DESIGN OF GEOTHERMAL DISTRICT HEATING SYSTEM OF UNIVERSIADE 2005 ATHLETES' VILLAGE

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ABSTRACT

Geothermal energy, which is the Earth's interior energy, has a broad application area for heating and energy production purposes. To develop healthy geothermal energy projects, conceptual planning study is one of the important tasks which should be done initially. Conceptual planning studies consists of technical, economical and political evaluation of the project showing that whether the project is feasible or not. In this study, conceptual planning study is applied to the Athletes' Village which has a dwelling area of 97,446 m^2. The total peak demand including hot water need for this system design is 11,7 MW_t. The existing heating system is fuel-firing system. A comparison between the existing system with geothermal district heating system is done by this study. The hot water at 140 ºC, which is planned to be extracted from new drilled wells, is first cooled down to 120 ºC and afterwards designed to give its energy to the closed city loop. Finally, city loop water will circulate in the buildings within the temperature range of 85 ºC/55 ºC. The economy of the system is studied for two different well locations considering different participating costs and operating costs. The monthly fixed charges which make the internal rate of return positive around 0 % is determined for the investor for different participating costs varying between $ 1250 and $ 2500. At the end, the net present worths for the payments that would be done to the heating systems are calculated for the consumers. As a result of the economic feasibility study, it is determined that geothermal district heating design would be feasible for the consumers when the same comfort conditions are considered for both of the designs.

ÖZET

Jeotermal enerji yeryüzünün kendi iç ısısı olmakla beraber geniş bir kullanım alanına sahiptir. Günümüzde jeotermal enerji ile ilgili sağlıklı projeler geliştirebilmek için yapılması gereken ilk çalışmalardan biri kavramsal planlama çalışmasıdır. Kavramsal planlama çalışmaları projenin teknik, ekonomik ve politik açılardan değerlendirmelerinden oluşup buradan yola çıkarak projenin uygulanabilirliğini tartışan çalışmalardır. Bu çalışmada 97, 446 m^2 konut alanına sahip Olimpiyat Köyü Evleri ile ilgili kavramsal planlama çalışması yapılmış ve bölgenin toplam pik yükü sıcak su ihtiyacı da dahil olmak üzere 11,7 MW_t olarak belirlenmiştir. Şu anda bu evlerin ısıtılması için düşünülen sistem mevcutta bulunan fuel-oil yakıtlı sıcak sulu sistemdir ve bu çalışmada mevcut bu sistemin, jeotermal bölge ısıtma sistemi ile karşılaştırılması yapılmıştır. Yeni açılacak kuyulardan elde edilmesi beklenen 140 ºC sıcaklıktaki jeotermal akışkanın sıcaklığının önce 120 ºC ‘ye düşürülmesi, daha sonrasında enerjisini şehir içi kapalı çevrim suyuna vermesi planlanmıştır. Son olarak, şehir hattı suyunun bina içlerinde 85 ºC/55 ºC sıcaklık aralığında dolaşması tasarlanmıştır. Sistemin ekonomisi, farklı kuyu senaryoları için farklı katılım payları ve aylık sabit enerji ücretleri göz önüne alınarak incelenmiştir. Farklı katılım payları düşünülerek iç karlılık oranını sıfıra en yakın pozitif yapan aylık ödemeler hesaplanmıştır. Son olarak, mevcut sistem ve jeotermal ısıtma sistemi ile ilgili senaryolar için ödenecek enerji tutarları sistem ömürleri hesaba katılarak bugünkü değerleri bulunmuştur. Ekonomik fizibilite çalışmasının sonucunda, eş konfor koşulları düşünüldüğünde, kullanıcılar için jeotermal ısıtma sisteminin uygunluğu görülmüştür.

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INTRODUCTION

1.1. Geothermal Energy

Geothermal energy is the energy produced in the Earth's interior. The source of this energy is due to the physical processes occurring in deeper parts of the Earth's structure. The heat flux of this energy is to the surface and it is known that the deeper inside the Earth's structure higher the temperature of the rocks forming this structure. This existing temperature gradient is found as 2.5 – 3 ºC/ 100 m (Barbier 2002).

The form of geothermal fields is based on the plate tectonics theory by the geologists. Our planet consists of three main parts: the crust, the mantle and the core. These parts of the Earth show different physical and chemical characteristics varying from the surface to the Earth's center. The outer shell of the Earth is called as lithosphere and it consists of the crust and the upper layer of the mantle. Below the lithosphere, there is asthenosphere which forms a less rigid behavior. In some parts of the Earth, the lithosphere is thinner and it can be broken by the upward movement of molten material in asthenosphere. This behavior of the Earth is resulted with forming of the plates. Thus, geothermal systems can be found in regions in result of these movements at fault zones (Dickson 2004, Barbier 1997).

Geothermal fields can be classified according to the source type, physical characteristics of the reservoir, the enthalpy of the fluid and geological settlement of the field.

Geothermal energy source types can be divided into parts as hydrothermal energy, pressurized underground energy, magma energy, hot dry rock energy, ground energy. The ground energy is the thermal energy formed near to the surface due to the normal temperature gradient of the Earth, so that it is not much affected by the geological events. It can be used for space heating by heat pumps, industrial demands and hot water need. Hot dry rock energy can be seen everywhere below 8-16 km depths from the surface or in the places where the temperature gradient Earth is higher due to geological events. Hydrothermal energy is the mostly known and used geothermal source. The formation of this system is due to some geological events under high pressures in the Earth's interior.

Hydrothermal geothermal system consists of three main elements:

- A heat source
- A reservoir
- A geothermal fluid for carrying heat

Molten material (magma) that have found way to move upwards to relatively shallow depths like 5-10 km, heats the rocks during its movement and the heat source occurs at the end of this process. "The reservoir is a volume of hot permeable rocks from which the circulating fluids extract heat." The geothermal fluid is rainwater that has penetrated into deeper parts of the crust and has been heated by the hot the rocks. Usually, the reservoir is covered with impermeable rocks, so that the geothermal fluid is stored under pressure (Barbier 2002).

When a productive geothermal system is considered, the characteristics of the reservoir are important. First of all, it should be composed of sufficiently large body of permeable rocks, which the magma body moves toward these rocks transferring its heat by conduction, at a depth which is accessible by drilling. There should be a certain fluid circulation through the body of the rocks, so that the heat can be carried to the surface. The reservoir is surrounded by cooler rocks hydraulically connected to the reservoir by fractures, so that the rainwater can penetrate underground. Rainwater moves to depth inside the reservoir by convection, due to density variations caused by the temperature. Through its movement, it contacts with the hot rocks, so the convection heat transfer occurs between the hot rock and the geothermal fluid, water. This kind of process results with the forming of a hydrothermal geothermal source. Hydrothermal systems can be classified according to the physical characteristics of the reservoir as: water-dominated fields and vapor-dominated fields (Wright 1995).

1.1.1. Water-Dominated Fields

Water-dominated fields can de divided in two different branches as hot water fields which produce hot water and wet steam fields which produces mixtures of water and steam.

Hot water fields are the fields which produces hot water at the surface at temperatures up to 100 ºC. These fields show the lowest temperature profile when compared with the others and the water is stored in liquid phase in the reservoir. Because the heat source is not large enough, the temperature of the water is below the boiling temperature at any pressure. On the surface, there are usually thermal springs whose temperatures are near 100 ºC.

Wet steam fields are consist of pressurized water having temperature more than 100 ºC and small quantities of steam in lower pressure parts of the reservoir. Most of the geothermal fluid in the reservoir is in the liquid phase and steam is occurring in the form of bubbles surrounded by the liquid. It is the liquid phase which controls the pressure inside the reservoir in this kind of fields. In fact, most of the time, the geothermal fluid is surrounded by an impermeable cap-rock to keep the fluid inside and keep it under pressure. When the fluid is carried to the surface and its pressure decreases, a small fraction of it is flashed into steam, while the greater part remains as boiling water. The pressure decreases because of the vaporization of some part of the water. This steam can be used for production of electricity (Barbier 2002).

1.1.2. Vapor-Dominated Fields

These kinds of fields produce dry saturated or slightly superheated steam at pressures above atmospheric pressure. The characteristics of these fields are similar to wet steam fields. However, these fields have higher heat transfer rate from the heat source. Similar to wet steam fields, there exists a permeable cap-rock in the reservoir. Different from the wet steam fields, steam is the predominant phase which controls the pressure in the reservoir. These fields are called dry or superheated fields. When a well is drilled into the reservoir, a depressurized zone occurs at the bottom of the well. Boiling starts with this pressure drop and the liquid which surrounds the rock vaporizes. At the end, a dry area occurs near the well-bottom and steam flows through this zone. When steam crosses the dry area, it starts to expand and cool, but as the heat is transferred from the hot rock, steam keeps its temperature above the vaporization value for the pressure existing at that point. Thus, the steam leaves the well as superheated steam (Barbier 1997).

The temperature of the fluid is another factor in the classification of the geothermal systems. The reservoirs where the temperature of the produced water is below 150 ºC is called low-temperature systems (Wright 2004). These kinds of systems are known with natural hot water reaching to the surface. Most of the known systems in Turkey are low-temperature systems. For this kind of systems, the heat source is the crust having a temperature above the normal conditions. After some undergoing Earth movements, fractures and fault zone are formed which are the channels for the water to circulate inside. In the Figure 1.1, it can be seen that how rainwater accumulates in the geothermal field from the higher elevated parts of the Earth. It penetrates to deeper parts and reaches to the hot rock, so that it can transfer heat from the rock. Then the water reaches to Earth, but this time heated by the hot rock. This hot water can be observed on the lower elevated parts of the surface or it can be pumped to the surface from the drilled wells. These kind of low-temperature systems are seen near places where there are active geological movements. Geothermal fields on the west side of Turkey are examples for this kind of geothermal systems (Wright 1995).

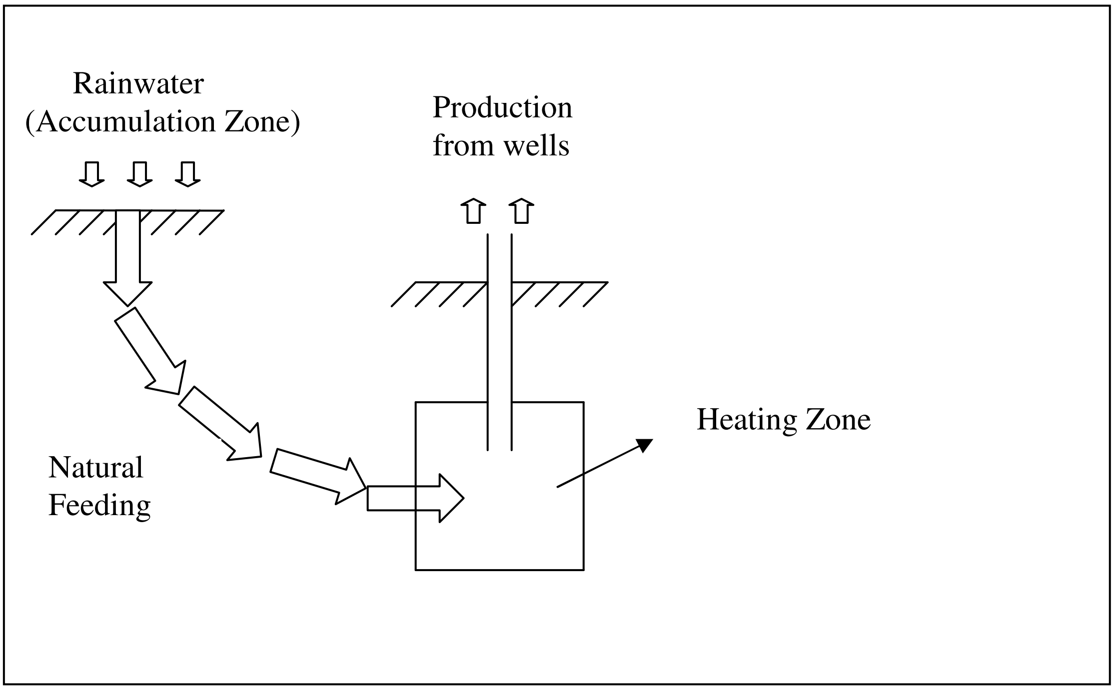


Figure1.1. Heating Mechanism for Low Temperature Systems (Satman 2003)

When the temperature of the water that is produced from the well is above 200 ºC, then these kinds of systems are called high-temperature fields. These kinds of systems are known with existing steam from the surface or with boiling mud ponds. These kinds of field are available for electricity generation.

Also the enthalpy, which is the used to express the value of the thermal energy of the system, is used for classifying geothermal resources. As a result of evaluation of the energy content of the fluids and their potential forms of utilization, the geothermal resources can be expressed as low, intermediate and high enthalpy resources. In literature, different scientists have suggested different temperature ranges for classification of the enthalpy of the resources and these are shown on Table 1.1 (Satman 2003, Dickson 2004).

Table 1.1. Classification of geothermal resources (ºC)

	Muffler and Cataldi (1978)	Hochstein (1990)	Benderitter and Cormy (1990)	Nicholson (1993)	Axelsson and Gunnlaugsson (2000)
Low enthalpy resources	< 90	< 125	< 100	≤ 150	≤ 190
Intermediate enthalpy resources	90 - 150	125 - 225	100 - 200	-	-
High enthalpy resources	> 150	> 225	> 200	> 150	>190

1.2. Impacts of Geothermal Energy on Environment

“Geothermal energy is usually referred to as a renewable source of energy and as such is listed with solar, wind and biomass as alternative energy options. It is also termed as environmentally friendly, by virtue of the particularly low emissions of greenhouse gases into the atmosphere. Both attributes are indeed applicable, but within certain limits, which must be addressed in a fully objective manner” (Rybach 2003)

Both of the main geothermal applications, power generation and direct use, can have an effect on the environment. As Rybach stated, these effects are needed to be identified, quantified and, if necessary, eliminated and the exploitation must be arranged according to certain environmental regulations (Rybach 2003).

The impacts of geothermal energy vary with the scale of the system. These impacts include changes in landscape, emissions to the atmosphere, surface and subsurface water, noise, land subsidence and solid waste, etc. The potential environmental impacts of direct use of geothermal energy can be seen on Table 1.2. On the table, the impacts are analyzed according to the probability of occurrence which may differ with the capacity of the system and the technology used for the exploitation. Then the impacts are classified according to the level of results if they occur.

Table 1.2 Potential environmental impacts of direct use geothermal projects (Rybach 2003)

Impact	Probability of occurring[a]	Severity of consequences[b]
Air pollution	L	M
Surface water pollution	M	M
Underground pollution	L	M
Land subsidence	L	L to M
High noise levels	H	L to M
Well blowouts	L	L to M
Conflicts with cultural and archeological features	L to M	M to H
Socioeconomic problems	L	L
Solid waste disposals	M	M to H

[a] Pollution can be chemical and/or thermal.
[b] L = Low, M = Medium, H = High

For example, air pollution is one of the impacts of geothermal energy to the environment. During drilling of flow tests, some undesirable gases may escape to the atmosphere resulting with air pollution if precautions are not taken. Also geothermal power plants can discharge CO_2 which can pollute the air. However, it should be stated that the CO_2 emission in geothermal power plants are much lower when these plants are compared with conventional power plants. In addition, by using the technology nowadays, the chance of occurrence of this impact is low.

