
2021			0	0	12,69	0,44	2,32	0	15,01	2,85
2022			0	0	13,82	0,45	2,36	0	16,18	3,08
2023			0	0	15,05	0,46	2,40	0	17,45	3,32
2024			0	0	16,39	0,47	2,45	0	18,84	3,58
2025			0	0	17,85	0,47	2,49	0	20,34	3,87
2026			0	0	19,44	0,48	2,54	0	21,97	4,18
2027			0	0	21,17	0,49	2,58	0	23,75	4,52
2028			0	0	23,05	0,50	2,63	0	25,68	4,88
2029			0	0	25,10	0,51	2,68	0	27,78	5,28
2030			0	0	27,34	0,52	2,72	0	30,06	5,71
2031			0	0	29,77	0,53	2,77	0	32,54	6,19
2032			0	0	32,42	0,54	2,82	9,94	45,19	8,59
2033			0	0	35,30	0,55	2,87	0	38,18	7,26
2034			0	0	38,45	0,56	2,93	0	41,37	7,87
2035			0	0	41,87	0,57	2,98	0	44,85	8,53
2036			0	0	45,59	0,58	3,03	0	48,63	9,24
2037			0	0	49,65	0,59	3,09	0	52,74	10,03
2038			0	0	54,07	0,60	3,14	0	57,21	10,88
2039			0	0	58,88	0,61	3,20	0	62,08	11,80
2040			0	0	64,12	0,62	3,26	0	67,38	12,81
2041			0	0	69,83	0,63	3,31	0	73,15	13,91
2042			0	0	76,05	0,64	3,37	0	79,42	15,10
2043			0	0	82,81	0,65	3,44	0	86,25	16,40
2044			0	0	90,18	0,66	3,50	0	93,68	17,81
2045			0	0	98,21	0,68	3,56	0	101,77	19,35
2046			0	0	106,95	0,69	3,62	0	110,58	21,02
2047			0	0	116,47	0,70	3,69	35,72	155,88	29,64
TOTAL LCC									1453,48	276,33

Table I.4 Life cycle cost calculation for geothermal in İzmir

İZMİR/GEOTHERMAL										
year	Inflation (%) (TL)	Inflation (%) ($)	$cost_{investment}$		$cost_{fuel}$	$cost_{CO2}$		$cost_{renovation}$	LCC (TL)	LCC ($)
			field	system		$	TL			
2018	8,9	1,8	0,06	2,84	5,33	0,27	1,41	0	9,65	1,83
2019			0	0	5,81	0,27	1,43	0	7,24	1,38
2020			0	0	6,32	0,28	1,46	0	7,78	1,48
2021			0	0	6,89	0,28	1,48	0	8,37	1,59
2022			0	0	7,50	0,29	1,51	0	9,01	1,71
2023			0	0	8,17	0,29	1,54	0	9,70	1,85
2024			0	0	8,89	0,30	1,57	0	10,46	1,99
2025			0	0	9,69	0,30	1,59	0	11,28	2,14
2026			0	0	10,55	0,31	1,62	0	12,17	2,31
2027			0	0	11,49	0,31	1,65	0	13,14	2,50
2028			0	0	12,51	0,32	1,68	0	14,19	2,70
2029			0	0	13,62	0,33	1,71	0	15,33	2,92
2030			0	0	14,83	0,33	1,74	0	16,58	3,15
2031			0	0	16,15	0,34	1,77	0	17,93	3,41
2032			0	0	17,59	0,34	1,81	0	19,40	3,69
2033			0	0	19,16	0,35	1,84	0	21,00	3,99
2034			0	0	20,86	0,36	1,87	0	22,73	4,32
2035			0	0	22,72	0,36	1,90	0	24,62	4,68
2036			0	0	24,74	0,37	1,94	0	26,68	5,07
2037			0	0	26,94	0,38	1,97	0	28,92	5,50
2038			0	0	29,34	0,38	2,01	0	31,35	5,96
2039			0	0	31,95	0,39	2,05	0	34,00	6,46
2040			0	0	34,80	0,40	2,08	0	36,88	7,01
2041			0	0	37,89	0,40	2,12	0	40,01	7,61
2042			0	0	41,27	0,41	2,16	0	43,42	8,26
2043			0	0	44,94	0,42	2,20	0	47,14	8,96
2044			0	0	48,94	0,43	2,24	0	51,17	9,73
2045			0	0	53,29	0,43	2,28	0	55,57	10,56
2046			0	0	58,04	0,44	2,32	0	60,35	11,47
2047			0	0	63,20	0,45	2,36	33,71	99,27	18,87
TOTAL LCC									805,34	153,11

Table I.5 Life cycle cost calculation for coal in Balıkesir

BALIKESİR/COAL											
year	**inflation (%) (TL)**	**inflation (%) ($)**	**$cost_{investment}$**		**$cost_{fuel}$**	**$cost_{CO2}$**		**$cost_{renovation}$**	LCC (TL)	LCC ($)
			field	system		**$**	**TL**			
2018	8,9	1,8	42,27	6,37	14,94	2,24	11,81	0	75,38	14,33
2019			0	0	16,27	2,28	12,02	0	28,28	5,38
2020			0	0	17,71	2,33	12,23	0	29,95	5,69
2021			0	0	19,29	2,37	12,45	0	31,74	6,03
2022			0	0	21,01	2,41	12,68	0	33,69	6,40
2023			0	0	22,88	2,45	12,91	0	35,78	6,80
2024			0	0	24,91	2,50	13,14	0	38,05	7,23
2025			0	0	27,13	2,54	13,38	0	40,50	7,70
2026			0	0	29,54	2,59	13,62	0	43,16	8,21
2027			0	0	32,17	2,64	13,86	0	46,03	8,75
2028			0	0	35,04	2,68	14,11	0	49,15	9,34
2029			0	0	38,16	2,73	14,36	0	52,52	9,98
2030			0	0	41,55	2,78	14,62	0	56,17	10,68
2031			0	0	45,25	2,83	14,89	0	60,14	11,43
2032			0	0	49,28	2,88	15,15	21,01	85,44	16,24
2033			0	0	53,66	2,93	15,43	0	69,09	13,13
2034			0	0	58,44	2,99	15,70	0	74,14	14,10
2035			0	0	63,64	3,04	15,99	0	79,63	15,14
2036			0	0	69,30	3,09	16,28	0	85,58	16,27
2037			0	0	75,47	3,15	16,57	0	92,04	17,50
2038			0	0	82,19	3,21	16,87	0	99,05	18,83
2039			0	0	89,50	3,26	17,17	0	106,67	20,28
2040			0	0	97,47	3,32	17,48	0	114,95	21,85
2041			0	0	106,14	3,38	17,79	0	123,94	23,56
2042			0	0	115,59	3,44	18,11	0	133,70	25,42
2043			0	0	125,88	3,51	18,44	0	144,32	27,44
2044			0	0	137,08	3,57	18,77	0	155,85	29,63
2045			0	0	149,28	3,63	19,11	0	168,39	32,01
2046			0	0	162,57	3,70	19,45	0	182,02	34,60
2047			0	0	177,03	3,77	19,80	75,48	272,31	51,77
								TOTAL LCC	2607,66	495,75

Table I.6 Life cycle cost calculation for fuel oil in Balıkesir

BALIKESİR/FUEL OIL										
year	**inflation (%) (TL)**	**inflation (%) ($)**	**$cost_{investment}$**		**$cost_{fuel}$**	**$cost_{CO2}$**		**$cost_{renovation}$**	LCC (TL)	LCC ($)
			field	system		**$**	**TL**			
2018	8,9	1,8	25,90	9,94	50,48	1,10	5,77	0	92,09	17,51
2019			0	0	54,97	1,12	5,87	0	60,85	11,57
2020			0	0	59,87	1,14	5,98	0	65,84	12,52
2021			0	0	65,19	1,16	6,08	0	71,28	13,55
2022			0	0	71,00	1,18	6,19	0	77,19	14,68
2023			0	0	77,32	1,20	6,31	0	83,62	15,90
2024			0	0	84,20	1,22	6,42	0	90,62	17,23
2025			0	0	91,69	1,24	6,53	0	98,22	18,67
2026			0	0	99,85	1,26	6,65	0	106,50	20,25
2027			0	0	108,74	1,29	6,77	0	115,51	21,96
2028			0	0	118,42	1,31	6,89	0	125,31	23,82
2029			0	0	128,95	1,33	7,02	0	135,97	25,85
2030			0	0	140,43	1,36	7,14	0	147,58	28,06
2031			0	0	152,93	1,38	7,27	0	160,20	30,46
2032			0	0	166,54	1,41	7,40	32,80	206,74	39,30
2033			0	0	181,36	1,43	7,54	0	188,90	35,91
2034			0	0	197,50	1,46	7,67	0	205,18	39,01
2035			0	0	215,08	1,48	7,81	0	222,89	42,37
2036			0	0	234,22	1,51	7,95	0	242,17	46,04
2037			0	0	255,07	1,54	8,09	0	263,16	50,03
2038			0	0	277,77	1,57	8,24	0	286,01	54,37
2039			0	0	302,49	1,59	8,39	0	310,88	59,10
2040			0	0	329,41	1,62	8,54	0	337,95	64,25
2041			0	0	358,73	1,65	8,69	0	367,42	69,85
2042			0	0	390,66	1,68	8,85	0	399,51	75,95
2043			0	0	425,43	1,71	9,01	0	434,44	82,59
2044			0	0	463,29	1,74	9,17	0	472,46	89,82
2045			0	0	504,52	1,77	9,34	0	513,86	97,69
2046			0	0	549,43	1,81	9,50	0	558,93	106,26
2047			0	0	598,32	1,84	9,68	117,83	725,82	137,99
								TOTAL LCC	7167,11	1362,57

Table I.7 Life cycle cost calculation for natural gas in Balıkesir

BALIKESİR/NATURAL GAS										
year	inflation (%) (TL)	inflation (%) ($)	$cost_{investment}$		$cost_{fuel}$	$cost_{CO2}$		$cost_{renovation}$	LCC (TL)	LCC ($)
			field	system		$	TL			
2018	8,9	1,8	3,13	3,43	18,19	0,77	4,07	0	28,82	5,48
2019			0	0	19,80	0,79	4,14	0	23,95	4,55
2020			0	0	21,57	0,80	4,22	0	25,79	4,90
2021			0	0	23,49	0,82	4,29	0	27,78	5,28
2022			0	0	25,58	0,83	4,37	0	29,95	5,69
2023			0	0	27,85	0,85	4,45	0	32,30	6,14
2024			0	0	30,33	0,86	4,53	0	34,86	6,63
2025			0	0	33,03	0,88	4,61	0	37,64	7,16
2026			0	0	35,97	0,89	4,69	0	40,67	7,73
2027			0	0	39,17	0,91	4,78	0	43,95	8,36
2028			0	0	42,66	0,92	4,87	0	47,53	9,04
2029			0	0	46,46	0,94	4,95	0	51,41	9,77
2030			0	0	50,59	0,96	5,04	0	55,63	10,58
2031			0	0	55,09	0,98	5,13	0	60,23	11,45
2032			0	0	60,00	0,99	5,22	11,32	76,54	14,55
2033			0	0	65,34	1,01	5,32	0	70,66	13,43
2034			0	0	71,15	1,03	5,41	0	76,57	14,56
2035			0	0	77,48	1,05	5,51	0	83,00	15,78
2036			0	0	84,38	1,07	5,61	0	89,99	17,11
2037			0	0	91,89	1,09	5,71	0	97,60	18,56
2038			0	0	100,07	1,11	5,82	0	105,88	20,13
2039			0	0	108,98	1,13	5,92	0	114,90	21,84
2040			0	0	118,67	1,15	6,03	0	124,70	23,71
2041			0	0	129,24	1,17	6,13	0	135,37	25,74
2042			0	0	140,74	1,19	6,25	0	146,98	27,94
2043			0	0	153,26	1,21	6,36	0	159,62	30,35
2044			0	0	166,90	1,23	6,47	0	173,38	32,96
2045			0	0	181,76	1,25	6,59	0	188,35	35,81
2046			0	0	197,94	1,28	6,71	0	204,64	38,91
2047			0	0	215,55	1,30	6,83	40,67	263,05	50,01
								TOTAL LCC	2651,73	504,13

Table I.8 Life cycle cost calculation for geothermal in Balıkesir

BALIKESİR/GEOTHERMAL										
year	inflation (%) (TL)	inflation (%) ($)	$cost_{investment}$		$cost_{fuel}$	$cost_{CO2}$		$cost_{renovation}$	LCC (TL)	LCC ($)
			field	system		$	TL			
2018	8,9	1,8	0,10	2,99	14,70	0,49	2,60	0	20,39	3,88
2019			0	0	16,01	0,50	2,65	0	18,66	3,55
2020			0	0	17,43	0,51	2,70	0	20,13	3,83
2021			0	0	18,98	0,52	2,75	0	21,73	4,13
2022			0	0	20,67	0,53	2,80	0	23,47	4,46
2023			0	0	22,51	0,54	2,85	0	25,36	4,82
2024			0	0	24,52	0,55	2,90	0	27,42	5,21
2025			0	0	26,70	0,56	2,95	0	29,65	5,64
2026			0	0	29,08	0,57	3,00	0	32,08	6,10
2027			0	0	31,66	0,58	3,06	0	34,72	6,60
2028			0	0	34,48	0,59	3,11	0	37,59	7,15
2029			0	0	37,55	0,60	3,17	0	40,72	7,74
2030			0	0	40,89	0,61	3,22	0	44,12	8,39
2031			0	0	44,53	0,62	3,28	0	47,82	9,09
2032			0	0	48,50	0,64	3,34	0	51,84	9,86
2033			0	0	52,81	0,65	3,40	0	56,21	10,69
2034			0	0	57,51	0,66	3,46	0	60,98	11,59
2035			0	0	62,63	0,67	3,53	0	66,16	12,58
2036			0	0	68,21	0,68	3,59	0	71,79	13,65
2037			0	0	74,28	0,69	3,65	0	77,93	14,82
2038			0	0	80,89	0,71	3,72	0	84,61	16,08
2039			0	0	88,09	0,72	3,79	0	91,87	17,47
2040			0	0	95,92	0,73	3,85	0	99,78	18,97
2041			0	0	104,46	0,75	3,92	0	108,39	20,61
2042			0	0	113,76	0,76	3,99	0	117,75	22,39
2043			0	0	123,88	0,77	4,07	0	127,95	24,33
2044			0	0	134,91	0,79	4,14	0	139,05	26,44
2045			0	0	146,92	0,80	4,21	0	151,13	28,73
2046			0	0	159,99	0,82	4,29	0	164,28	31,23
2047			0	0	174,23	0,83	4,37	35,42	214,01	40,69
TOTAL LCC									2107,58	400,68