Also, surface and subsurface water pollution is another impact of geothermal fluids. Geothermal fluids usually consists of dissolved gases like carbon dioxide, hydrogen sulphide, ammonia, methane and dissolved chemicals as sodium chloride, boron, arsenic and mercury. These dissolved chemicals and gases can influence the environment in a negative way if they are discharged. Further, the waste water from geothermal plants can be discharged to the environment (ponds, lakes, etc), so that the temperature of surface water could increase. Thus, ecological life will be damaged in the result of this discharge. Therefore, the geothermal water should be treated or re-injected to the reservoir to prevent the thermal and chemical pollution.

Furthermore, subsidence may occur after the extraction of large quantities of geothermal fluids from the geothermal reservoirs. However, this subsidence can be prevented by re-injecting fluid to geothermal reservoir.

Noise is another problem which is mostly encountered when electricity is generated from geothermal power plants. At the power plants, the main noise pollution comes from the plant components such as cooling tower fans, the steam ejector and the turbine. In direct systems, the noise generated is usually negligible in nowadays' technology.

1.3. Sustainability of Geothermal Energy

"The term sustainable development was used by the World Commission on Environment and Development to mean development that meets the needs of the present generation without compromising the needs of future generations (Rybach 2003)." In general, the term sustainability for a resource is related its initial quality, its rate of generation and its rate of consumption. The rate of generation over any time period must be greater than the rate of consumption, so that the resource can be considered as a sustainable resource. Otherwise, if the production is only done to meet the economic goals and to sustain the quick payback of the capital investment, then, the resource would be consumed totally over a time period. To determine these rates for a geothermal resource, the studies on the performance of the reservoir should be carried out. When a geothermal resource is considered, the rate of consumption is in relation with financial, political and regulatory factors which can be called "economic factors". These factors can be determined before the production of geothermal fluids by conceptual planning studies (Wright 1995).

Muffler and Cataldi had defined geothermal resource as the thermal energy that could reasonably be extracted at costs to its competitive with other forms of energy at some specified future time. In their studies, they stated only a small portion of the resource base is economical to use when the resource base is analyzed deeply as it is seen in Figure 1.2. The depth of the well is a major factor in determination of the drilling cost. The thermal energy in the shallower part of the crust is to be extracted economically in foreseeable future. Because of this reason, it will be correct to divide the resource as the "accessible resource" where the thermal energy can be reached by drilling and the "inaccessible resource" where the thermal energy in deeper parts can not be reached by drilling. The depth separates these categories and the drilling technology and economics are the factors which determine the depth for that time (Muffler 1978).

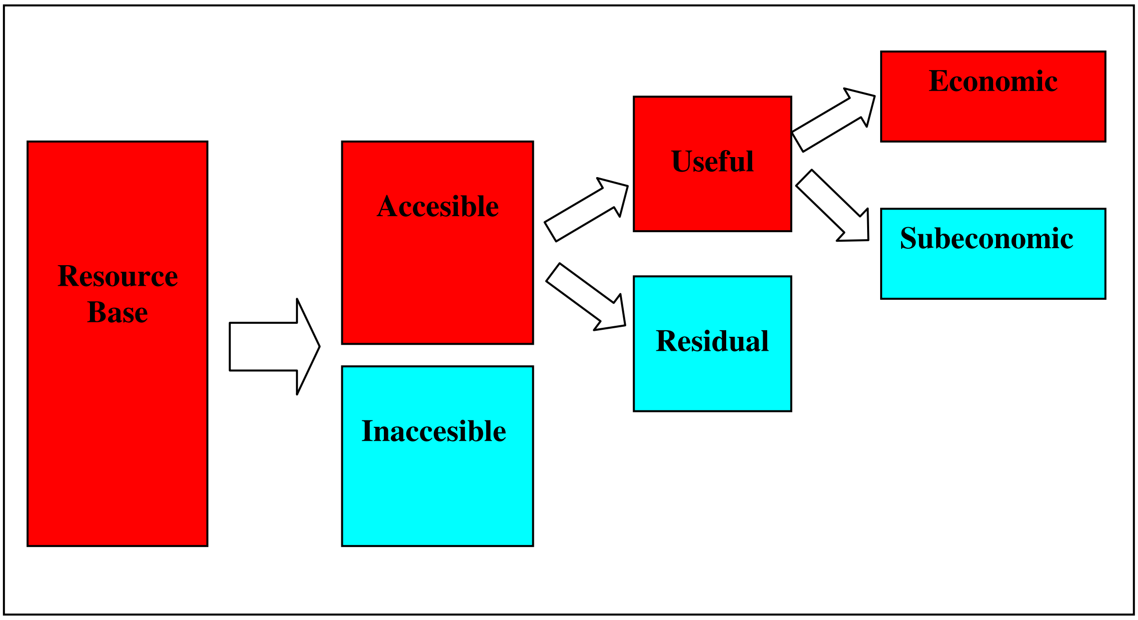


Figure 1.2. Subdivisions of the geothermal base in Muffler and Cataldi's studies

"It is commonly recognized that not all the thermal energy accessible by drilling can be collected and extracted, even under the most optimistic assumptions of technology and economics. Because of the some physical reasons, legal and environmental considerations, some portion of it will not be extracted. When these factors are considered, the accessible resource should be divided into two parts as "useful" and "residual". Muffler and Cataldi explains "useful accessible resource" as "the thermal energy which could reasonably be extracted at costs competitive with other forms of energy at a specified time in the future, under the general assumptions of progressively improving technology and of increasingly favorable economic situation." (Muffler 1978)

At the end, useful accessible resource can be analyzed if it is economic or sub-economic. A geothermal source can be called economical when the geothermal energy can be extracted within the legal policies at a cost which is competitive with other energy sources at the time of extraction. The sub-economic category is the one which is not competitive, but could be extracted competitively by the help of progressing technology in future time. Therefore, because there is a chance of extracting this portion with improved technology in future, this portion is still included in the "useful" part of the reservoir (Muffler 1978).

1.4. Application Areas of Geothermal Energy

The application areas of geothermal resources can be grouped as direct heat uses and non-direct uses. The direct uses includes snow melting, air conditioning, heat pumps, space heating, bathing, agricultural drying, greenhouses, fish farming and industry. The distribution for these usage areas for the direct use of geothermal is shown on the Figure 1.3.

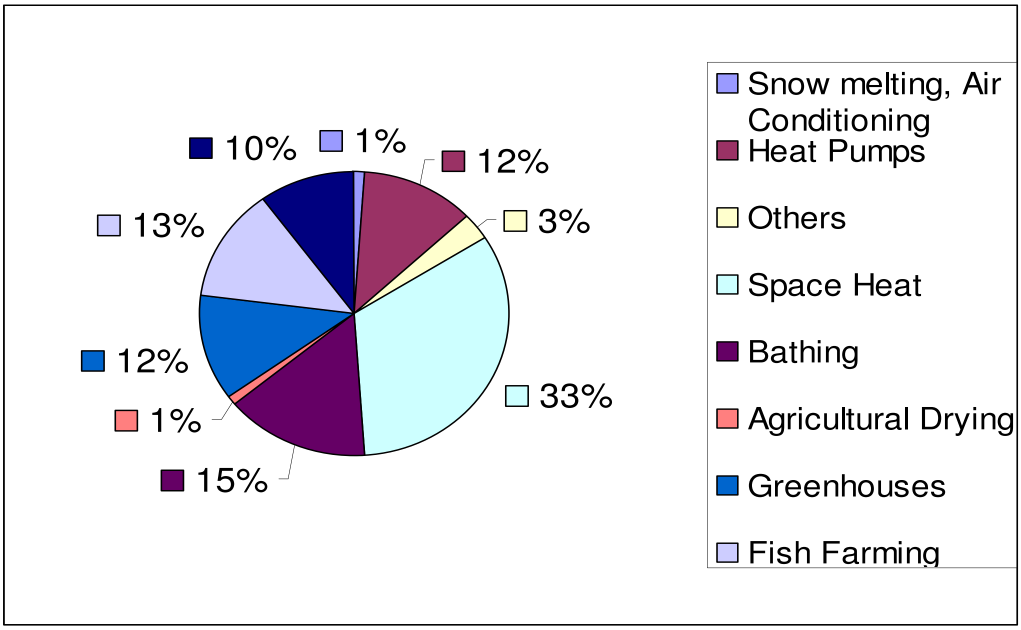


Figure1.3. Direct use of geothermal heat on worldwide from 23 countries. Total capacity = 102,268 TJ/year (Freeston 1995)

1.5. Direct Uses of Geothermal Energy

1.5.1. Space and District Heating

Space and district heating is common form of utilization of geothermal energy. In a study about the fundamentals and applications of district system, Valdimarsson have made a fine definition for the district heating systems as “district heating is a system, composed of many elements, building a chain from the resource over to the interior of the buildings which are heated. All elements in this chain are equally important, from the geothermal well over to the building radiators, and they all have to be designed with utmost care” (Valdimarsson 2003).

As in the definition, these systems are consist of many elements like production and injection wells, down-hole and transmission pumps, pipelines and distribution networks, monitoring and control equipment, peaking stations and storage tanks. Mainly, costs for these elements add up to form the “capital cost” for the district system. The other cost factors for the system are pumping costs, maintenance costs and costs related with heat and water loss in the distribution system (Valdimarsson 2003). These factors can be classified under a group, “operating costs”. The economy of the geothermal system is related with the thermal load density for the system which the heat demand divided by the ground area of the district. Therefore, the peak load analysis for the district heating system is important in feasibility studies for the system. Peak load analysis is a crucial analysis in feasibility studies, since the geothermal systems includes the investment for drilling which is high compared with the investment in boiler stations and the energy cost of the operation of a geothermal system is mainly the pumping cost (Bloomquist 2003, Dickson 2004).

As it is expressed in Valdimarsson’s study , the minimum operational demands for a district heating systems are (Valdimarsson 2003):

- Pressure difference between the supply and the return pipe at every consumer connection must be sufficient.
- Maximum line pressure must be lower than the design value.
- Water inlet temperature by every consumer should be sufficiently high.
- Water temperature in the secondary and tap water system must not exceed a safety limit set for inhabitants and equipment

- Sufficient reliability

1.5.2. Space Cooling

Space cooling can be sustained where absorption machines can be adapted to the geothermal use. The absorption cycle is a process going under the reaction of two fluids, a refrigerant which circulates, evaporates and condenses; and secondary fluid which is absorbent. Lithium bromide/water and ammonia/water cycles are the most known absorption cycles. Geothermal fluids provide the energy to drive these machines, although their efficiency decreases with temperatures lower than 150 ºC (Dickson 2004).

1.5.3. Geothermal Space Conditioning

Geothermal space conditioning is spread with the usage of heat pumps. Heat pumps are devices working mechanism is similar to refrigeration devices; however the only difference is heat pumps are reversible, so they can provide both heating and cooling. They can be grouped according to the application areas as ground-coupled heat pumps and ground-water heat pumps (Dickson 2004).

1.5.4. Agricultural Applications

Open-field agriculture and greenhouse heating are the most known applications for the agricultural applications. Thermal water can be used for irrigating and/or heating the soil in open-field agriculture. The other and most common application of geothermal energy in agriculture is greenhouse heating. The optimum conditions for growing of vegetables and flowers out of season or in an unnatural climate can be supplied by greenhouse heating. Greenhouse heating can be sustained by forced circulation of air in heat exchangers, hot-water circulating pipes or ducts located in or on the floor, finned units located along the walls and under benches or a combination of these methods (Dickson 2004).

1.5.5. Industrial Applications

Geothermal energy also can be used in industrial applications like process heating, evaporation, drying, distillation, sterilization, washing, de-icing and self extraction.

1.6. Non-direct Uses of Geothermal Energy

The non-direct use of geothermal energy occurs in conventional steam turbines and binary plants by electricity generation. Conventional steam turbines requires geothermal fluids with high temperatures (>150 ºC) to generate electricity. On the other hand, the low to medium temperature geothermal resources can be used in binary plants where secondary fluid is needed for electricity generation (Dickson 2004).

CHAPTER 2

GEOTHERMAL DISTRICT HEATING SYSTEMS

2.1. District Heating

Energy is used either to perform work or to produce heat. The transformation of work to heat always can be performed without any losses. On the other hand, when the reverse process is considered and work is transformed to heat, this transformation process is not possible without having to reject some of heat fed in at a lower temperature. The second law of thermodynamics explains this procedure. These forms of energy can be divided into two groups as first and second class energy. Electricity is an example for the first class energy form because its transformation into heat occurs without losses and it can also be transformed into work with high efficiency.

The domestic energy use could be both first and second class energy. The electrical network can supply first class energy, but the second class energy may be supplied in various forms such as fossil fuel for use in a domestic boiler, electricity and heat distributed by a district heating network. A district heating system can use different power utilities to produce heat to its customers. It can use the heat which is rejected from industrial processes or from electrical power generation. Also, heat from unconventional energy sources can be adapted to these systems, such as geothermal energy. “The main purpose of a district heating system is to supply adequate heat to its customers. The heat will be used to maintain indoor temperature at a reasonably constant level and counter for building heat loss to the surroundings and for preparation of domestic hot water (Valdimarsson 2003)”.

The method used for heat generation is the main classification standard for district heating systems. The most common method of heat generation for district heating is firing of fossil fuel, either in boilers dedicated to the district heat production, or in the boilers of a power station, where the steam plant reject (condensation) heat is used for the district heating system. Then, the distribution of heat to the customers is supplied through a closed network. By the use of customer, it is cooled down, and then it is piped back to the boiler in the return network to be re-heated (Bloomquist 2003).

2.2. History of Geothermal District Heating in World

It is known that the use of geothermal energy is date back to ancient time. In early times, geothermal energy was used for purposes as bathing, cooking and washing. Some ancient evidence showed that geothermal energy was used by Romans, Greeks, Indians, Chinese, Japanese and Mexican. Therefore, these ancient applications lead the way to modern applications of geothermal energy (Özgener and Hepbaşlı 2004).

The first documented geothermal district heating system was built in Chaudes-Aigues Cantal in France, in the 14th century. It is one of the oldest application areas of geothermal energy. In the United States the Boise, Idaho system known as the Boise Warm Springs Water district, went online in 1893 and is now one of the four independent systems that serve the Boise metropolitan area (Bloomquist 2000). In 1818, a boric acid industry is established in Italy to extract boric salts from the geothermal water of that area. In 1909, first geothermal space heating was installed in a house Reykjavik, Iceland (Hepbaşlı 2004). After that, the commercial generation of electricity from geothermal energy has started in a power plant in Tuscany, Italy with a capacity of 250 kW_e in 1913. Further, the first geothermal district heating system was installed in Reykjavik in Iceland in 1930. New geothermal district heating systems in Idaho, Oregon, New Mexico and California had been installed during 1980's, but the extremely low natural gas prices were an obstacle on the development of new geothermal district heating systems in that period (Bloomquist 2003).