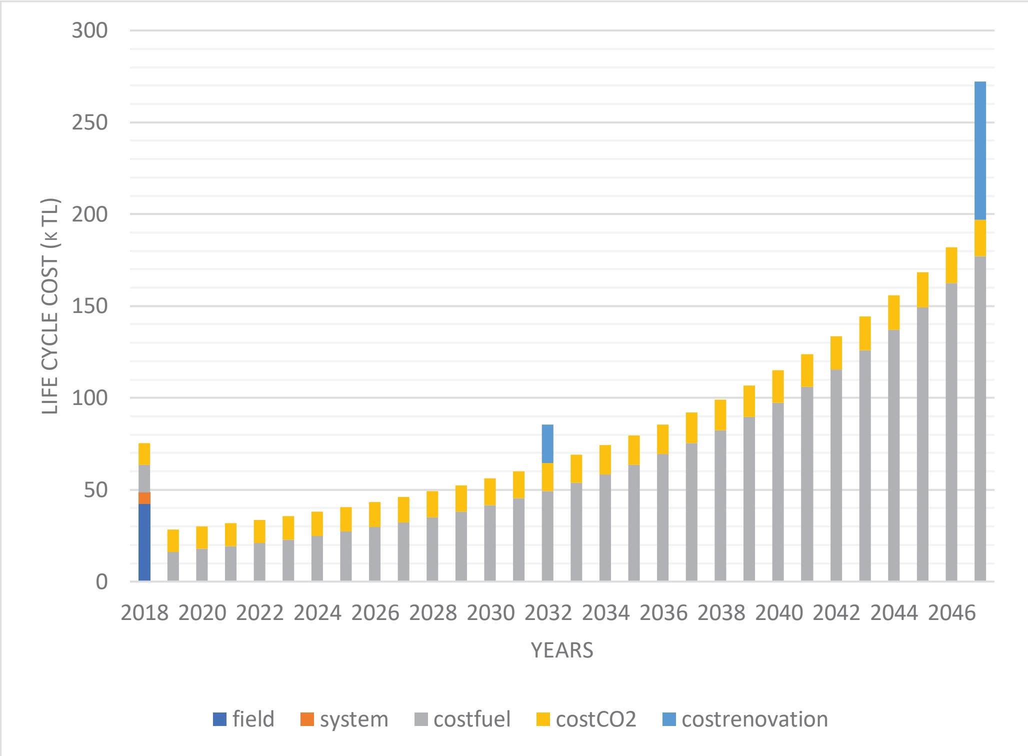

Figure I.1 Life cycle cost calculation for coal in Balıkesir

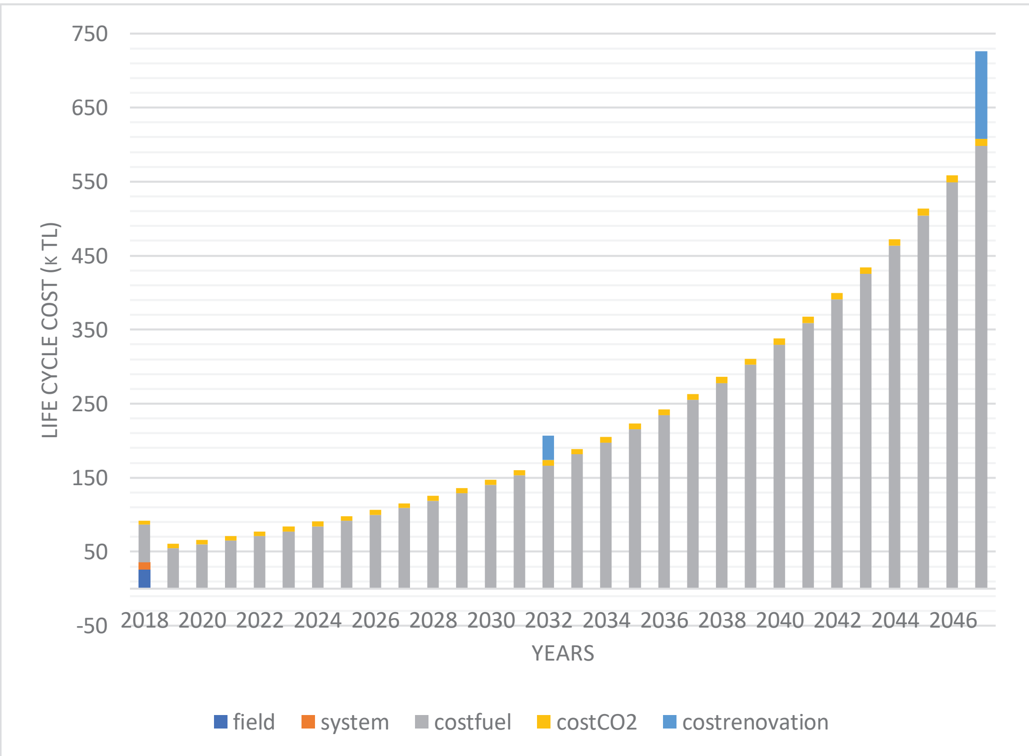

Figure I.2 Life cycle cost calculation for fuel oil in Balıkesir

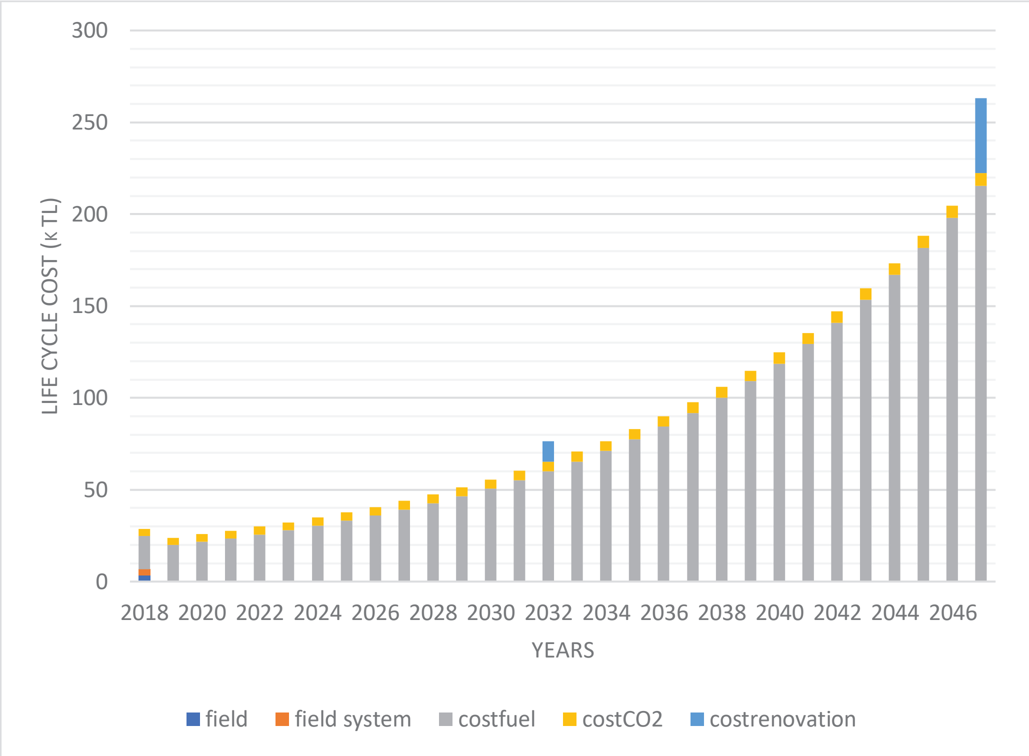

Figure I.3 Life Cycle Cost Calculation for Natural Gas in Balıkesir

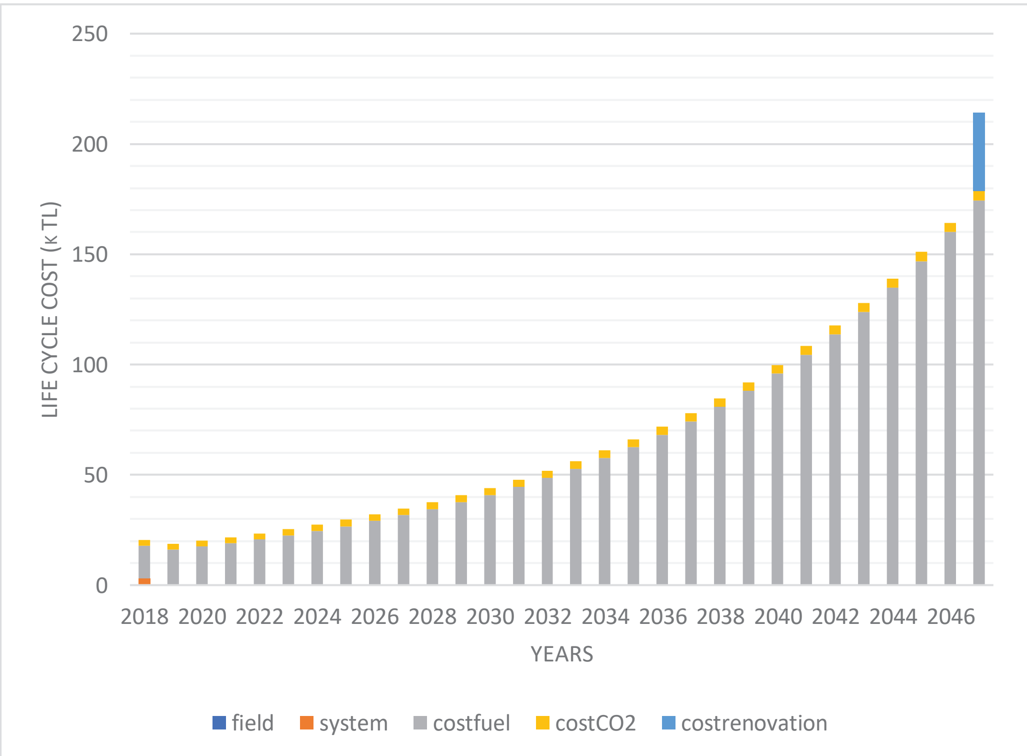

Figure I.4 Life Cycle Cost Calculation for Geothermal in Balıkesir

Table I.9 Life cycle cost calculation for coal in Kütahya

KÜTAHYA/COAL										
year	**inflation (%) (TL)**	**inflation (%) ($)**	**$cost_{investment}$**		**$cost_{fuel}$**	**$cost_{CO2}$**		**$cost_{renovation}$**	LCC (TL)	LCC ($)
			field	system		**$**	**TL**			
2018	8,9	1,8	32,71	6,37	16,49	2,48	13,04	0	68,61	13,04
2019			0	0	17,96	2,52	13,27	0	31,23	5,94
2020			0	0	19,56	2,57	13,51	0	33,07	6,29
2021			0	0	21,30	2,61	13,75	0	35,06	6,66
2022			0	0	23,20	2,66	14,00	0	37,20	7,07
2023			0	0	25,26	2,71	14,25	0	39,52	7,51
2024			0	0	27,51	2,76	14,51	0	42,02	7,99
2025			0	0	29,96	2,81	14,77	0	44,73	8,50
2026			0	0	32,63	2,86	15,04	0	47,66	9,06
2027			0	0	35,53	2,91	15,31	0	50,84	9,67
2028			0	0	38,69	2,96	15,58	0	54,28	10,32
2029			0	0	42,14	3,02	15,86	0	58,00	11,03
2030			0	0	45,89	3,07	16,15	0	62,04	11,79
2031			0	0	49,97	3,13	16,44	0	66,41	12,63
2032			0	0	54,42	3,18	16,74	21,01	92,16	17,52
2033			0	0	59,26	3,24	17,04	0	76,30	14,51
2034			0	0	64,54	3,30	17,34	0	81,88	15,57
2035			0	0	70,28	3,36	17,66	0	87,93	16,72
2036			0	0	76,53	3,42	17,97	0	94,51	17,97
2037			0	0	83,35	3,48	18,30	0	101,64	19,32
2038			0	0	90,76	3,54	18,63	0	109,39	20,80
2039			0	0	98,84	3,60	18,96	0	117,80	22,40
2040			0	0	107,64	3,67	19,30	0	126,94	24,13
2041			0	0	117,22	3,74	19,65	0	136,87	26,02
2042			0	0	127,65	3,80	20,00	0	147,65	28,07
2043			0	0	139,01	3,87	20,36	0	159,38	30,30
2044			0	0	151,38	3,94	20,73	0	172,11	32,72
2045			0	0	164,86	4,01	21,10	0	185,96	35,35
2046			0	0	179,53	4,08	21,48	0	201,01	38,22
2047			0	0	195,51	4,16	21,87	75,48	292,85	55,68
								TOTAL LCC	2855,06	542,79

Table I.10 Life cycle cost calculation for fuel oil in Kütahya

KÜTAHYA /FUEL OIL										
year	**inflation (%) (TL)**	**inflation (%) ($)**	**$cost_{investment}$**		**$cost_{fuel}$**	**$cost_{CO2}$**		**$cost_{renovation}$**	LCC (TL)	LCC ($)
			field	system		**$**	**TL**			
2018	8,9	1,8	20,26	3,43	55,75	1,21	6,37	0	85,81	16,31
2019			0	0	60,71	1,23	6,48	0	67,19	12,77
2020			0	0	66,11	1,25	6,60	0	72,71	13,82
2021			0	0	72,00	1,28	6,72	0	78,72	14,97
2022			0	0	78,41	1,30	6,84	0	85,25	16,21
2023			0	0	85,38	1,32	6,96	0	92,35	17,56
2024			0	0	92,98	1,35	7,09	0	100,07	19,02
2025			0	0	101,26	1,37	7,22	0	108,47	20,62
2026			0	0	110,27	1,40	7,35	0	117,62	22,36
2027			0	0	120,08	1,42	7,48	0	127,56	24,25
2028			0	0	130,77	1,45	7,61	0	138,38	26,31
2029			0	0	142,41	1,47	7,75	0	150,16	28,55
2030			0	0	155,08	1,50	7,89	0	162,97	30,98
2031			0	0	168,89	1,53	8,03	0	176,92	33,63
2032			0	0	183,92	1,55	8,18	32,80	224,89	42,75
2033			0	0	200,29	1,58	8,32	0	208,61	39,66
2034			0	0	218,11	1,61	8,47	0	226,58	43,08
2035			0	0	237,52	1,64	8,63	0	246,15	46,80
2036			0	0	258,66	1,67	8,78	0	267,44	50,84
2037			0	0	281,68	1,70	8,94	0	290,62	55,25
2038			0	0	306,75	1,73	9,10	0	315,85	60,05
2039			0	0	334,05	1,76	9,26	0	343,32	65,27
2040			0	0	363,79	1,79	9,43	0	373,22	70,95
2041			0	0	396,16	1,83	9,60	0	405,76	77,14
2042			0	0	431,42	1,86	9,77	0	441,19	83,88
2043			0	0	469,82	1,89	9,95	0	479,77	91,21
2044			0	0	511,63	1,93	10,13	0	521,76	99,19
2045			0	0	557,17	1,96	10,31	0	567,48	107,89
2046			0	0	606,75	2,00	10,50	0	617,25	117,35
2047			0	0	660,76	2,03	10,69	117,83	789,27	150,05
								TOTAL LCC	7883,36	1498,74

Table I.11 Life cycle cost calculation for natural gas in Kütahya

KÜTAHYA /NATURAL GAS										
year	inflation (%) (TL)	inflation (%) ($)	$cost_{investment}$		$cost_{fuel}$	$cost_{CO2}$		$cost_{renovation}$	LCC (TL)	LCC ($)
			field	system		$	TL			
2018	8,9	1,8	2,45	3,43	20,08	0,85	4,49	0	30,46	5,79
2019			0	0	21,87	0,87	4,58	0	26,45	5,03
2020			0	0	23,82	0,89	4,66	0	28,48	5,41
2021			0	0	25,94	0,90	4,74	0	30,68	5,83
2022			0	0	28,25	0,92	4,83	0	33,07	6,29
2023			0	0	30,76	0,93	4,91	0	35,67	6,78
2024			0	0	33,50	0,95	5,00	0	38,50	7,32
2025			0	0	36,48	0,97	5,09	0	41,57	7,90
2026			0	0	39,73	0,99	5,18	0	44,91	8,54
2027			0	0	43,26	1,00	5,28	0	48,54	9,23
2028			0	0	47,11	1,02	5,37	0	52,48	9,98
2029			0	0	51,30	1,04	5,47	0	56,77	10,79
2030			0	0	55,87	1,06	5,57	0	61,44	11,68
2031			0	0	60,84	1,08	5,67	0	66,51	12,64
2032			0	0	66,26	1,10	5,77	11,32	83,35	15,85
2033			0	0	72,15	1,12	5,87	0	78,03	14,83
2034			0	0	78,58	1,14	5,98	0	84,56	16,08
2035			0	0	85,57	1,16	6,09	0	91,66	17,43
2036			0	0	93,19	1,18	6,20	0	99,38	18,89
2037			0	0	101,48	1,20	6,31	0	107,79	20,49
2038			0	0	110,51	1,22	6,42	0	116,93	22,23
2039			0	0	120,35	1,24	6,54	0	126,88	24,12
2040			0	0	131,06	1,27	6,66	0	137,71	26,18
2041			0	0	142,72	1,29	6,78	0	149,50	28,42
2042			0	0	155,42	1,31	6,90	0	162,32	30,86
2043			0	0	169,26	1,33	7,02	0	176,28	33,51
2044			0	0	184,32	1,36	7,15	0	191,47	36,40
2045			0	0	200,72	1,38	7,28	0	208,00	39,54
2046			0	0	218,59	1,41	7,41	0	226,00	42,97
2047			0	0	238,04	1,43	7,54	40,67	286,25	54,42
TOTAL LCC									2921,63	555,44