Nowadays, geothermal energy is used for especially, district heating in worldwide and governments are exploring new geothermal potentials in their countries. Hungary, Iceland, France, Poland, Romania, China, Turkey, Sweden and Denmark can be counted in these countries which are working for developing newer geothermal district heating systems. Iceland is the leader in the development of geothermal district heating systems, and as of 97 % of the inhabitants of the capital city of Reykjavik are benefiting from geothermal district heating to supply their space heating as well as domestic hot water heating requirements. However, in his study Lund (2002) states that "Iceland may soon lose its leadership role as Turkey is quickly emerging as a leader in the development of new geothermal district heating systems. By 2000, Turkey had over 51,600 residences connected to district heating networks and projects to supply geothermal district energy services to approximately 500,000 residences, or 3 % of the residences in the country, by 2010."

2.3. Design of Geothermal District Heating

The design purpose of district heating network is to provide space heating to multiple consumers from a single well or from multiple wells or fields, since district heating is one of the oldest uses of geothermal energy.

Geothermal energy is the thermal energy within the Earth's interior. It is a renewable energy source, however when electricity generation is considered, a geothermal source usually has a projected life of 30 to 50 years. The life of a source may be expanded by re-injecting the waste fluid, which is the most common method of disposal. Re-injection may also help to maintain reservoir pressure (Kanoğlu 1998). On the other hand, for the district heating systems, system life is related with usage rate of the reservoir. "Sustainable geothermal utilization involves energy production at a rate which may be maintained for 100-300 years (Hepbaşlı 2004)". Therefore, for all the applications of geothermal energy, sustainability depends on efficient utilization of the system, re-infection, careful monitoring and modeling of the reservoir.

In the design of direct use systems one of the major goals is capturing the most possible heat from each volume of fluid pumped. This arises from the fact that investment and operating costs for the systems are composed primarily of well pumping and well components. When the ΔT for the system is maximized, (minimizing flow requirements), well capital cost and pump operating costs are minimized. In many cases the system design benefits from connecting loads in series according to temperature requirements (Dimitrov 2000).

District heating is one of the usage areas of the geothermal source, consists of many elements, building a chain from the resource over to the interior of the buildings which are heated (Valdimarsson 2003). The components of a geothermal district energy system are:

- One or multiple wells or in some cases even well fields
- Well and circulating pumps
- Transmission and distribution piping
- Central or individual building heat exchangers

- Peaking/backup boilers
- Thermal storage units

Also many factors affect the cost of energy delivered from geothermal resources. These factors are as follows (Ashrae 2003):

- Depth of resource: The cost of the well is one of the important cost components of geothermal district heating systems, since the drilling cost increases with the depth of the resource.
- Distance between resource location and application site: The direct use of geothermal energy is primarily economic, when the resource is near the application area. However, the geothermal fluid (or a secondary fluid) could be transmitted over moderately long distances (greater than 60 miles) without a great temperature loss; such transmission would not generally be economically feasible.
- Well flow rate: The energy output from a production well varies directly with the fluid flow rate. The energy cost at the wellhead varies inversely with the well flow rate.
- Resource temperature: In geothermal resources, the available temperature is determined by the resource and is essentially a fixed value for a given resource. The temperature may or may not increase with deeper drilling. The temperature would stay constant in fluid-dominated resources where natural convection keeps the temperature relatively uniform throughout the aquifer. However, if there are deeper, separate aquifers (producing zones) in the area, a higher temperature can be sustained by deeper drilling.
- Temperature drop: Since well flow is limited with the characteristics of the well, the power output from the geothermal well is directly proportional to the temperature drop of the geothermal fluid. Thus, lower energy cost can be sustained with a larger temperature drop at the wellhead.
- Load size: The load of the district affects the viability of a geothermal system.
- Composition of the fluid: The quality of the fluid influences the design parameters in material selection, since the materials selected should resist against the corrosive components of the fluid.
- Method for disposal: The costs associated with disposal affect the development costs. Besides the re-injection, geothermal fluid can be discharged to irrigation, rivers, and lakes near the resources. This method of disposal is less expensive

than the construction of re-injection wells. However, drilling of re-injection wells or not is a decision which would affect the sustainability of the resource. If re-injection is required, the depth at which the fluid can be injected affects well cost. In some cases, re- injection wells are needed to be drilled to the same depth as the production well.

- Resource life: The production rate must be determined in optimum values, so that the life of the resource can be expanded. Since, the resource life is an important parameter of determining the viability of a geothermal system in design stage.

2.3.1. Geothermal Wells

The volume of the necessary geothermal water for a district system is the main parameter in determination of the diameter and the depth of the well. Due to the higher demands, geothermal wells for the district systems are often drilled with a larger diameter and often much deeper than the wells for individual systems. As a result, geothermal district heating system designs could be planned to be cost-effective. The depths of these wells may be as deep as 2000 – 3000 m or more in some systems (Bloomquist 2003).

After drilling the wells, the well head tests must be conducted, so that the designer will have information about the flow rates, water quality and well-head pressure. As it is mentioned before, to sustain a long resource life, an injection well may be needed to dispose of the return fluid from the system.

2.3.2. Well and Circulating Pumps

Production well pumps are among the most critical components in a geothermal system. Therefore, it is very important to select the proper well pump and to design it.

For most of the wells, pumping is needed for bringing water to the surface and maintaining the pressure, to prevent the release of gases which could result in scale formation. Unless the well is artesian, down-hole pumps are needed, especially in large-scale direct utilization system. The two most common types are: line-shaft pump systems and submersible pump systems.

The line-shaft pump system is composed of a multi-stage down-hole centrifugal pump, a surface mounted motor and a long driveshaft assembly extending from the motor to the pump. Most are enclosed, with the shaft rotating within a lubrication column which is centered in the production tubing. The bearings are lubricated by oil by the help of this assembly, as hot water may not provide adequate lubrication. Instead of turning the pump on and off, the flow can be regulated with a variable-speed drive which is set below the motor (Lund 1998).

The electric submersible pump system is composed of a multi-stage down-hole centrifugal pump, a down-hole motor, a seal section (also called a protector) between the pump and motor, and electric cable extending from the motor to the surface electricity supply. When the electrical submersible pump is compared with line-shaft pumps, the electrical submersible pump has several advantages. For example, it is better to use the electrical submersible pumps for wells requiring greater pump bowl setting depths. Also, the submersible pumps are more economic for the deeper well depths. Thus, it is can easily adapt to different depths.

Control of well pumps can be sustained by the usage of variable speed drives as it is mentioned before. “Historically, vertical turbine pumps have employed fluid couplings for this purpose but more recently variable frequency drive (VFD) has been more common. Submersible pumps can also be controlled using a VFD but special precautions are required. Drive rated motors are not commonly available for these applications and as a result, external electronic protection should be used to prevent premature motor failure. In addition, the motor manufacturer must be aware that his product will applied in a variable speed application. Finally, due the large static head in many well pump applications, controls should be configured to eliminate the potential for the pump to be operated at no flow conditions (Ashrae 2003)”.

2.3.3. Transmission and Distribution Piping

Transmission and distribution piping generally consists of pre-insulate and jacketed welded steel. However, asbestos cement and some other types of non-metallic pipe have been used successfully in some applications. Carbon steel is now the most widely used material for geothermal transmission lines and distribution networks; especially if the fluid temperature is over 100°C. For temperatures the distribution networks below 100°C, polyvinyl chloride (PVC) piping is often used. Also, un-insulated waste disposal lines are another place where this kind of piping can be used.

Other common types of piping material are fiberglass reinforced plastic (FRP) and asbestos cement (AC) where temperatures are well below 100°C. Conventional steel piping requires expansion provisions. This can be sustained by the usage of either bellows arrangements or by loops. Moreover, in every 100 m, the piping installation must have supported with fixed points and expansion points (Lund 1998).

Nowadays, usually pre-insulated pipes (Figure 2.1) are preferred because they minimize heat losses during the transmission of brine and binary fluid. Transmission of a 115°C brine over 3 km distance in 1 m diameter pipes is calculated to cause only about a 1°C drop in temperature when pre-insulated pipes are used (Kanoğlu 1998).

Non-metallic pipes are used more often in cooling systems than in heating systems and the pipes may or may not be insulated. Above-ground and below-ground transmission lines can be preferred according to the conditions of the application area, but in most cases, distribution piping is installed underground. In cases where piping is applied above the ground, expansion loops and anchors must be used and supports must be constructed to allow for some pipe movement. When piping is below the ground, the preferred method is direct burial and this is the most common method. Expansion is again supported by the use of compensators and pre-stressing the pipe before burial is all the more common. During construction, it is very important that all welds are checked and that water-tight mufflers are used wherever jointing occurs. After the installation of the muffler, insulation is applied to the area between the pipe and the muffler jacket. The muffler prevents water to move to the carrier pipe, so external corrosion is kept in minimum.

In direct buried systems, the most common way for preventing leakage is the use of a leak detection system. It is not a necessity, but the minimal extra cost is often considered to be very inexpensive insurance. In some of below-ground applications, covered trenches or utilidors are used. However they are expensive, these applications provide easy access to the piping system for maintenance and repair. When the below-ground piping is installed in covered trenches or utilidors, proper anchors and expansion loops must be used so that the stress would be minimized (Rafferty 1996). In larger systems, another application which is considered is usage of valves and bypasses. They are used to reduce the risk of water hammer in applications where flow velocity must be rapidly changed or stopped. Meters which are installed at critical locations provide data used by operators with not only enhanced system control, but also they control and optimize the system to meet best load, so that the operation costs can be reduced (Bloomquist 2003).

Supply and distribution systems can be composed of either a single-pipe or a two-pipe system. The single-pipe is a once-through system where the fluid is disposed of after use. This kind of distribution system is generally preferred when the geothermal energy is abundant and the geothermal water is pure enough to be circulated through the distribution system. In a two-pipe system, the geothermal fluid is re-circulated so the fluid and residual heat are conserved. In the applications of two-pipe system, the spent cold fluid is needed to be injected into the reservoir and the return pipes are insulated as well as the supply pipes. However, only the supply lines are insulated in the single-pipe systems. Two-pipe distribution systems cost typically 20 to 30 percent more than single piped systems (Lund 1998).

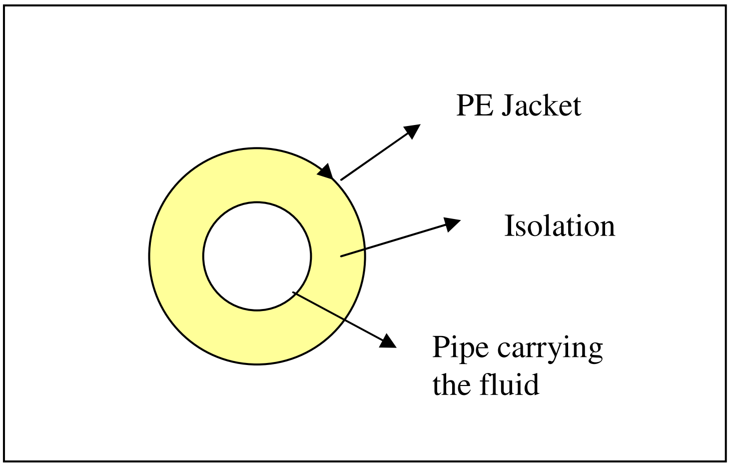


Figure 2.1. The layers of a pre-insulated pipe

2.3.4. Central or Individual Building Heat Exchangers

Although geothermal fluids may be circulated through the transmission and distribution system directly to end users, there will be the serious risk of corrosion and/or scaling in the system. To prevent the corrosion in the applications, the heat energy of the geothermal fluid is transferred to a secondary fluid for transmission and/or distribution. These kinds of systems are called as closed loop systems. After giving its heat to the secondary fluid, the geothermal fluid is returned to the reservoir through an injection well. The distribution fluid used is generally water containing freeze and corrosion protection additives, although in some countries, the use of de-ionized water is common. In this process, the heat transfer is accomplished through a heat exchanger. The heat exchangers mostly used in the geothermal systems are plate and frame, shell-tube and downhole heat exchangers.

Plate and frame heat exchangers are the most commonly used design. As it is is seen in Figure 2.2, plates in series with gaskets held in a frame by clamping rods form the structure of these exchangers. Plate and frame exchangers are easily cleanable, available in corrosion resistant materials and readily able to accommodate future increases in load (through the addition of plates), so they are well suited to geothermal applications in worldwide. Another reason why they are preferred is they provide efficient thermal exchange in small volumes by the result of counter-current flow and high turbulence which is achieved in these exchangers. These exchangers have relatively compact size when they are compared with shell-tube heat exchangers.

The high performance of plate heat exchangers is also an asset in many system designs. Since geothermal resource temperatures are often less than those used in conventional hot water heating system design, minimizing temperature loss at the heat exchanger is frequently a design issue. Materials for plate heat exchangers in direct use applications normally include Buna-N or EPDM gaskets and stainless steel or titanium plates. The plates are selected according to the temperature and chloride content of the water.

On the other hand, shell-tube heat exchangers are not much popular as plate and frame heat exchangers, since fouling can be occurred during their application and they have larger size. Also they need greater approach temperature which is the difference between incoming and outgoing fluid temperature.

Downhole heat exchangers consist of the arrangement of pipes or tubes suspended in a well and heat is extracted from the reservoir by the circulation of secondary fluid in a closed loop. The usage areas of these exchangers are limited to small heating load as small individual houses.

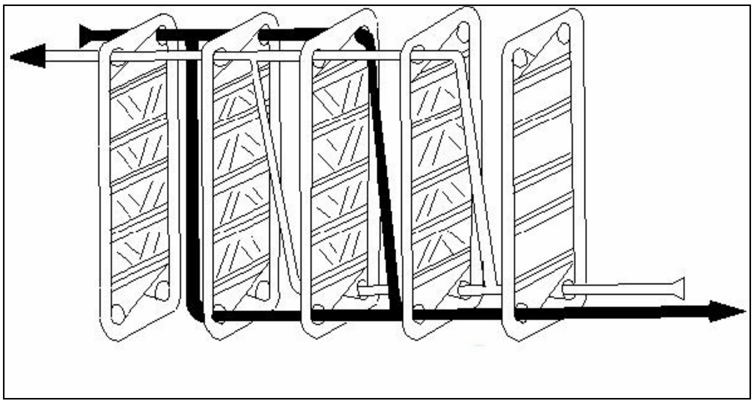


Figure 2.2. Plate and frame heat exchangers (Lund 1998)

2.3.5. Thermal Storage Units

“Both closed and open loop systems may incorporate thermal storage and/or peaking and/or backup equipment into the “production plant”. Thermal storage equipment can minimize the flow required by the geothermal wells needed to meet peak demand” (Bloomquist 1998). When peak demand is tried to be supplied with solely with geothermal flow, then it is seen that there can be increase in flows-sometimes as much as a 50 % increase with increased demand. This occurs because the temperature that is available from the geothermal wells can not be varied, forcing the system operators to meet peak only by increasing flow. In these cases, fossil fuel boilers, electric boilers or heat pumps are used for peaking. Also, if peak demand is encountered by increasing geothermal flow, then over-sizing would occur in transmission and/or distribution piping network. Therefore, thermal storage tanks are used for keeping the flow at a constant level through the heat exchanger while the changes occur in network flow (Dimitrov 2000).

On the other hand, also, peak can be met by varying temperatures while holding flow constant. Since, peak demand occurs only 3-5 % of the time, peaking can be done by the usage of fossil fuels. In result, the usage of peaking in the system design can reduce the number of production and injection wells by as much as 50 % and reduce the diameter of transmission and/or distribution piping by 40-60 %, so the capital cost would be reduced because of the reducing diameter (Bloomquist 2003).

2.3.6. Consumer Side of the District Heating Design

Consumers may be connected to the distribution network by two methods. Connection to the geothermal system with HVAC system where distribution fluids circulated directly through the system is one of the methods. Alternatively, each end user may be connected to the central distribution system via a heat exchanger or exchangers-one for heating and a second for the provision of domestic hot water. In most of the applications, consumers are connected through a plate-and-frame heat exchanger. In some cases, the heat exchanger can be eliminated from the system. This can be applied to the systems where the geothermal content of the water is de-ionized, so the geothermal water can be carried directly to the in-building equipment. The heating method used for heating a room in geothermal systems is similar like in conventional systems. Room radiators, ceiling or floor radiant heaters, forced-air heaters and finned radiators can easily adapted to the end of the geothermal system to supply heat to the rooms.

In most of the district energy systems, metering of energy consumption is used for billing purposes. However, in some systems, billing is based on per square meter of conditioned space or flow basis which is called as flat-rate approach. When the flat-rate approach is applied to determine the bill, flow limiters are installed which will restrain flow to a certain pre-determined limit. Where energy consumption is used as the basis for billing, energy meters that integrate in-flow and out-flow temperatures and flow are the standard. Energy or flow meters have advantages like providing real-time data for system operation as well as eliminating the personnel needed for meter reading and billing and updating databases (Lund 1998).

2.4. Benefits of District Systems in General

Generally, district energy systems produce steam or hot water from a central plant and then heat is distributed to the consumers of the network with a pipeline. These systems are energy efficient, environment-friendly, reliable, and convenient which are easy to operate, have low operational costs and flexible in design (WEB_1 2005):

- **Energy efficient:** In district heating systems, steam, hot water or chilled water arrives at the building connection in ready to use. Because they are 100 percent efficient at the consumer's connection, when they are compared with burning natural gas or fuel oil at a building with about 80 percent or lower efficiencies, district heating becomes more convenient for the customers. In addition, the reject heat from these systems can be used to produce electricity at a power plant. When this kind of an application is considered, the system becomes a combined heat and power system - generating both electricity and heat for customers. As a result of this, power plant's efficiency can nearly be doubled and this kind of production also lowers the emissions typically associated with standard electrical production. Therefore, when the less energy is used, the less sulfur dioxide and carbon dioxide is disposed to the environment.

- **Environment-friendly:** Besides the district energy enables building owners and managers to conserve energy and improve operating efficiency, the environment is protected with the application of district systems. Since fuel-oil is not stored and burned in the buildings, the region becomes safer and the environment is lesser polluted. Also, there is no need to use smokestacks. During the operation of district heating systems, since stringent emission controls are used, the air quality of that region increases in time.

- **Easy to operate and maintain:** Also, the customers should not worry about heating with the application of district heating systems because heat is delivered directly to the consumer's building in ready to use. These systems can be connected easily to the HVAC applications. In addition, boilers or chillers in the buildings are not used no more, so there is less maintenance, monitoring and equipment permitting. After connecting to the district energy network, customers also do not have to worry about fuel deliveries, handling and storage of fuels so this brings relax and safer medium for the building employees and building occupants. The building occupants will gain more space from the existing storage areas which are not in use in district heating systems.

- **Reliable:** These systems are reliable for the consumers, since they are operated by the energy professionals and these kinds of systems have usually backup systems readily available.

- **Comfortable and convenient:** During the operation of district energy, building operators are capable to manage and control their own indoor environments. Building occupants can be both comfortable and satisfied, no matter what the outdoor temperature. Energy will be supplied whenever the district needs to be heated. So evening the cold days of winter, the consumers won’t deal with problems like whether enough fuel is stored or not. Further, the consumers won’t encounter with noise problems, since district energy reduces vibrations in the system that could annoy building occupants.

- **Lower life-cycle costs:** When district heating systems are compared with the individual heating systems, it is seen that the fuel costs and maintenance of the individual systems brings high operating costs to the consumer. During the heating with the district energy network, the energy demand will be arranged by the professionals and they will maintain comfortable indoor environment for the consumers, so the energy will be used more efficiently. Therefore, the operating costs for these systems will be lowered and the consumers will pay less money for heating.

- **Design flexibility:** Design flexibility is sustained to the architects with the usage of district systems, since no smoke stacks, boilers or cooling towers are need to be used. Thus, the existing space can be used for other purposes and an aesthetic view can be gained to the region.

CHAPTER 3

GEOTHERMAL ENERGY IN TURKEY

3.1. Present Energy Evaluation of Turkey

Energy affects all aspects of modern life. Energy issues are directly related to the development of a country and the living standards of its people. Turkey is currently in a rapid industrialization process with a young and dynamic population. Primary energy demand is rising due to relatively high growth rate of population. Turkey's primary energy sources include lignite, hard coal, oil, natural gas, hydropower, geothermal, wood, biomass, solar and wind energy. However, these energy resources are not sufficient for the annual demand of the country to sustain the energy demand; Turkey imports more than half of energy requirements (Demirbaş 2001, Kaya 2004).

The energy policy in Turkey tries to assure energy supply in a reliable, sufficient, on time, economical way with considering the environmental impacts. Also, its goal is supporting and orienting targeted growth and social developments. "The government focused its efforts on improvement in domestic production by utilizing public, private and foreign utilities and increasing efficiency by rehabilitation and acceleration of existing construction programs to initiate new investments" (Kaygusuz 2004). Existing energy policies of Turkey are (Kaya 2004):

- Planning energy research and development activities to meet requirements,
- Meeting long term demand using public and private capital, domestic and foreign,
- Developing existing sources of energy, while speeding on new sources,
- Adding new and renewable resources (geothermal, heat, solar, wind, etc.) as soon as possible to the process of meeting energy requirements,
- Taking into consideration supply costs of energy imports,
- Diversifying energy supplies and avoiding dependence on a single source or country,
- Meeting demands as much as possible through indigenous resources,

- Implementing measures for energy efficiency, preventing waste and minimizing losses in energy production, transmission, distribution, and consumption,
- Protecting the environment and public health in the process of meeting energy requirements.

3.2. Geothermal Energy Applications in Turkey

Renewable energy is an important energy source for the future development of countries. The geologists state that Turkey has a high level of renewable geothermal energy sources that can be a part of the total energy network in the country. As it is expressed in Özgener's study, "Turkey is located in the Mediterranean sector of Alpine-Himalayan Tectonic Belt and has a place among the first seven countries in the world in the abundance of geothermal resources. The share of its potential is, however, only about 2-3 %" (Özgener and Hepbaşlı. 2004). On the other hand, Aksoy states that the exploration studies have not completed, yet and suggests that reservoir studies and feasibility studies should be prepared to determine the accurate capacities of geothermal systems in Turkey (Aksoy 2003).

Geothermal energy exploration in Turkey started in 1962 with MTA, and MTA performed an inventory study on the distribution of hot water springs and potential geothermal fields over the country in cooperation with the United Nations Development Program. In this survey, geological, geophysical, geomorphologic and geochemical methods were used and number of wells drilled at prospective sites.

Furthermore, during these studies, some new areas with considerable geothermal energy potential were discovered. It was then proved that the Anatolian territory consists of a young tectonic belt and has numerous grabens, volcanic activities, hydrothermal alterations, fumaroles and more than 600 hot water resources with temperatures between 20 ºC and 100 ºC (WEB_2 2005). Since, then the following evaluation in time of geothermal energy development has been published in Özgener and Hepbasli's study as below (Özgener and Hepbaşlı 2005):

- The first geothermal well was drilled in the İzmir-Balçova geothermal field in 1963.
- The Denizli – Kızıldere geothermal field was discovered in 1963.

- The first space heating application by geothermal energy was in a hotel in Gönen-Balıkesir in 1964.
- The first geological, geochemical, and geophysical studies were carried out with the support of the United Nations Development Program (UNDP) in the Denizli – Kızıldere geothermal field in 1966.
- The investigations of geothermal energy in the country gained speed in the 1970s. A pilot power plant with a capacity of 0.5 MW_e was installed in the Denizli-Kızıldere geothermal field in 1974.
- With early 1980s, important developments have been recorded in geothermal energy utilization.
- The Aydin geothermal field was discovered in 1982.
- The first down-hole heat exchanger system was installed in İzmir-Balçova in 1983.
- The Denizli –Kizildere geothermal power plant (the only operating geothermal power plant in Turkey), was put into operation by TEAS in 1984.
- The first greenhouse heating system of 0.45 ha by geothermal energy was begun in Denizli - Kizildere geothermal field in 1985.
- In 1986, liquid CO_2 and dry ice production, which is the most well-known industrial application of geothermal energy, was started in a factory, adjacent to the Denizli –Kizildere geothermal power plant, with a capacity of 40,000 ton/year.
- The first experimental study on a geothermal (ground-source)heat pump with a horizontal loop configuration at the university level was carried out at the Mechanical Engineering Department, Middle East Technical University, Ankara, in 1986. Then, a vertical loop configuration was performed in the Solar Energy Institute, Ege University, İzmir, in 2000.
- Geothermal district heating applications started in 1987 in Turkey with the heating of 600 residences in Balıkesir-Gönen.
- After 1990, geothermal direct-use applications increased as steeply as 185% from 1990 to 1995.
- The first residential geothermal heat pump system (or ground-source heat pump system) was installed in a house in Istanbul in 1998.

In Turkey, there are fields like Denizli-Kızıldere (200-242 ºC), Aydın-Germencik (232 ºC), Çanakkale-Tuzla (174 ºC), Aydın-Salavatlı (171 ºC), Kütahya-Simav (162 ºC), Manisa-Salihli (150 ºC) and İzmir-Seferihisar (153 ºC) which are high enthalpy resources, so that electricity generation is available in these fields. On the other hand, district heating application is widespread in Turkey. The reason is %95 of the known 170 geothermal fields is low enthalpy resources which are suitable for direct use applications. As the district heating system installation started with geothermal district heating system investments in Turkey, the GDHS are operated very economical, which is the result of optimization of the geothermal resource characteristics with the consumer's characteristics, suitable design and technology.

People in Turkey usually live in apartment houses in cities and for heating, a boiler-radiator system for each building or various flat heating systems are used. The heating systems other than geothermal heating systems are designed with a 90/70 ºC temperature interval. Local or imported coal, fuel oil or natural gas is usually used in these heating systems. The prices of these fuels are determined in international market conditions. Because fuel costs are high, in some cities which have rich geothermal potential, such as İzmir, Denizli, Kırşehir, district heating systems are being converted to geothermal systems. The conversion of existing systems to GDHS can be applied easily because of following points:

- Geothermal energy projects are supported by consumers because the price of geothermal is held constant for the entire year.
- The existing heating systems are connected directly to GDHS.
- The radiator area designed according to 90/70 ºC temperature intervals, has not caused any problem at temperature intervals like 80/40, 80/45 and 70/50 ºC. This is because the radiator areas have been designed larger than necessary.
- The GDHS have low operational costs and the sales price is low when it is compared with the prices of conventional fuels.

As a result, since Turkey is an energy importing country for development, the geothermal energy becomes more crucial in the energy supply of Turkey (Kaygusuz 2004). Nowadays, Turkey is among the five leading countries in its direct use applications. Turkey has significant potential for geothermal power production, possessing one-eighth of the world's total geothermal potential. As mentioned above, much of this potential is of relatively low enthalpy that is not suitable for electricity production but is still useful for direct heating applications. Direct use of geothermal resources has expanded rapidly from space heating of single buildings to district heating, greenhouse heating, industrial usage, modern balneology and physical treatment facilities. In Turkey, about 600 prospects and 170 geothermal fields have been discovered. The total geothermal electricity generation capacity is 200 MW_e while direct use/space heating capacity is 2046 MW_t. The space heating capacities varying by the years for various locations are listed on Table 3.1.

Table 3.1.Geothermal space heating in Turkey (Kaygusuz 2004)

	Space Heating Capacity Variations By The Years (MW_t)					
Location	1996	1997	1998	1999	2000	2010
İzmir-Balçova	50	70	100	120	180	380
Balıkesir-Gönen	35	35	40	50	55	300
Denizli-Kızıldere	40	80	120	160	200	600
İzmir-Seferihisar	80	120	150	250	260	450
İzmir-Dikili	40	50	70	90	100	300
Çanakkale-Tuzla	100	200	300	380	500	900
Kütahya-Simav	80	100	120	160	200	340
Afyon	70	90	110	140	180	500
Tokat-Reşadiye	10	12	15	20	25	100
Nevşehir-Kozaklı	25	35	50	70	90	300
Manisa-Salihli	47	80	100	110	110	400
Aydın-Salavatlı	100	200	300	380	500	1,600
Others	150	175	215	260	310	600
Total	802	1,192	1,775	2,065	2,520	6,500

3.3. Geothermal Energy Applications in İzmir

İzmir has important geothermal fields within its confines. Seferihar, Balçova-Narlıdere, Dikili, Bergama, Aliğa, Çiğli–Menemen, Urla, Bayındır, Menderes and Kemalpaşa are the fields which has geothermal potential in İzmir. Within these fields, the most important one and with the largest capacity is Balçova–Narlıdere field (Toksoy and Serpen 2003).

Balçova–Narlıdere field is located along the Izmir Fault Zone. This geothermal system is a fracture zone system in which hot water ascends over an area of about 2 km along a major fracture zone associated with the Agamemnon Fault, reaching almost boiling temperatures close to surface (Serpen 2004). Nowadays, total area of 646,517

m^2 is heated in Balçova–Narlidere district heating system and the peak heating capacity has been reached up to 55 MW_t . There are plans to increase this capacity by drilling of new wells and preventing the runaway geothermal water (Toksoy and Serpen 2003).

CHAPTER 4

EVALUATION OF ATHLETES' VILLAGE GEOTHERMAL DISTRICT HEATING SYSTEM

4.1. Introduction to Conceptual Planning

"Energy has deep and broad relationships with each of the three pillars of sustainable development such as the economy, the environment and the social welfare. Economic growth requires a secure and reliable energy supply, but is sustainable only if it does not threaten the environment or social welfare (Kaygusuz 2004)."