Table I.12 Life cycle cost calculation for geothermal in Kütahya

KÜTAHYA /GEOTHERMAL										
year	**inflation (%) (TL)**	**inflation (%) ($)**	**cost$_{investment}$**		**cost$_{fuel}$**	**cost$_{CO2}$**		**cost$_{renovation}$**	LCC (TL)	LCC ($)
			field	system		**$**	**TL**			
2018	8,9	1,8	0,08	2,99	8,64	0,55	2,87	0	14,57	2,77
2019			0	0	9,40	0,56	2,93	0	12,33	2,34
2020			0	0	10,24	0,57	2,98	0	13,22	2,51
2021			0	0	11,15	0,58	3,03	0	14,19	2,70
2022			0	0	12,15	0,59	3,09	0	15,23	2,90
2023			0	0	13,23	0,60	3,14	0	16,37	3,11
2024			0	0	14,40	0,61	3,20	0	17,60	3,35
2025			0	0	15,69	0,62	3,26	0	18,94	3,60
2026			0	0	17,08	0,63	3,32	0	20,40	3,88
2027			0	0	18,60	0,64	3,38	0	21,98	4,18
2028			0	0	20,26	0,65	3,44	0	23,69	4,50
2029			0	0	22,06	0,67	3,50	0	25,56	4,86
2030			0	0	24,02	0,68	3,56	0	27,58	5,24
2031			0	0	26,16	0,69	3,63	0	29,79	5,66
2032			0	0	28,49	0,70	3,69	0	32,18	6,12
2033			0	0	31,02	0,71	3,76	0	34,78	6,61
2034			0	0	33,79	0,73	3,82	0	37,61	7,15
2035			0	0	36,79	0,74	3,89	0	40,69	7,74
2036			0	0	40,07	0,75	3,96	0	44,03	8,37
2037			0	0	43,63	0,77	4,03	0	47,67	9,06
2038			0	0	47,52	0,78	4,11	0	51,62	9,81
2039			0	0	51,75	0,79	4,18	0	55,93	10,63
2040			0	0	56,35	0,81	4,26	0	60,61	11,52
2041			0	0	61,37	0,82	4,33	0	65,70	12,49
2042			0	0	66,83	0,84	4,41	0	71,24	13,54
2043			0	0	72,78	0,85	4,49	0	77,27	14,69
2044			0	0	79,25	0,87	4,57	0	83,82	15,94
2045			0	0	86,31	0,88	4,65	0	90,96	17,29
2046			0	0	93,99	0,90	4,74	0	98,73	18,77
2047			0	0	102,35	0,92	4,82	35,42	142,59	27,11
								TOTAL LCC	1306,87	248,46