Turkey is an energy importing nation with more than half of our energy requirements supplied by imported fuels. Air pollution is becoming a significant environmental concern in the country. Fuel prices are high to be afforded in the concern of the economical conditions. Thus, geothermal energy and other renewable energy sources are becoming attractive solution for clean and sustainable energy future for Turkey.

It is known that Turkey is the seventh richest country in the world in geothermal energy potential. In this regard, geothermal district heating systems have become the main goal of most local administrates which have geothermal potential in their cities. However, it is seen that these GDHS projects are not carried out by the application scientific geothermal development models. Because of this reason, these projects are resulted with extreme technical and economical problems. To avoid these problems, Aksoy mentioned the importance of conceptual planning studies which includes technical, economical and political feasibility studies (Aksoy 2003).

Renewable energy sources have in common some characteristics that make their development very attractive especially for local use. However, at the beginning of the project, the evaluation of the project in all aspects should be done and discussed. Geothermal energy is one of the important forms of renewable energy and some of the advantages advocating the promotion of renewable energy sources are (Goumas 1999):

- Decentralized production and use that results in a more balanced regional development,

- Independence from imported oil,
- Minimum environmental impact,
- Low operating cost,
- Rather simple technology.

There are however some limitations that have to be considered and carefully balanced against these advantages such as:

- High investment costs,
- Difficulties in matching the supply to the demand resulting in increased cost for energy storage and/or low utilization factor for the installation,
- Sometimes, the necessity for parallel use of various energy forms.

Feasibility studies are one of the initial tasks in any project to get healthy results at the end. Feasibility is the process of determining whether a project can be applied or not. Numerous factors are considered in feasibility reports for geothermal district heating systems such as “commercial administrative and organizational aspects of the project and additional qualitative concepts which are not measured by monetary units like legal problems (water and land rights, rights of ways, safety, reliability), social acceptance (public reaction to the geothermal project, either long – term or short term impacts on local economy, impact on quality of life, noise and vibration generated at heat exchanger and pumping stations and at well – head buildings), environmental impacts (water and air pollution, visual damage to terrain, damage to vegetation which includes the pipeline routes), effects on tourism and cultural factors (Erdoğmuş 2003)”. Conceptual planning reports include evaluation of all the factors mentioned above, so that decision makers can foresee the future better and avoid the failures in the project before facing with them.

4.2. Importance of Social and Economical Analysis

Social and economical analyses are crucial studies to determine the characteristics of the district in the conceptual planning studies. This is also important for developing better and sufficient geothermal district heating projects, since this kind of studies can supply data about the district before the design stage. Thus, Toksoy and Gülşen had prepared a questionnaire for the conceptual planning of Balçova System-2 project and this questionnaire seeks answers for below questions (Gülşen 2005):

1) The location of the buildings,
2) The areas of the houses,
3) Type of heating systems that has been preferred before (stove, flat heating system, electrical radiators, etc.),
4) The annual amount of fuel that is used and the cost of it,
5) For flat heating systems existence of installation project,
6) The radiator types and the radiator lengths if the flat heating system exists,
7) Existence of thermometer in the houses, therefore the indoor temperatures during the heating period,
8) Window and glass types,
9) Hot water sources and number of LPG's used for hot water sources
10) Desire of participating in the GDHS,
11) Paying the fee implied for participating in the geothermal district heating system,
12) Installing flat heating system if not existing.

4.3. Information about the Athletes' Village

İzmir have been a host for a huge organization, Universiade '05, in 2005 summer. For the athletes to stay, Athletes' Village is constructed in Limontepe at the upper part of Balçova. After the organization, these houses are planned to be sold, so that a new settlement area will be formed for İzmir. The settlement consists of 64 blocks having a total area of 97.446 m^2. The distribution of the blocks over the village and the areas of the blocks are given in Table 4.1.

Figure 4.1. View of houses with terrace in Athletes' Village

Figure 4.2. View of apartment blocks in Athletes' Village

Table 4.1 The distribution and areas of blocks in the region

Block Type	Number of blocks	Area of each block (m^2)	Total area of each block (m^2)
Block 1	8	877	7,015
Block 2	5	1,860	9,299
Block 2A	15	1,860	27,898
Block 2B	3	1,754	5,262
Block 3	7	1,543	10,804
Block 3A	10	1,543	15,435
Block 4	4	1,676	6,703
Block 5	2	1,230	2,460
Block 5A	1	1,230	1,230
Block 6	5	1,260	6,300
Block 6A	4	1,260	5,040
Total	64	-	97,446

The aim of this study is to apply the conceptual planning model which is suggested by Toksoy and Gulşen in their study (Gülşen 2005) to the geothermal district heating system in Athletes' Village. The district is designed to be heated by central heating system however this study will discuss whether it is feasible to replace the existing system with geothermal district heating system. By this way, it is planned to supply 24 hours of heating and hot water to the district, so the consumers will be more comfortable no matter what the outdoor temperature is. Also this makes the system more reliable. Also geothermal district system will have major advantages on environment impacts when it will be compared with the existing system. Since geothermal district heating systems are environment-friendly systems, the emission of sulfur dioxide, nitrous oxide and dust particles will be reduced in important amounts. Further, comparison will be made between capital and operating costs of the systems. It is known that although, the capital costs are high in geothermal district heating systems, low operating costs will make them feasible against the fuel-oil fired systems.

For Athletes' Village, geothermal energy is planned to be transmitted from Balçova, since the geothermal potential has not been found near the village. However, it has been thought that there will be well exploration studies in this area in near future, so there is still chance to find a potential in that area. The location of the well is important in geothermal district heating system designs because the most of the capital cost of the systems are composed of the cost of the transmission and distribution network. Here the distance between the well and the pumping station is about 4500 m. In this case study, it is also assumed that there is another well near village and its distance will be 1000 m. The analyses are made for these two scenarios. Also, the height difference is another problem which will affect the selection of the well pump. In the first scenario where the geothermal is transmitted from Balçova, the height difference between the well and the pumping station will be 150 m, so the well pump should have a high power to overcome this head. This will also affect the capital cost, since the capital cost of the pump will increase with increasing power demand.

4.3.1. Dwelling Areas

When the installation reports are analyzed, it is seen that there are 7 different dwelling types in the area. The areas of these dwellings are given on Table 4.2. These dwellings are not distributed in the blocks homogeneously, so their distribution over the blocks can be seen on the Table 4.3.

Dwelling areas are one of the factors that should be considered at the beginning of the conceptual planning. The information about the dwelling areas can be collected by using several methods. One of the methods is getting from the servicing maps prepared by the aerial photographs, the other one is applying the questionnaire as mentioned before and the last method is measuring the areas from the installation projects if they exist. For the Athletes' Village because the installation project has been prepared before, it is used for determining the areas. Thus, the areas are measured from the auto cad drawings.

Table 4.2. Dwelling areas form the auto cad drawings and the distribution of the dwellings over the village

Dwelling Type	Dwelling area from auto cad drawings (m^2)	Number of dwellings over the village	Total District Area (m^2)
A	147	192	28,259
B	120	192	23,040
C	105	150	15,777
D	66	200	13,220
E	123	30	3,690
F	70	162	11,340
Employee House	53	40	2,120
			97,446

Table 4.3. The distribution of dwellings in each block

	Number of Dwellings In Each Block						
Block Type	A	B	C	D	E	F	Employee House
Block 1	2	2	2	2	-	-	-
Block 2	4	4	4	4	-	-	2
Block 2A	4	4	4	4	-	-	2
Block 2B	4	4	4	4	-	-	-
Block 3	4	4	2	4	-	-	-
Block 3A	4	4	2	4	-	-	-
Block 4	4	4	2	6	-	-	-
Block 5	-	-	-	-	10	-	-
Block 5A	-	-	-	-	10	-	-
Block 6	-	-	-	-	-	18	-
Block 6A	-	-	-	-	-	18	-

4.4. Information about the Existing Heating System

In the village, central heating system is designed and it is taken under application. It is planned that the distribution of heat will be supplied from 12 boiler rooms. The location of the boiler rooms can be seen on Appendix A.

For the system design, the outdoor temperature is taken as 0 ºC and the second type operation where the boilers will work for 14 hours is chosen. The steel boilers which will work under the operation temperatures 90/70 ºC are used for the central heating system. The boiler capacities are given in Table 4.4 according to the installation reports taken from the construction site.

Table 4.4. The capacities of the boilers chosen in the installation report

Boiler Room Number	Total Capacity For That Boiler Room (kcal / h)	Capacity Of Chosen Boiler (kcal / h)	Number Of Boilers Used
1 st	504,098	250,000	2
2 nd	2,237,275	1,250,000	2
3 rd	2,130,596	1,250,000	2
4 th	2,009,834	1,000,000	2
5 th	1,455,360	800,000	2
6 th	1,962,860	1,000,000	2
7 th	1,700,088	900,000	2
8 th	1,164,288	600,000	2
9 th	2,344,111	1,250,000	2
10 th	761,019	400,000	2
11 th	1,752,342	900,000	2
12 th	1,537,411	900,000	2
Total Boiler Capacity (kcal /h)	**19,559,282**		

As it is seen on the Table 4.4, there are 12 boiler rooms in the region to supply heat to 64 blocks. Then the total boiler capacity is calculated as 19,559,282 kcal / h for the peak period. The capacities of these boilers are calculated to provide energy for heating and the hot water services.

4.4.1. Heat Losses in the Existing System

One of the initial steps of the district heating design is determining the heating loads of the system which will make the system economic or not. Over-estimating the load may cause equipment such as radiator, service pipe, control valve, etc to be chosen oversized. Therefore, the efficiencies of these equipments are related to the determination of the heating load of the system (Hong 1998). The outdoor temperature and the comfort temperatures which are desired by the society influence the heat demand of the systems mostly. The best way to determine the heat load of the system is to find out the energy consumption of the system or analyze the system from the heat loss project. In the study for Athletes' Village, the value that is determined in the installation project is checked whether it is overestimated or not by using a method suggested by Toksoy and Çanakçı. In their study, they suggested that the heat load of a standard building in Balçova can be found by using the average peak load value (which is determined at the end of their study of 40 building in Balçova by static heat loss method), 54, 9 kcal/h.m^2 (Toksoy and Çanakçı 2003).

Although the system capacity is expressed as 21 MW$_t$ in the installation report, the heating demand is find out much lower at the end of the study which is expressed above. Because of this reason, it is agreed that the heat losses of the system should be again studied by applying TS 825 standards which are expressed by MMO. At the end of this heat loss study, the problems with the existing heating system are found out as below:

- The thermal conductivities of the construction materials are calculated according to the MMO standards, but then they are multiplied by a safety factors which is unnecessary. This can be seen on the Table 4.12
- Because the central heating system is been thought for heating while heat loss calculations, the second type operation factor is chosen where the boilers will work for 14 hours. However, while the design of geothermal district heating systems, first type operation factor must be chosen where the system would supply heat for 24 hours.
- The value that is found for domestic water need in the installation project is an over-estimated value for the design of GDHS.
- In the determination of each boiler capacity, after adding the heating demand and domestic water demand, the total value is multiplied by a factor which makes the total peak demand over-estimated. This factor is stated as a safety factor for determination of the boiler in the installation report.

Table 4.5. The overall heat conductivity coefficients of the construction materials used in the village

Construction material	The overall heat conductivity coefficient for the installation report	The overall heat conductivity coefficient that is calculated
Outer wall (ponza block)	1	0.6209
Inner wall	1.85	1.25
Floor	0.7	0.61
Roof	0.70 / 0.90	0.53
Window	3.6	3.6

After these corrections on the installation project, the total peak demand is found as 11,7 MW_t including the hot water need. Therefore all the calculations for the geothermal district heating design are done according to this peak value.

4.4.2. Radiator Types

According to the installation report, only panel type radiators are used in the region. All the radiators have 600 mm height. For the central heating system, radiators are chosen to provide comfort temperatures 18 ºC, 20 ºC, 22 ºC and 26 ºC. Because the radiator lengths are more than the demand, therefore when the system will be converted to the geothermal district heating system, there won't be problems with radiator capacities. Furthermore, since the heat load density is over-estimated in the installation report, the selected radiators will supply sufficient heat capacity while working in geothermal heating system where the working temperatures are lower.

The return temperatures from the radiators in geothermal district system application are calculated and stated in the further part of this study. The radiator types and the surface areas of these radiators are given below at Table 4.6.

Table 4.6. The radiator types and the surface areas

	Total Surface Area	Percentage (%)
PKKP 600 - 18	9	0.4
PKKP 600 - 20	923	36.9
PKKP 600 - 22	1,041	41.6
PKKP 600 - 26	528	21.1

4.4.3. Indoor Temperatures

When a central heating system project is designed, the standards which are determined by the Chamber of Mechanical Engineers are used. For each room of the dwelling, there is a certain comfort temperature value which should be provided by the usage of heating system. Therefore, the indoor temperatures of the heated rooms of the village differ in a range between 18 ºC – 26 ºC.

4.4.4. Operating Costs of the Existing System

Operating costs are the expenses which are needed to provide a service for a certain project. Because some of the components of the existing heating system are planned to be used in the geothermal district heating design, the operating costs of these components are neglected. Operating costs of the existing system consists of mainly, fuel-oil costs, electricity consumption and the maintenance. However, among these costs, the most important component is the fuel-oil expenses, since the unit price of fuel-oil is high. The explanation of how these costs affect the existing system and how these costs are calculated are given below. All costs for the operating costs of the existing system are given on Table 4.8.

- **Fuel Types and Costs in the Existing System**

In the region, only fuel that will be used is planned to be fuel-oil as it is expressed in the installation reports. To determine the annual fuel oil cost for the district, first of all, the annual heating demand is calculated for Athletes' Village by distributing the peak demand over all the year by considering changing outdoor temperatures.

$$\text{Total Annual Heat Demand} = \sum_{n=1}^{365} \text{Peak demand} \times \frac{T_{comfort} - T_{out}}{T_{comfort} - T_{design}} \qquad (4.1)$$

Where,

$T_{comfort} = 22$ °C , $T_{design} = 0$ °C

When a fuel type which has a heating value of 9,700 kcal / kg and an efficiency of 0.8 is chosen, the total annual fuel demand is determined (Table 4.7). Since total annual heating demand is known, from this value, the total fuel oil needed for 966 houses is found as 2,108 tons. Then, the total annual fuel oil cost for the village can be calculated, since the unit price of fuel oil is determined as 1.16 YTL/kg on 9th of November 2005. During conversions of YTL to \$, 1 US \$ is taken as 1.353 YTL based on the average of November 2005 values.

Also, the calculations are converted to find out the fuel oil need of 100 m^2 house. Then, according to the re-calculated heat loss of the district, it is determined that 2.17 tons of fuel oil is needed which costs about 2,517 YTL (Table 4.7) to provide heating and hot water service during the heating period. However, this value is seen much higher according to the heat loss value stated in the installation project. The annual heat demand and the amount of fuel-oil that is needed for the district heating according to the installation report are stated on Table 4.8.

Table 4.7. The annual fuel oil cost of the village according to re-calculated heat loss

Total Annual Heating Demand (kcal)	16,359,566,610
Heating Value for fuel oil(kcal / kg)	9,700
Efficiency	0.8
Total Fuel oil Needed (kg)	2,108,192
Total Annual Fuel Oil Cost for Athletes' Village (YTL)	2,453,007
Total Fuel Oil Cost For 100 m2 house(YTL)	2,517

- **Electricity Consumption of the Fuel-Oil Burners**

One of the components of the operating costs for the existing system is the operating cost of fuel-oil burners. From the catalogues, it is calculated that 171,606 kW_e/year will be consumed from 24 fuel-oil burners and the electricity price that should be paid will be about $ 13,000/year.

- **Maintenance Cost**

The boilers and fuel-oil burners have to be cleaned and maintained every year, so the cost for this operation must be added to the operating costs. The estimated maintenance cost for 24 boilers in Athletes' Village is $ 4320/year.

Table 4.8. All of the operating costs for the existing system

		Operating Costs (US $/ year)
1	Fuel-Oil Cost	1,807,467
2	Maintenance	4,320
3	Electricity Consumption	13,000
Total		1,824,787

4.5. Geothermal District Heating System Design

4.5.1. Heat Load Density

Heat load density is an important parameter while determining the investment and operating costs of the geothermal district heating system. To determine heat load density, first of all heat loads of each building must be known. Heat loads of each building according to the installation project and according to the modifications can be seen on Table 4.9 and Table 4.10, respectively. Then, heat load density can be determined by dividing the heat loads of the dwellings in each city block to the areas of the city blocks. The economic availability related to heat load density (Bloomquist 2000) can be seen on Table 4.11 and the color-coded distribution of heat load density on city blocks can be seen on Figure 4.3.

Table 4.9. Heat load density according to the installation project prepared for the central heating system

Block Type	Area (m^2)	Heat loss stated (kcal/h)	Domestic water demand stated (kcal/h)	Total peak demand (kcal/h)
B1	877	71,817	66,900	138,717
B2	1,860	153,136	144,675	297,811
B3	1,543	125,896	133,950	259,846
B4	1,676	160,562	141,600	302,162
B5	1,230	90,882	93,000	183,882
B6	1,260	92,521	97,875	190,396

Table 4.10 Heat load density according to geothermal district heating system design which heat losses are modified

Block Type	Area	Modified heat loss value for GDHS design (kcal/h)	Modified domestic water demand for GDHS design (kcal/h)	Total peak demand for GDHS design (kcal/h)
B1	877	53,853	12,852	66,705
B2	1,860	116,027	27,909	143,936
B3	1,543	95,800	25,326	121,126
B4	1,676	121,551	26,208	147,759
B5	1,230	73,619	17,640	91,259
B6	1,260	67,874	19,845	87,719

Table 4.11. Economic Availability Analysis Related To Heat Load Density

Construction Type	Heat Load Density (kcal/h.m2)	Availability for district heating system
City Center, skyscrapers	Over 60	Very available
City Center, buildings with many floors	44 - 60	Available
City Center, commercial buildings with many dwellings	18 - 44	Applicable
Buildings with 2 dwellings	10 -18	Questionable
Single Houses	Less than 10	Impossible

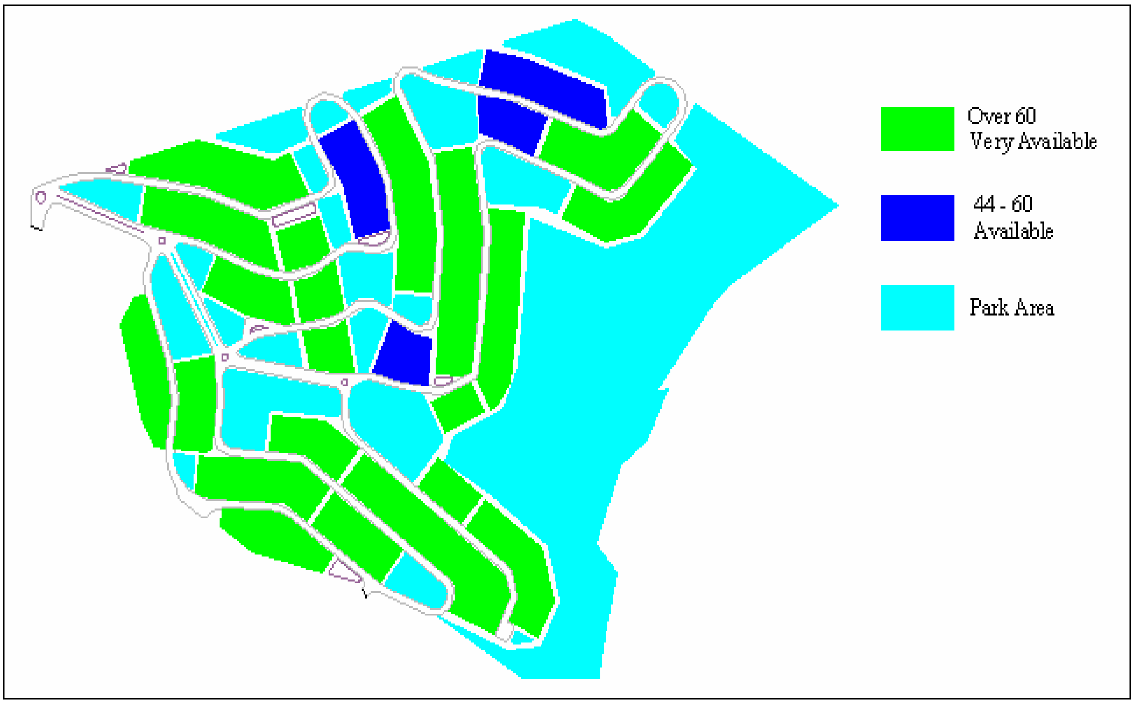


Figure 4.3. The distribution of heat load density on city blocks

4.5.2. Energy Transfer System

For GSHS design of Athletes' Village, energy is thought to be transferred in a two stage system. First of all geothermal fluid will transfer its energy to the main heat exchanger in the pumping station where it is located near the village. After it passes its energy, the geothermal fluid will return to re-injection well. Then in the city circuit, clean water will be circulated and this circulating water will reach to 12 heat exchanger rooms within the village with a certain degree of hot water. The location of heat exchanger rooms on the village can be seen on Figure A1. In each heat exchanger room, the circulating city water will transfer its energy and then the existing water from the heat exchangers will be circulated in the buildings. By a design of two stage system, the corrosion in the pipes and the effects of high pressures are planned to be prevented, since the height differences in closed systems are negligible.

4.5.3. Service Life of Materials

In geothermal systems, the components of the system are always in contact with the geothermal fluid having a high temperature and containing corrosive chemicals dissolved in the geothermal fluid. Thus, the mechanical properties of the components changes due to the time and the effects of the geothermal fluid. For a good decision making process, the characteristic of the geothermal fluid should be analyzed deeply to determine the life cycle of the materials. According to the service life of materials, replacement time cost of amortization and salvage values differ. Then, the economic analysis for the materials that is planned to be used should be done to choose the combination of materials that will minimize the total cost of the system. The main components of the geothermal district system that will be affected by the geothermal fluid are:

- Pipes
- Heat exchangers
- Pumps
- Valves

In geothermal applications, the location of the well is far from district area, so piping is very important in geothermal district heating system design. The district heating can be designed in two different ways as open loop or closed loop, so these kinds of difference in design state can change the materials of piping. In open loop systems, the geothermal fluid is directly send to the customer and the rejected or cooled water is send back to the re-injection wells. Because of this reason, in open loop systems, insulation is only needed for feeding pipes. In closed loop systems, geothermal fluid arrives to the heat exchanger and it transfers its energy to the clean water. In the circulation within the city, this clean water is used. In closed loop systems, different from the open loop designs, the return pipes are also insulated (Bujakowski 2004).

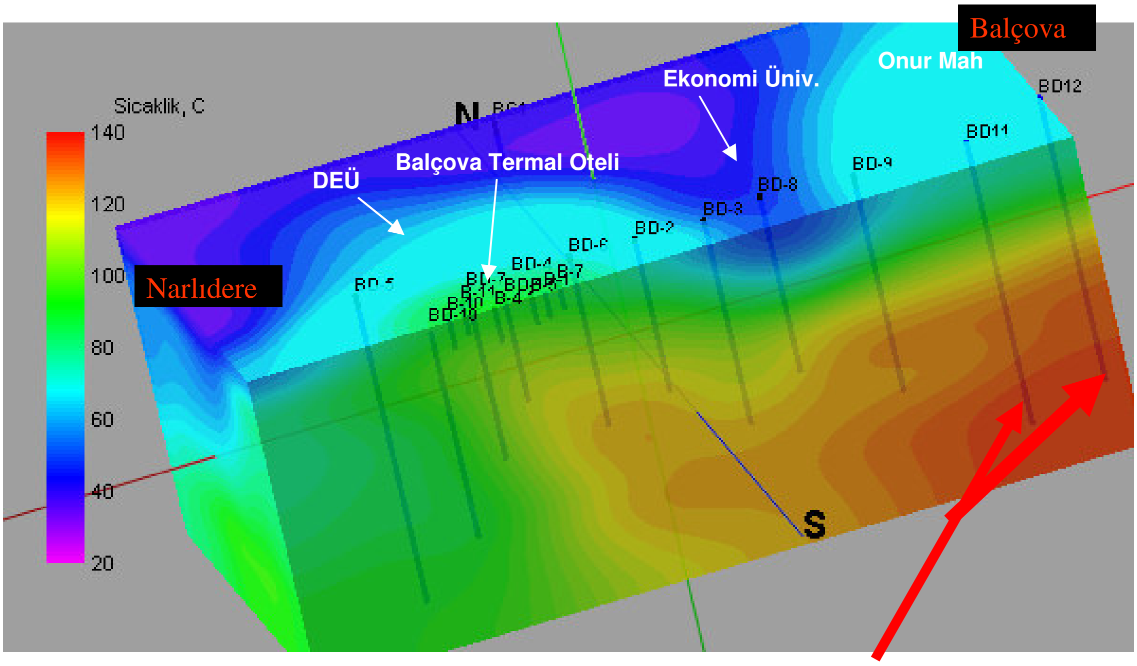
In the study, the system is designed to be closed loop, so for the geothermal and city networks, pre-insulated pipes are suggested. These kinds of pipes are mostly selected when the geothermal fluid is transferred for long distances. These pipes have three layers. One of the layers is inner pipe which is composed of steel or FRP. The second layer is the insulation material which is polyurethane. Finally, the third layer is the protecting jacket which can be composed of polyethylene, PVC or fiberglass. Also, the material can be used together as forming pre-insulated pipes, but then their combined life differs from their simple lives. Combined life of piping materials is found from the component which has the minimum life cycle in the combination. Therefore, the life cycle of this material is chosen to be the combine life of the material.

For Athletes' Village, steel pre-insulated pipes are designed to be used and the service life of these materials is given as 20 years by the manufacturers of these pipes.

4.5.4. The Characteristics of the Geothermal Well

For this study, first of all a well place is chosen to extract the geothermal fluid. The existing wells in Balçova have not been thought because it is known that they have been reached to their limits. However, it is also known that the reservoir will be develop to the east of B9 well and respected to the iterative development model for the reservoir, there are two possible well locations for the new district heating system designs. From BD - 9 well which is drilled in 2003, 135 ºC hot water with a flow rate of 100 l/s can be supplied to the system. According to the iterative development model, it is expected to get hot water at 140 ºC with a similar flow rater from the new wells which are BD - 11 and BD – 12. BD – 12 well is chosen for this study because of its shorter distance to the Athletes' Village. However, this distance is more than 4 km. Also there is another scenario which is if a geothermal potential is found near to the Athletes' Village. These two scenarios are analyzed both economically and technically in this conceptual planning study.

For the geothermal district heating system of Athletes' Village, for the peak load heating and domestic hot water need, the amount of geothermal that is needed is to be determined as 58.5 l/s as it is seen in Table 4.12.



Possible wells for the district heating system design for the Atheletes' Village

Figure 4.4. The distribution of the potential of the geothermal in Balçova (Aksoy 2005)

Table 4.12.The amount of geothermal water that should be extracted from the well

Heating peak load (kcal/h)	7,526,968
Total peak load (kcal/h)	11,000,000
T feed (ºC)	120
T return (ºC)	65
Flow-rate for heating (m^3/h)	144
Flow-rate for heating (l/s)	40
Total flow-rate (m^3/h)	211
Total peak flow-rate (l/s)	58.5

4.5.5. Operating Temperatures

The operation temperatures are determined by considering the main heat exchanger, heat exchangers for the buildings and the radiator areas. For the Athletes' Village, the operation temperatures are like below:

- **Geothermal Network**

After the geothermal fluid is extracted from B12 well with a flow rate of 58.5 l/s having a temperature of 140 ºC, the hot water is mixed with returning hot water at 65 ºC which is going to the re-injection well. The temperature of the mixture will be 120 ºC and then it will send to the pumping station which is 4500 m far from the geothermal well. In the design stage, it is seen that because the insulated pipes are used in the geothermal network, the heat loss along the geothermal network would be neglible. Then, the geothermal fluid will return to the re-injection well with a temperature of 65 ºC.

- **City Network**

The geothermal fluid will give its energy to the clean water for the circulation in the city network, so the system is designed to be a closed loop system. The clean circulating water will leave the main heat exchanger with a temperature of 110 ºC and will return back to the heat exchanger with a temperature of 60 ºC. Within the city network, the circulating hot water will arrive to the 12 heat exchanger rooms to distribute energy to the blocks.

- **In-building Temperatures**

The temperature regime in the buildings is determined by calculating the temperature regime that will give the same capacity of 90 ºC / 70 ºC from the radiators. Thus, it is seen that the appropriate temperature regime for the buildings is 85 ºC / 55 ºC.

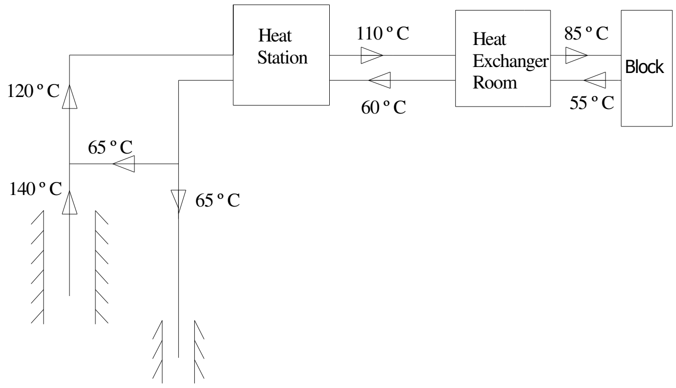


Figure 4.5. Schematic view of temperature regimes within the system

4.5.6. Location of the Pumping Station

For the Athletes' Village, two different well locations are been thought, so two different pumping station alternatives are analyzed. When the well location is determined, the economic analysis for the distribution and transmission networks can be made. Thus, the location of the pumping station is important for the geothermal district heating system design, so several factors affect the location:

- The distance of the pumping station and the geothermal well affects the investment cost because of the pipe length and selection of the piping material,
- The topographic elevation of the pumping station and the geothermal well affects the management cost because of the choice that is done for the well pump according to the elevation,
- The topographic characteristics of the city network affect the management costs of the city network circulation pumps and the network pressures.