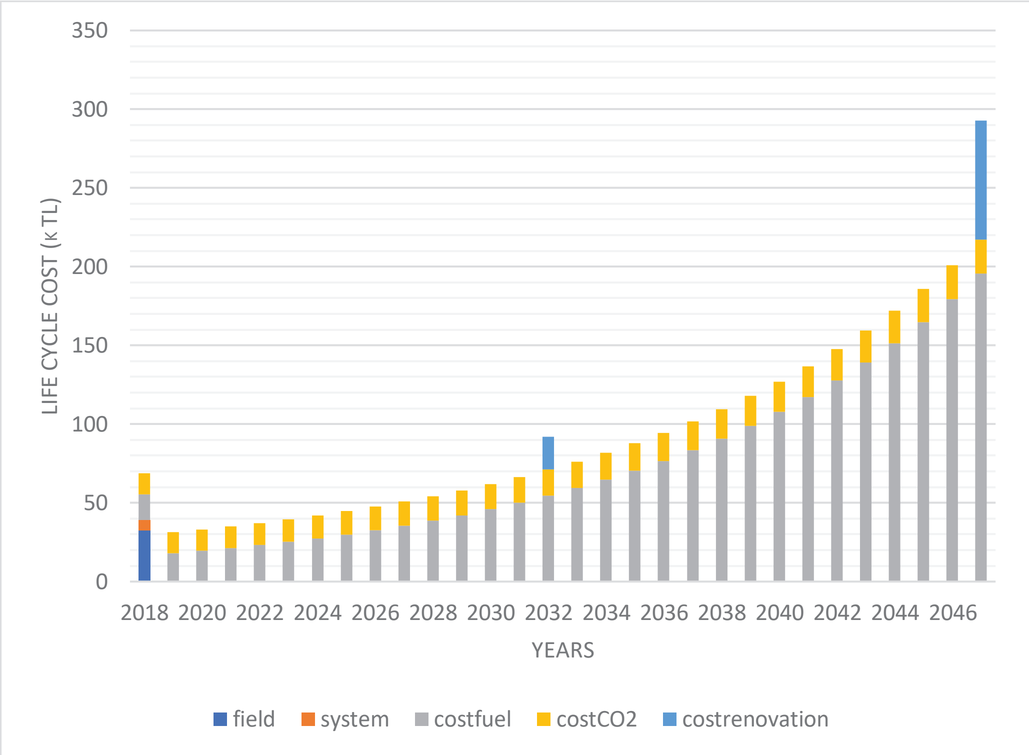

Figure I.5 Life Cycle Cost Calculation for Coal in Kütahya

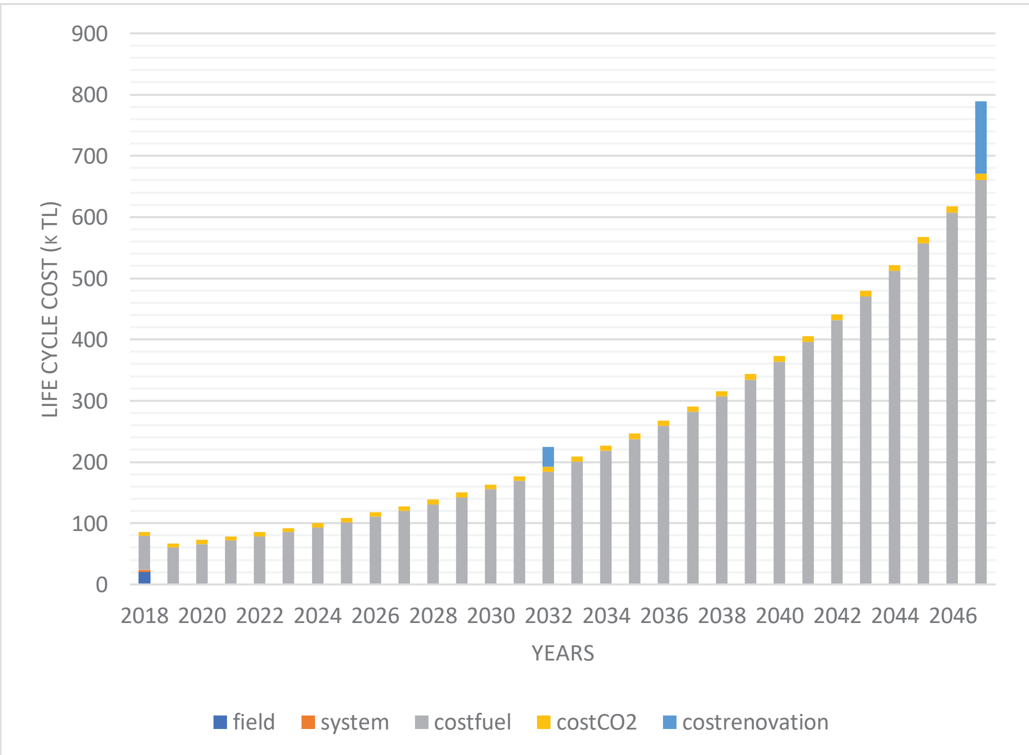

Figure I.6 Life Cycle Cost Calculation for Fuel Oil in Kütahya

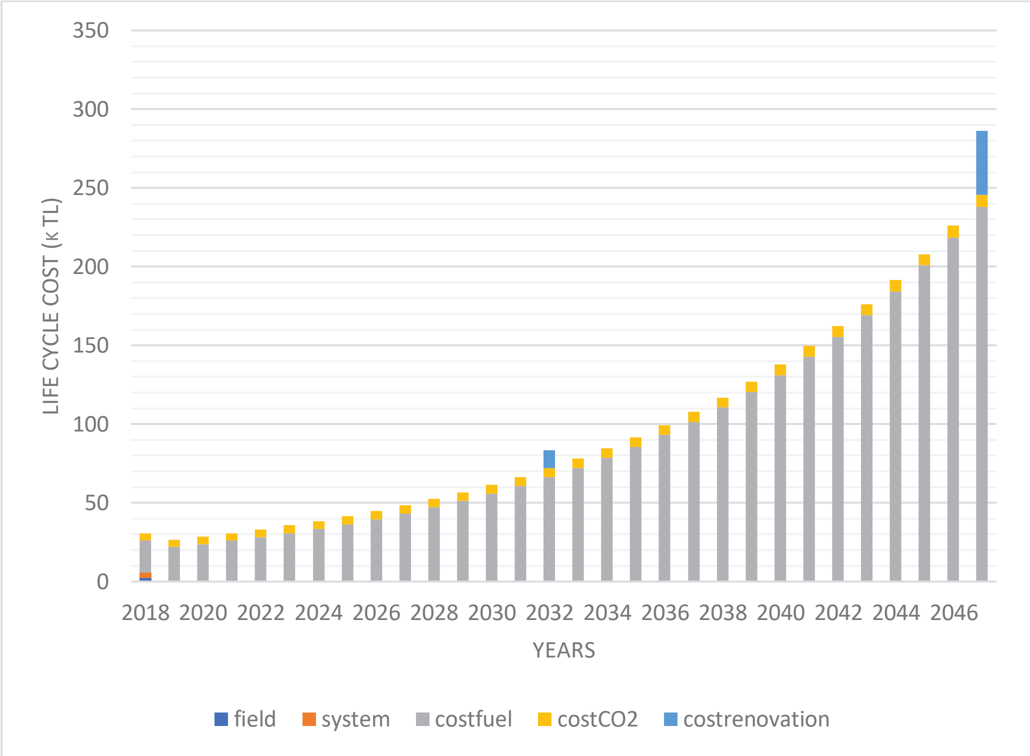

Figure I.7 Life Cycle Cost Calculation for Natural Gas in Kütahya

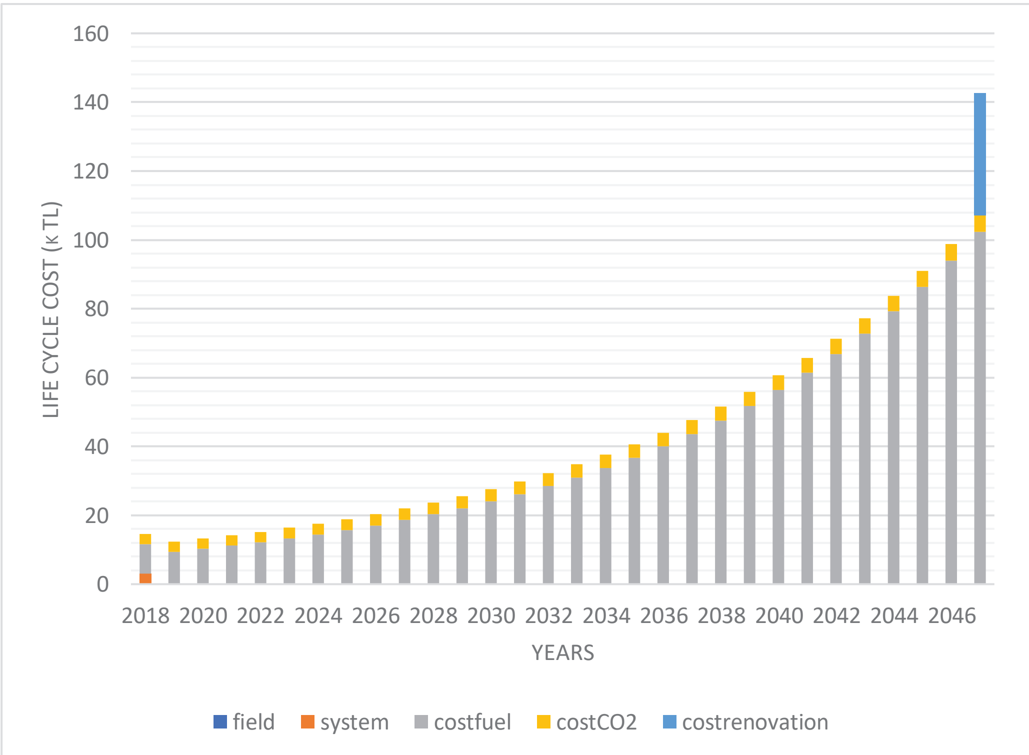

Figure I.8 Life Cycle Cost Calculation for Geothermal in Kütahya

Table I.13 Life cycle cost calculation for coal in Ağrı

AĞRI/COAL										
year	**inflation (%) (TL)**	**inflation (%) ($)**	**$cost_{investment}$**		**$cost_{fuel}$**	**$cost_{CO2}$**		**$cost_{renovation}$**	LCC (TL)	LCC ($)
			field	system		**$**	**TL**			
2018	8,9	1,8	25,41	10,57	27,89	4,19	22,04	0	85,92	16,33
2019			0	0	30,37	4,27	22,44	0	52,81	10,04
2020			0	0	33,08	4,34	22,84	0	55,92	10,63
2021			0	0	36,02	4,42	23,26	0	59,28	11,27
2022			0	0	39,23	4,50	23,67	0	62,90	11,96
2023			0	0	42,72	4,58	24,10	0	66,82	12,70
2024			0	0	46,52	4,66	24,53	0	71,05	13,51
2025			0	0	50,66	4,75	24,98	0	75,63	14,38
2026			0	0	55,17	4,83	25,43	0	80,59	15,32
2027			0	0	60,08	4,92	25,88	0	85,96	16,34
2028			0	0	65,42	5,01	26,35	0	91,77	17,45
2029			0	0	71,25	5,10	26,82	0	98,07	18,64
2030			0	0	77,59	5,19	27,31	0	104,89	19,94
2031			0	0	84,49	5,28	27,80	0	112,29	21,35
2032			0	0	92,01	5,38	28,30	34,88	155,19	29,50
2033			0	0	100,20	5,48	28,81	0	129,01	24,53
2034			0	0	109,12	5,58	29,33	0	138,45	26,32
2035			0	0	118,83	5,68	29,85	0	148,68	28,27
2036			0	0	129,41	5,78	30,39	0	159,80	30,38
2037			0	0	140,92	5,88	30,94	0	171,86	32,67
2038			0	0	153,47	5,99	31,49	0	184,96	35,16
2039			0	0	167,13	6,10	32,06	0	199,19	37,87
2040			0	0	182,00	6,21	32,64	0	214,64	40,81
2041			0	0	198,20	6,32	33,23	0	231,42	44,00
2042			0	0	215,84	6,43	33,82	0	249,66	47,46
2043			0	0	235,05	6,55	34,43	0	269,48	51,23
2044			0	0	255,97	6,66	35,05	0	291,02	55,33
2045			0	0	278,75	6,78	35,68	0	314,43	59,78
2046			0	0	303,56	6,91	36,33	0	339,88	64,62
2047			0	0	330,57	7,03	36,98	125,33	492,88	93,70
								TOTAL LCC	4794,47	911,50

Table I.14 Life cycle cost calculation for fuel oil in Ağrı

AĞRI /FUEL OIL										
year	**inflation (%) (TL)**	**inflation (%) ($)**	**cost$_{investment}$**		**cost$_{fuel}$**	**cost$_{CO2}$**		**cost$_{renovation}$**	LCC (TL)	LCC ($)
			field	system		**$**	**TL**			
2018	8,9	1,8	18,13	12,33	94,26	2,05	10,77	0	135,49	25,76
2019			0	0	102,65	2,08	10,96	0	113,62	21,60
2020			0	0	111,79	2,12	11,16	0	122,95	23,37
2021			0	0	121,74	2,16	11,36	0	133,10	25,30
2022			0	0	132,57	2,20	11,57	0	144,14	27,40
2023			0	0	144,37	2,24	11,77	0	156,14	29,69
2024			0	0	157,22	2,28	11,99	0	169,21	32,17
2025			0	0	171,21	2,32	12,20	0	183,41	34,87
2026			0	0	186,45	2,36	12,42	0	198,87	37,81
2027			0	0	203,04	2,40	12,65	0	215,69	41,01
2028			0	0	221,11	2,45	12,87	0	233,99	44,48
2029			0	0	240,79	2,49	13,10	0	253,90	48,27
2030			0	0	262,22	2,54	13,34	0	275,57	52,39
2031			0	0	285,56	2,58	13,58	0	299,14	56,87
2032			0	0	310,98	2,63	13,83	40,67	365,47	69,48
2033			0	0	338,65	2,68	14,07	0	352,73	67,06
2034			0	0	368,79	2,72	14,33	0	383,12	72,84
2035			0	0	401,62	2,77	14,59	0	416,20	79,13
2036			0	0	437,36	2,82	14,85	0	452,21	85,97
2037			0	0	476,29	2,87	15,11	0	491,40	93,42
2038			0	0	518,68	2,93	15,39	0	534,06	101,53
2039			0	0	564,84	2,98	15,66	0	580,50	110,36
2040			0	0	615,11	3,03	15,95	0	631,06	119,97
2041			0	0	669,85	3,09	16,23	0	686,09	130,43
2042			0	0	729,47	3,14	16,53	0	746,00	141,82
2043			0	0	794,39	3,20	16,82	0	811,22	154,22
2044			0	0	865,09	3,26	17,13	0	882,22	167,72
2045			0	0	942,09	3,31	17,43	0	959,52	182,42
2046			0	0	1025,93	3,37	17,75	0	1043,68	198,42
2047			0	0	1117,24	3,43	18,07	146,12	1281,43	243,62
								TOTAL LCC	13252,11	2519,41