Table 4.13. Geothermal network characteristics for pumping station alternatives

Pumping Station	Location	Geothermal Pipe Length (m)	Geothermal Network Investment Cost (US $)	Geothermal Pipe Circuit Losses (mSS)	Height Difference (m)
Alternative 1	In Balçova	4,500	1,413,400	325	150
Alternative 2	Near Athletes' Village (assumption)	1,000	290,994	91	50

There are two alternatives for the pumping stations according to the two different scenarios. In the first alternative, it is inevitable that the high pressures will be in the geothermal and city loops because of the elevation and the distance of the well location. In the second alternative, it is assumed that a geothermal potential (having the same well characteristics defined for the first alternative) is found near the village with a distance of 1000 m to the village. If this scenario exists in future, the investment cost for the geothermal network and the investment cost for the well pump will decrease which will make the project much feasible.

4.5.7. Geothermal Network

As it is mentioned above, there are two well scenarios considered for this study. In the first alternative where the well is located in Balçova, the geothermal network will be approximately 4500 m long and pre-insulated (polyurethane and polyethylene) steel pipes are chosen. The geothermal loop, the well location and the place of Athletes' Village can be seen on Figure B1. The elevation will affect the total head loss because there is about 150 m height difference between the geothermal well and the pumping station. The total head loss for the first alternative can be seen on the Table 4.14.

In the second alternative, it is assumed that the geothermal well is located near the village with a distance of 1000 m. It is thought that since the well is near the village, the elevation between the well and the pumping station will not exceed 50 m because of the topographic characteristics of the area. Since, then, the elevation will cause problem as it does in the first alternative in the determination of the total head loss of the geothermal network. In addition, the length of the geothermal network will be shorter when it is compared with the first alternative. The total head loss for the second alternative can be seen on Table 4.15.

For the Athletes' Village, the diameter of the pipes in the geothermal network are selected to be 200 mm in the first alternative by optimizing the investment cost and operating costs of the system. The selected diameters for the second alternative is again 200 mm, however this time total friction loss is much lesser than the first alternative, so the investment cost and the annual operating cost for the well pump will be lesser.

Table 4.14. The total head loss in the geothermal network for the first alternative

Flow Rate	Diameter	Velocity	Re	Friction Factor	Length	Elevation	Friction Loss Along The Distance	Total Friction Loss
Q	DN	V		f	L	H		
(m3/h)	m	m/s			m	m	mSS	mSS
211	0.200	1.86	777,708	0.0152	4.500	150	121.31	325

Table 4.15. The total heal loss in the geothermal network for the second alternative

Flow Rate	Diameter	Velocity	Re	Friction Factor	Length	Elevation	Friction Loss Along The Distance	Total Friction Loss
Q	DN	V		f	L	H		
(m3/h)	m	m/s			m	m	mSS	mSS
211	0.200	1.86	777,708	0.0152	1.000	50	29.96	91

4.5.8. City Network

The temperature regime of the city network is planned to be 110 ºC / 60 ºC. The steel pipes are taken in consideration which will stand for this regime. The investment costs and operational cost are calculated and the relation between these costs are considered while the choice of the diameters within the city network, since it is known that as the investment cost increases while the operating cost decreases. Investment costs are consist of cost of the pipe, cost of the pipe installation and the cost of the excavation. Operating cost is the sum of the cost for electricity consumption of the circulating pumps and cost of inhibitor for corrosion.

In the Figure 4.6, the relation between the electricity cost and the investment cost can be seen according to the changing pipe diameters. To find the optimum pipe diameter, investment and operating costs for the diameters between 150-300 mm are analyzed and the curves for investment cost-target head loss and the operating costs-target head loss curves are drawn on the same figure. The intersection of the two curves gives the target head loss which will make the cost minimum. Therefore, the diameters of the pipes which make total cost minimum around 29 mmSS/m target head loss in the city network are selected.

Also, another criteria which should be taken in consider is the velocity of the fluid inside the pipe. The flow velocity should be within a sensible range and in designs of Balçova district heating system, the flow velocities are below 2 m/s. Thus, in the design of the district system of Athletes' Village, this is also considered while the choice of pipe diameters. The diameters of the pipes selected for the city network and their unit prices are given in Table 4.16. The city network is shown on the auto-cad figure on Figure C.1.

Table 4.16 Selected pipe diameters and their costs for the city network

Diameter (mm)	Pipe Type	Length (m)	Unit Cost (USD / m)	Total Cost (USD)
40	St 37 Steel	366	11.49	4,204
50	St 37 Steel	64	14.80	947
65	St 37 Steel	316	18.60	5,878
80	St 37Steel	1124	23.43	26,340
100	St 37 Steel	460	34.04	15,659
125	St 37 Steel	562	43.40	24,391
150	St 37 Steel	250	50.91	12,727
200	St 37 Steel	552	70.90	39,134
			Total	**129,278**

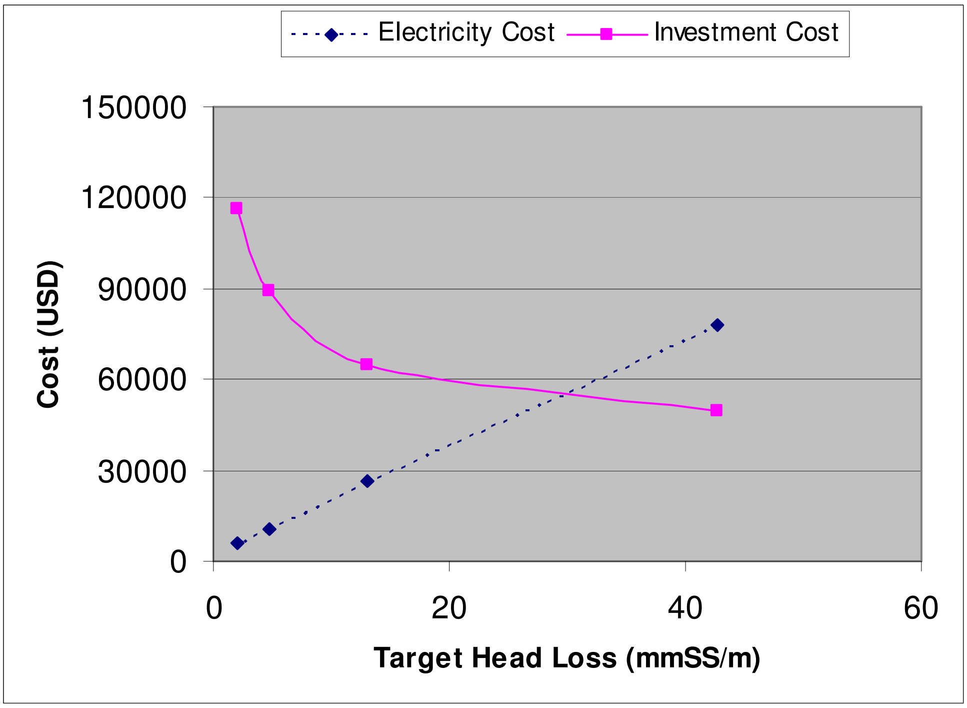


Figure 4.6 Change of investment and electricity cost with target head loss

4.5.9. Heat Exchangers

For the design of Athletes' Village, one main heat exchanger and 12 units of heat exchanger for the city distribution are selected. Plate type heat exchangers are selected for the heat transfer, since (Vestergen 2003):

- Plate type heat exchangers provide high efficiency with minimum heat transfer area,

- The materials which resist corrosion is used in economical amounts in these kind of HEX,
- They have small volume because of their compact base,
- Installation and operation of these kind of HEX are simple,
- Cleaning of all heat transfer areas can be done easily.

For the Athletes' Village, at the pumping station, there is one main heat exchanger with the capacity of 11,000,000 kcal/h and for the distribution of geothermal within the city network, the selected heat exchanger are given in Table 4.17. The plates of the heat exchangers within the city network are selected as stainless steel. However, because of the corrosive content carried by the geothermal fluid, the plates of the heat exchanger at the pumping station are selected as titanium.

Table 4.17. Capacities of heat exchanger in each heat exchanger station in the city

Heat Exchanger Station No	Capacity (KW)	Selected Plate Material
1	325.76	AISI 316
2	1,408.35	AISI 316
3	1,462.89	AISI 316
4	1,280.87	AISI 316
5	725,96	AISI 326
6	1,245.21	AISI 316
7	1,065.30	AISI 316
8	580.76	AISI 316
9	1,641.19	AISI 316
10	445.82	AISI 316
11	914.89	AISI 316
12	1,052.26	AISI 316

4.5.10. Circulation Pumps

Circulation pumps are selected according to the system characteristic from which is given in Figure 4.7 from the catalogues. The most efficient pumps, which will satisfy the conditions of 235 m^3/h flow rate and 80 m head loss during peak load, are chosen for the system design. Thus, two in-line type pumps are planned to work in parallel with efficiency about 70- 75 %. By this way, the pumps would work with a high efficiency during partial and peak load.

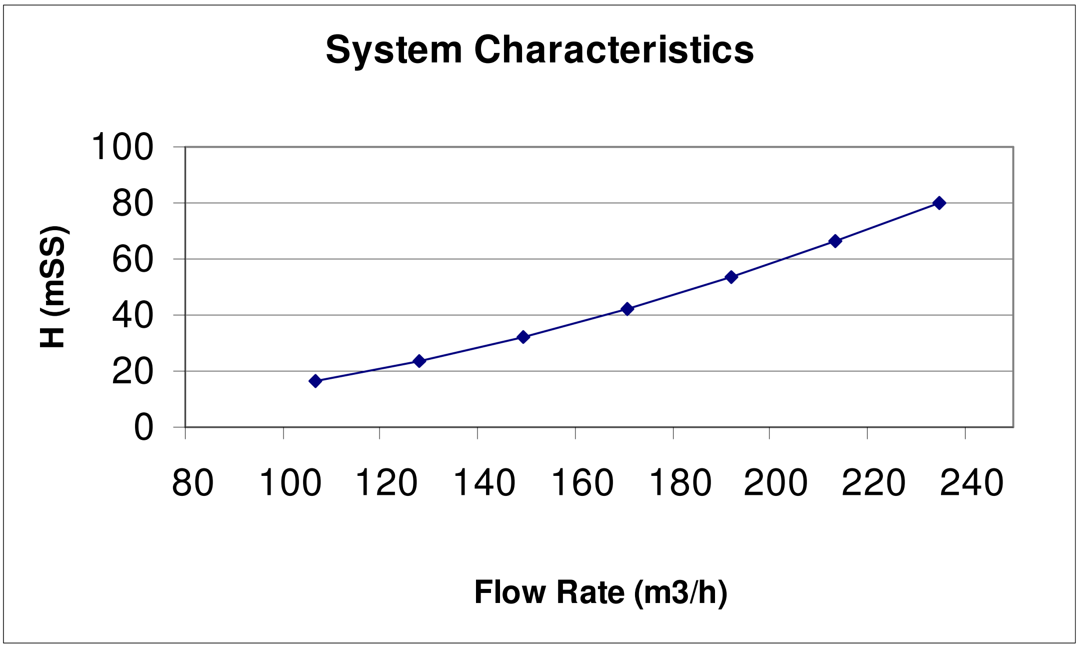


Figure 4.7 System Characteristics of the circulation pump in the pumping station

Table 4.18 System characteristics with changing outdoor temperature

Outdoor temperature	ºC	12	10	8	6	4	2	0
Flow Rate	m3/h	107	128	150	171	192	214	235
Head Loss	mSS	17	24	32	42	54	66	80

4.5.11. Efficiency of Radiators in the Buildings

Geothermal district heating systems are similar to the central heating systems however they differ from the central heating systems in some ways. The main differences are the temperature range within the buildings and the flow rate of the circulating fluid (İlken 2003).

In the Athletes' Village, the radiators are selected according to the central heating system design with boilers, so the radiators give the same capacity while working in the temperature range of 90 ºC / 70 ºC. However, it is known that these radiators will give low efficiency when the system is converted to the geothermal district heating system where the temperature range will differ from the existing system. On the below Table 4.19, the feeding and return temperatures that should be in the geothermal district heating system are calculated, so that the radiator will supply the same capacities while working in the temperature range of 90 ºC / 70 ºC. The return temperatures are calculated according to DIN standards. According to DIN standards, radiator capacity is the function of radiator temperature and the temperature of the heated space where the logarithmic temperature difference of the radiators and the heating space are defined in the below formula (Kücüka 2001).

$$Q_{calculated} = Q_0 \left[\frac{\Delta T_{lm}}{\Delta T_{lm,0}} \right]^{\frac{1}{3}} \tag{4.2}$$

Where,

$Q_{calculated}$ = The modified heat loss

Q_0 = The heat loss stated in the installation project

Also,

$$\Delta T_{lm} = \frac{85 - T_{return}}{\ln \dfrac{85 - T_{comfort}}{T_{retun} - T_{comfort}}} \tag{4.3}$$

$$\Delta T_{lm,0} = \frac{90 - 70}{\ln \dfrac{90 - T_{comfort}}{70 - T_{comfort}}} \tag{4.4}$$

Where,

$T_{comfort}$ = Desired room temperature

Table 4.19. Feeding and return temperatures of radiators in the geothermal district heating design

			Feeding Temperature (ºC)	Return Temperature (ºC)
Block 3 - A Type	Living Room (Z01)	Base Floor	85	55.97
Block1 - B Type	Bedroom (309)	Roof	85	48.46
Block 3 - C Type	Living Room (404)	4 th Floor	85	59.95
Block 2 - D Type	Bedroom (704)	Roof	85	57.74
Block 5 - E Type	Living Room (504)	Roof	85	57.02
Block 6 - F Type	Bedroom (604)	Roof	85	47.48

As it is seen on Table 4.21, the return temperatures of the radiators for different spaces vary between 48.46 - 59.95 ºC. Since, their standard average is so closed to 55 ºC, it is assumed that the return temperatures from the buildings is 55 ºC as it is stated before in the Figure 4.4.

4.6. Economics of the Geothermal System

4.6.1. Investment Costs

Investment costs are the expenses occurred before beginning of business operations. It is known that the geothermal heating projects are characterized by high investment costs when they are compared with other heating projects with fuel-oil, coal and natural gas, etc. Although, the geothermal heating projects have high investment costs, the advantages of these systems are the low operating costs because of the low marginal cost of fuel (Piwowarski 2001).