Table I.15 Life cycle cost calculation for natural gas in Ağrı

AĞRI /NATURAL GAS										
year	**inflation (%) (TL)**	**inflation (%) ($)**	**cost$_{investment}$**		**cost$_{fuel}$**	**cost$_{CO2}$**		**cost$_{renovation}$**	LCC (TL)	LCC ($)
			field	system		**$**	**TL**			
2018	8,9	1,8	1,78	3,88	33,96	1,44	7,60	0	47,22	8,98
2019			0	0	36,98	1,47	7,74	0	44,72	8,50
2020			0	0	40,27	1,50	7,88	0	48,15	9,15
2021			0	0	43,86	1,52	8,02	0	51,87	9,86
2022			0	0	47,76	1,55	8,16	0	55,92	10,63
2023			0	0	52,01	1,58	8,31	0	60,32	11,47
2024			0	0	56,64	1,61	8,46	0	65,10	12,38
2025			0	0	61,68	1,64	8,61	0	70,29	13,36
2026			0	0	67,17	1,67	8,77	0	75,94	14,44
2027			0	0	73,15	1,70	8,92	0	82,07	15,60
2028			0	0	79,66	1,73	9,08	0	88,74	16,87
2029			0	0	86,75	1,76	9,25	0	96,00	18,25
2030			0	0	94,47	1,79	9,41	0	103,88	19,75
2031			0	0	102,88	1,82	9,58	0	112,46	21,38
2032			0	0	112,03	1,85	9,76	12,79	134,58	25,59
2033			0	0	122,00	1,89	9,93	0	131,94	25,08
2034			0	0	132,86	1,92	10,11	0	142,97	27,18
2035			0	0	144,69	1,96	10,29	0	154,98	29,46
2036			0	0	157,56	1,99	10,48	0	168,04	31,95
2037			0	0	171,59	2,03	10,67	0	182,25	34,65
2038			0	0	186,86	2,06	10,86	0	197,72	37,59
2039			0	0	203,49	2,10	11,05	0	214,54	40,79
2040			0	0	221,60	2,14	11,25	0	232,85	44,27
2041			0	0	241,32	2,18	11,46	0	252,78	48,06
2042			0	0	262,80	2,22	11,66	0	274,46	52,18
2043			0	0	286,19	2,26	11,87	0	298,06	56,67
2044			0	0	311,66	2,30	12,09	0	323,74	61,55
2045			0	0	339,40	2,34	12,30	0	351,70	66,86
2046			0	0	369,60	2,38	12,52	0	382,13	72,65
2047			0	0	402,50	2,42	12,75	45,96	461,21	87,68
								TOTAL LCC	4906,63	932,82

Table I.16 Life cycle cost calculation for geothermal in Ağrı

AĞRI /GEOTHERMAL										
year	**inflation (%) (TL)**	**inflation (%) ($)**	**$cost_{investment}$**		**$cost_{fuel}$**	**$cost_{CO2}$**		**$cost_{renovation}$**	LCC (TL)	LCC ($)
			field	system		**$**	**TL**			
2018	8,9	1,8	0,05	3,06	4,50	0,92	4,86	0	12,47	2,37
2019			0	0	4,90	0,94	4,95	0	9,85	1,87
2020			0	0	5,34	0,96	5,04	0	10,37	1,97
2021			0	0	5,81	0,97	5,13	0	10,94	2,08
2022			0	0	6,33	0,99	5,22	0	11,55	2,20
2023			0	0	6,89	1,01	5,31	0	12,21	2,32
2024			0	0	7,51	1,03	5,41	0	12,92	2,46
2025			0	0	8,17	1,05	5,51	0	13,68	2,60
2026			0	0	8,90	1,07	5,61	0	14,51	2,76
2027			0	0	9,69	1,09	5,71	0	15,40	2,93
2028			0	0	10,56	1,10	5,81	0	16,37	3,11
2029			0	0	11,50	1,12	5,91	0	17,41	3,31
2030			0	0	12,52	1,14	6,02	0	18,54	3,52
2031			0	0	13,63	1,17	6,13	0	19,76	3,76
2032			0	0	14,85	1,19	6,24	0	21,09	4,01
2033			0	0	16,17	1,21	6,35	0	22,52	4,28
2034			0	0	17,61	1,23	6,47	0	24,07	4,58
2035			0	0	19,17	1,25	6,58	0	25,76	4,90
2036			0	0	20,88	1,27	6,70	0	27,58	5,24
2037			0	0	22,74	1,30	6,82	0	29,56	5,62
2038			0	0	24,76	1,32	6,95	0	31,71	6,03
2039			0	0	26,96	1,34	7,07	0	34,03	6,47
2040			0	0	29,36	1,37	7,20	0	36,56	6,95
2041			0	0	31,98	1,39	7,33	0	39,31	7,47
2042			0	0	34,82	1,42	7,46	0	42,28	8,04
2043			0	0	37,92	1,44	7,59	0	45,52	8,65
2044			0	0	41,30	1,47	7,73	0	49,03	9,32
2045			0	0	44,97	1,50	7,87	0	52,84	10,05
2046			0	0	48,98	1,52	8,01	0	56,99	10,83
2047			0	0	53,34	1,55	8,15	36,27	97,76	18,59
								TOTAL LCC	832,57	158,28

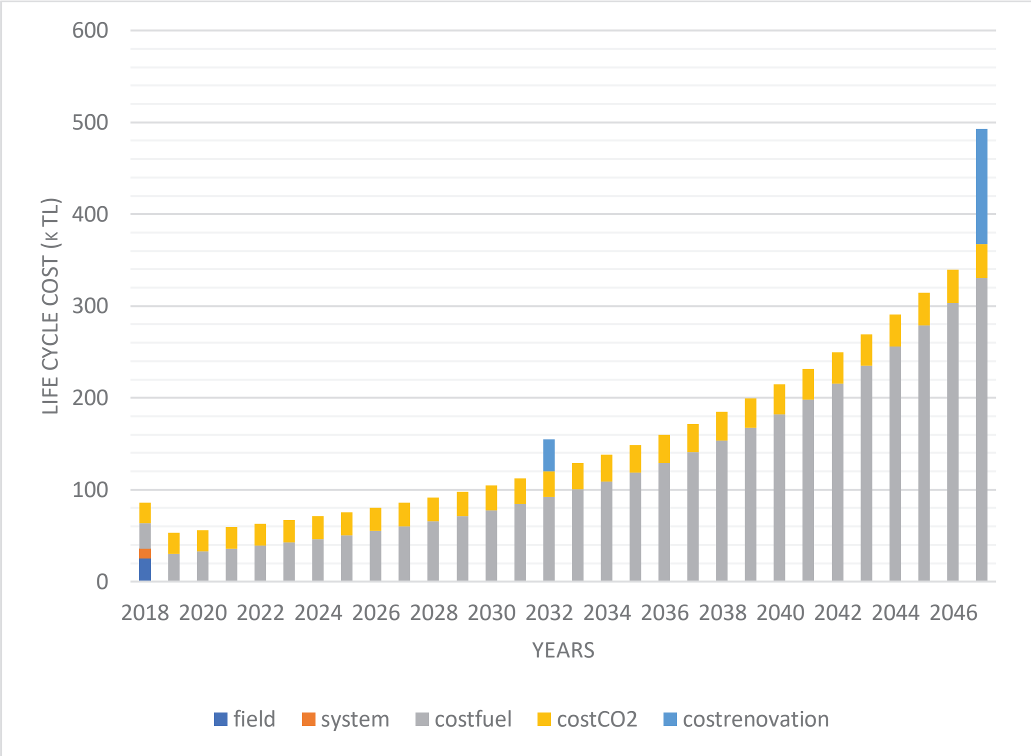

Figure I.9 Life Cycle Cost Calculation for Coal in Ağrı

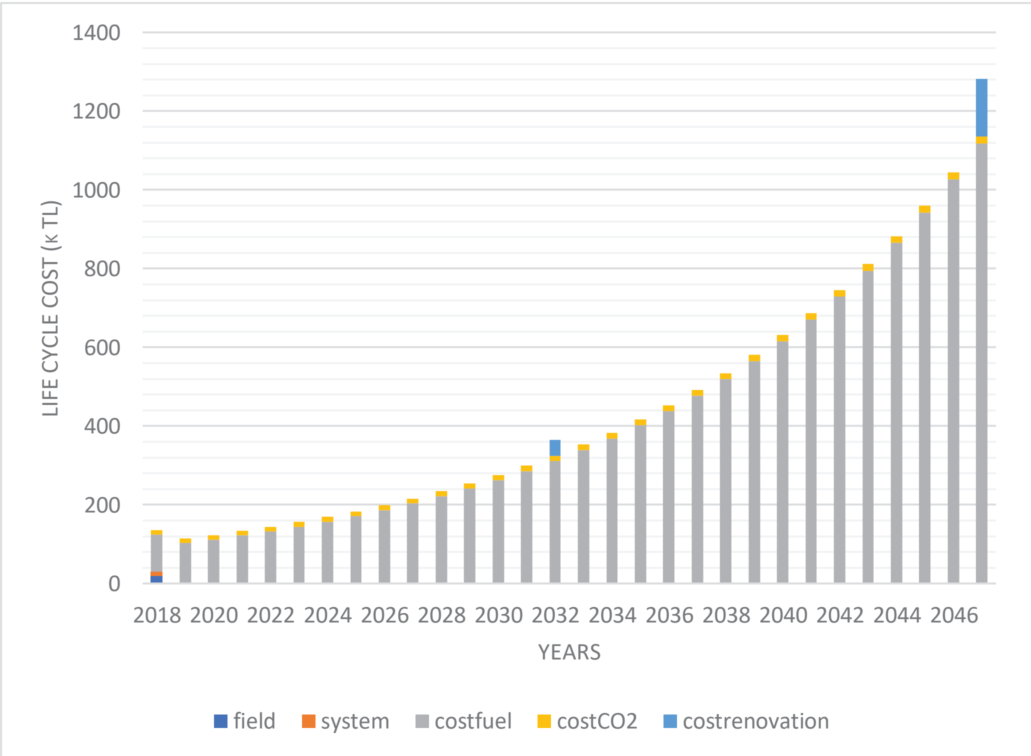

Figure I.10 Life Cycle Cost Calculation for Fuel Oil in Ağrı

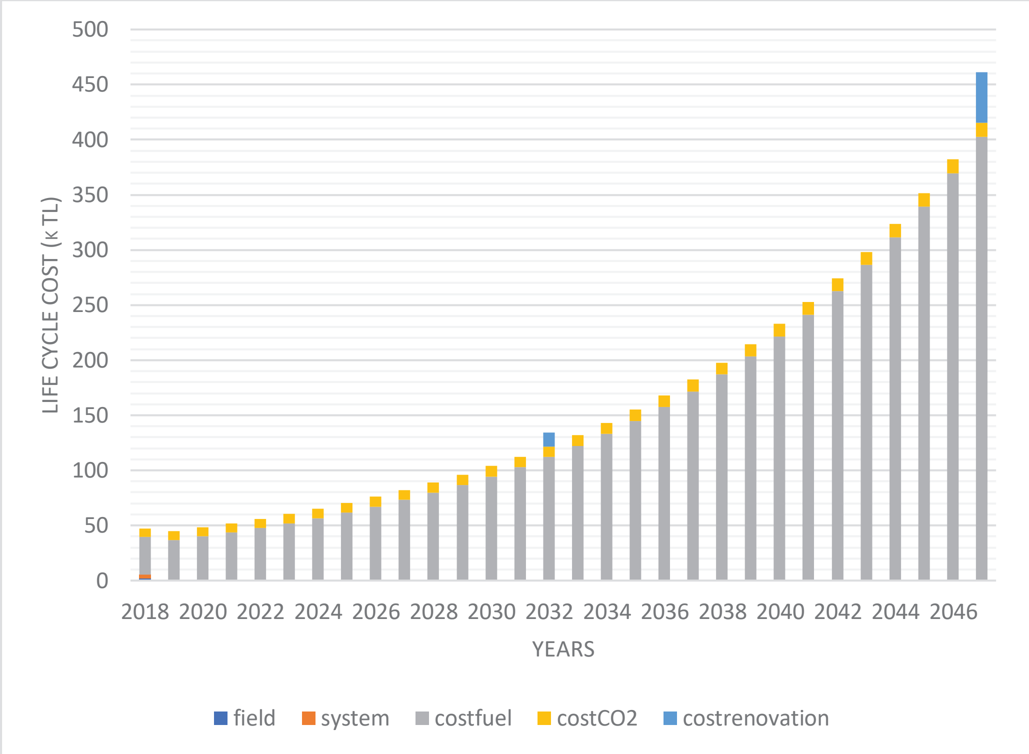

Figure I.11 Life Cycle Cost Calculation for Natural Gas in Ağrı

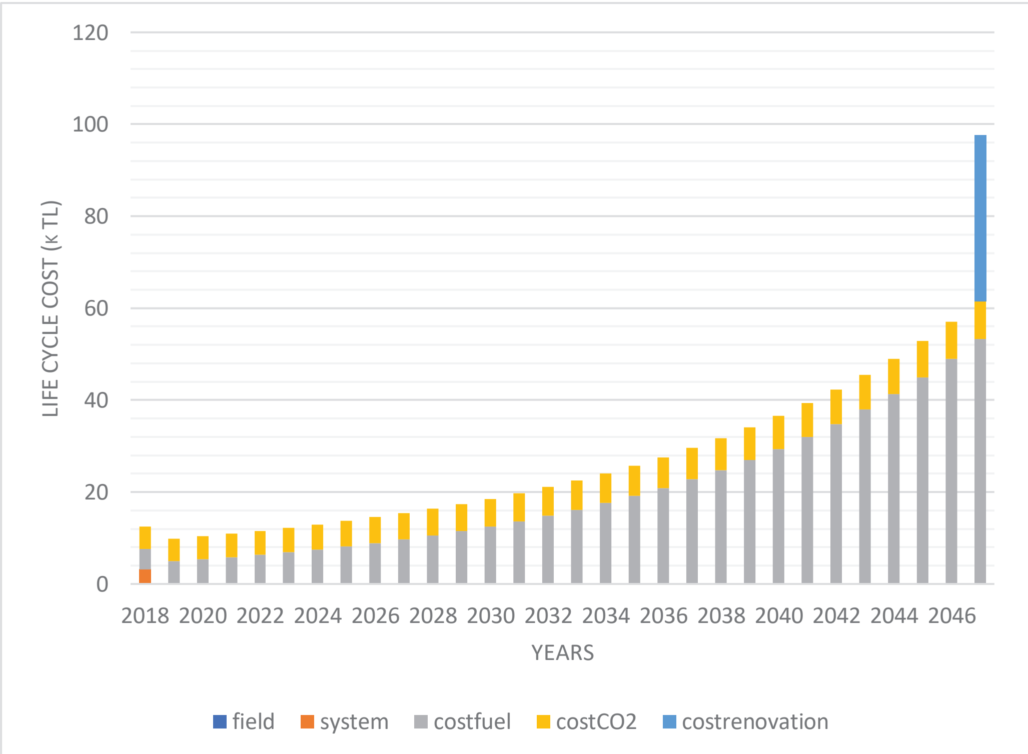

Figure I.12 Life Cycle Cost Calculation for Geothermal in Ağrı