For a geothermal district heating design, all the cost of stages starting from the exploration of the geothermal reservoir to the distribution of water to the customers are the components of the investment cost for GDHS. The main components of GDHS are as preparation of the project, exploration studies for the reservoir, drilling of the geothermal well, civil engineering works (construction of roads, wellhead housing, heat exchanger and pumping stations), wellhead housing, transmission and distribution networks, heat exchangers, pumping stations, documentation, adjusting and testing.

In the district design, generally, the most important components of the investment cost are the costs for the transmission and distribution networks and the drilling of the geothermal well. The costs for transmission and distribution can form the 40 – 60 % of the total investment cost in some cases (Piwowarski 2001, Erdoğmuş 2003). In the project, it is calculated that this percentage is 54.58 % for the first alternative and it is 31.24 % for the second alternative as it is seen on Table 4.22. and Table 4.23. The transmission and distribution cost is found by taking the sum of the costs for geothermal network, city network and excavation.

For Athletes’ Village, as it is mentioned in the before sections, there are two well scenarios. The investment costs for these two scenarios are as follows on Table

4.20. and Table 4.21. The costs are taken from the related companies by proposal and also from the Balçova Jeotermal Enerji San. Tic. Ltd. Şti.

Table 4.20. The components of the investment costs according to the first scenario where the geothermal network is 4500 m

Components of the investment cost	Cost (US $)	Percentage
Drilling Wells	1,000,000	27.38
Pumps	32,559	0.89
Geothermal network	1,413,400	38.70
City Network	129,278	3.54
Well Head Construction	73,910	2.02
Pumping Station Construction	40,000	1.10
Excavation	450,628	12.34
Building Connections	25,000	0.68
Project	7,391	0.20
Heat Exchangers	94,512	2.59
Fittings	385,670	10.56
Total	3,652,348	100

Table 4.21. The components of the investment costs according to the second scenario where the geothermal network is 1000 m

Components of the investment cost	Cost (US $)	Percentage
Drilling Wells	1,000,000	50.27
Pumps	21,919	1.10
Geothermal network	290,994	14.63
City Network	129,278	6.50
Well Head Construction	73,910	3.72
Pumping Station Construction	40,000	2.01
Excavation	201,183	10.11
Building Connections	25,000	1.26
Project	7,391	0.37
Heat Exchangers	94,512	4.75
Fittings	105,068	5.28
Total	1,989,255	100

4.6.2. Operating Costs

In general, operating costs are incurred by the operation of the plant or equipment needed to provide in service. These costs can vary in years, since the unit prices of the components of the operating costs can change through years.

In the design for Athletes' Village, total cost for operating costs differs for the two different well scenarios. The difference comes from the electricity consumption of the pumps. For the first alternative, the total annual operating cost is $ 125,219. However, for the second alternative, this value is $ 110,140. All of the costs for the first alternative are listed in Table 4.30. The items that are related with the operating costs of the geothermal heating system are like below (Gülşen 2005):

- **Electricity consumption of the pumps**

Monthly electric consumption cost is one of the main items which is important to consider in the operating costs of geothermal district heating systems. The monthly electric consumption of the pumps is calculated by using the hourly temperature data for the typical year which is 1993 and the Conventional Energy Ratio (CER_0) for the optimized production (Şener 2003). Thus, the geothermal energy production would not be in peak demand all of the year.

The energy demand would change with changing outdoor temperature. Thus, the electricity consumption would change as the energy production varies in periods of the year. Conventional energy ratio is defined as the geothermal energy produced for each unit of electricity consumption. The CER_0 is calculated as 79.5 and the monthly electric consumption of the system for the first alternative for the design is calculated according to this value. The results are given in Table 4.22. For the second alternative, also costs for monthly electric consumption is calculated according to CER_0 value of 200.5 and from Table 4.23, it can be seen that these costs are much lesser when they are compared with the costs in the first alternative.

Table 4.22. Monthly electricity consumption and its cost for the first alternative

Month	Energy Production (kWh)	Energy Production according to CER_0 (kWh e)	Electricity Cost (US$)
1	4,431,038	55,736	4,124
2	4,206,285	52,909	3,915
3	3,264,820	41,067	3,039
4	1,961,061	24,667	1,825
5	944,917	11,886	880
6	92,375	1,162	86
7	94,006	1,182	88
8	87,800	1,104	82
9	300,498	3,780	280
10	660,763	8,311	615
11	2,745,927	34,540	2,556
12	3,069,469	38,610	2,857
Total	**21,858,961**	**274,955**	**22,970**

Table 4.23. Monthly electricity consumption and its cost for the second alternative

Month	Energy Production (kWh)	Energy Production according to CER_0 (kWh e)	Electricity Cost (US$)
1	4,431,038	21,615	1,599
2	4,206,285	20,518	1,518
3	3,264,820	15,926	1,179
4	1,961,061	9566	708
5	944,917	4,609	341
6	92,375	451	33
7	94,006	459	34
8	87,800	428	32
9	300,498	1,466	108
10	660,763	3,223	239
11	2,745,927	13,395	991
12	3,069,469	14,973	1,108
Total	**21,858,961**	**106,629**	**7,891**

- **Cost of personnel working in GDHS**

When the components of the operating costs are analyzed, it is seen that personnel cost has the biggest percentage on overall components. The number of personnel is assumed according to the number of personals in Balçova System-2. Since the studied system is a smaller district heating system, personnel number is reduced proportionally. It is assumed that 8 personals would be sufficient for the district heating system in Athletes’ Village. The gross salaries of these personals are re-arranged according to the information taken from the Balçova Jeotermal Enerji San. Tic. Ltd. Şti. The costs of personals in the system can be seen on Table 4.24.

Table 4.24. The costs of personnel of Athletes' Village for each month

		Number	Gross Salary (YTL)	Total (YTL)	Total (US $)
1	Operator	2	751.308	1,502.616	1110.58
2	Manager	1	1,332.745	1,332.745	985.03
3	Accountant	1	697.662	697.662	515.64
4	Maintenance Personnel	2	487.322	974.644	720.36
5	Public Relations	1	1,112.831	1,112.831	822.49
6	Servant	1	487.322	487.322	360.18
7	Administrative Committee				4,916
Total					**9,430**

- **Water consumption in the system**

The water consumption in the system is calculated by adding the water volume in city network pipes, building and pumping station heat exchangers and expansion tank. While this calculation, it is assumed that there won't be leakage problems. The volume of water in the city network components are as seen on Table 4.27. The volume in the city network is the biggest component of the water consumption in the system. The water that is needed in city network is calculated as 79 m^3. Generally, water demands by the heat exchangers are very small. In this system, it is calculated as 1.19 m^3 and the volumes of heat exchangers are listed on Table 4.26.

To calculate the overall water consumption in the system, it is thought that the system will be filled twice in a year, so the water consumption of the system for a year will be 81 x 2 = 162 m^3. Also, it is assumed that there will be water consumption by the personals and this value is assumed to be 10 liters per person, so that the total water consumption of the system will be 191 m^3. The unit price of water that is determined by IZSU is 5.7 YTL, so the cost of the water consumption is calculated as $ 804.

Table 4.25. The volume of water in city network

Diameter (mm)	Length (m)	Unit Volume (m3/m)	Total (m3)
40	183	0.00126	0.23
50	282	0.00196	0.55
65	6458	0.00332	21.44
80	3262	0.00502	16.38
100	2030	0.00785	15.94
125	1131	0.01227	13.88
150	125	0.01766	2.21
200	276	0.0314	8.67
Total			**79.29**

Table 4.26. Volumes of the heat exchangers

Placement	Capacity (kcal/h)	Number of plates	Unit volume for each plate (m3/amount)	Total (m3)
Exchanger Room	280,107	25	0.00082	0.02
Exchanger Room	1,210,959	93	0.00082	0.08
Exchanger Room	1,257,863	95	0.00082	0.08
Exchanger Room	1,101,346	83	0.00082	0.07
Exchanger Room	624,209	55	0.00082	0.05
Exchanger Room	1,070,685	81	0.00082	0.07
Exchanger Room	915,994	75	0.00082	0.06
Exchanger Room	499,367	39	0.00082	0.03
Exchanger Room	1,411,168	105	0.00082	0.09
Exchanger Room	383,334	35	0.00082	0.03
Exchanger Room	786,661	65	0.00082	0.05
Exchanger Room	904,784	73	0.00082	0.06
Pumping Station	11,000,000	128	0.004	0.51
Total				**1.19**

Table 4.27. All the components of water consumption in the system

	Volume (m3)
City network pipe volume	79.29
Building heat exchangers volume	0.68
Pumping station heat exchangers	0.51
Expansion tank volume	0.50
Total	80.97

- **Other costs**

Also, inhibitor cost, maintenance cost, cost of the chemicals, marketing costs, insurance costs, taxes, etc should be considered while the calculation of the operating costs. For example, inhibitor is needed in the production network to prevent the obstacles in flow of the geothermal water. Also, the geothermal fluid contains chemicals dissolved inside which has an affect on the system components as heat exchangers, pipes, valves, etc. These components should be checked and cleaned each year, so this will bring additional maintenance cost to the system. Thus, some chemicals like nitric acid, rock salt and NaOH are used for cleaning the heat exchangers. The cost of these chemicals should be also added to the operating costs. All of these costs can be seen on Table 4.28. These costs are calculated by interpolating the operating costs of these components in recent geothermal district heating projects according to the heating capacities of these systems.

In addition, all of the operating costs of the system for different well scenarios are showed on Table 4.29. The main difference between the operating costs of these two different scenarios is the costs for the electricity consumption.

Table 4.28. Inhibitor, chemical and maintenance costs per year

	Balçova-Narlıdere GDHS	Balçova System-2 GDHS	Athletes' Village GDHS
Heating Capacity (m2)	1,150,000	310,700	97,445
Inhibitor Cost (US $)	3,753	1,014	318
Other Chemicals (US $)	1,912	517	162
Maintenance Costs (US $)	53,417	14,432	4,526

Table 4.29. All of the operating costs for Athletes' Village considering the alternatives

		Operating Cost for Alternative 1 (US $/year)	Operating Cost for Alternative 2 (US $/year)
1	Cost of inhibitor	318	318
2	Cost of chemicals	162	162
3	Water consumption	804	804
4	Personnel Cost	75,438	75,438
5	Electricity Consumption	22,970	7,891
6	Cost of maintenance	4,526	4,526
7	Marketing cost	1,000	1,000
8	General expenditures	20,000	20,000
Total		**125,219**	**110,140**

4.6.3. Finance Model

Finance model of any district heating system can be determined after the determination of the investment and the operating costs. In all of the application of geothermal district heating system in Turkey, the investment capital of a geothermal system is covered up with the participation cost taken from the customers when they first enter the system and the monthly fixed energy cost. For the economical analysis of the system, the internal rate of return analysis is applied to the different participating costs and monthly fixed charges, which make the internal rate of return positive around 0 %, are calculated for these participating costs.

Also, after the determination of monthly fixed charges in a result of internal rate of return analysis, the net present values of these payments for 20 year period is compared with the net present value of the payments that will be done for the existing system. By this way, the conventional system and the geothermal design can be compared to their economies.

Therefore, in economical analysis, two well scenarios are considered and the finance model is determined according these two scenarios. Also another parameter taken in consideration is there will be full participation in Athletes' Village, since this will be the district heating system of the all village.

4.6.3.1. Internal Rate of Return Analysis

One of the concerns of investment projects is whether and when the money invested in a project can be recovered. Internal rate of return analysis is one of the instruments that can be applied to the project to decide if it will be recovered or not. As a definition, internal rate of return is the interest rate which is referred for project's return over a certain service life.

For Athletes' Village, while the economical analysis, the depreciation costs are also considered, since at the end of the service life, the project can be recovered. As a result of this, the monthly fixed charges, which make internal rate of return positive around % 0, are found for different participating costs varying between \$1,250- \$1,500. These charges are given in Table 4.30. Since these prices are for %0 internal rate of return, if the company takes more than these charges, then the investment will be more profitable for the investor.

Table 4.30. Monthly fixed charges for different participating costs which make IRR = 0

	The Monthly Fixed Charges for Well Scenarios (For IRR = 0)	
Participating Cost	Alternative 1	Alternative 2
1250	37	21.5
1500	36	20.4
1750	35	19.4
2000	33.5	18.3
2250	32.5	17.25
2500	31.5	16.25

4.6.3.2 Comparison with the Existing System

As it is stated in before sections, the advantage of the geothermal district heating system against the conventional heating systems is the lower operating costs. However, geothermal district systems have higher investment costs.

On Table 4.31, it can be seen that the investment cost for the existing system is much lower than the geothermal district heating, but the operating cost for that system, which includes the annual payments for fuel-oil usage, the electricity consumption of the fuel-oil burners, and he annual maintenance cost for the boilers, will be so high.

Table 4.31. Comparison between the costs of the existing heating system and GDHS

	Investment Cost ($)	Operating Cost ($)
Existing Heating System	168,713	1,824,787
GDHS – 1st Alternative	3,652,348	125,219
GDHS – 2nd Alternative	1,989,255	112,763

Also, to provide a better decision-making condition for the consumers, also the net present worth for different cost scenarios (from Table 4.30) considering a service life of 20 years, are calculated for the geothermal district design and these values are compared with the net present worth of heating with the existing system for the same time period. The interest rate for 20 years is assumed to be 8 %. The results for the costs found different well alternatives are stated on Table 4.32 and Table 4.33. Since, the annual payment for the existing system for the consumers is estimated as $1860/year from the total operating costs of the existing system, net present worth of heating with the existing system is calculated $ 18,262 when the same comfort conditions in heating with geothermal system is considered. Therefore, when this value is compared with the net present worth values calculated on below tables, the project will be also feasible for the consumers, since they will pay lower costs for the geothermal district heating.

Table 4.32. Net present worth of different cost scenarios for alternative 1

	Monthly Fixed Costs (US $) For IRR = 0 in Alternative 1					
Participating Costs (US $)	31.5	32.5	33.5	35	36	37
1,250	4,961	5,079	5,197	5,374	5,491	**5,609**
1,500	5,211	5,329	5,447	5,624	**5,741**	5,859
1,750	5,461	5,579	5,697	**5,874**	5,991	6,109
2,000	5,711	5,829	**5,947**	6,124	6,241	6,359
2,250	5,961	**6,079**	6,197	6,374	6,491	6,609
2,500	**6,211**	6,329	6,447	6,624	6,741	6,859

Table 4.33. Net present worth of different cost scenarios for alternative 2

	Monthly Fixed Costs (US $) For IRR = 0 in Alternative 2					
Participating Costs (US $)	16.25	17.25	18.3	19.4	20.4	21.5
1,250	3,165	3,282	3,406	3,536	3,653	**3,783**
1,500	3,415	3,532	3,656	3,786	**3,903**	4,033
1,750	3,665	3,782	3,906	**4,036**	4,153	4,283
2,000	3,915	4,032	**4,156**	4,286	4,403	4,533
2,250	4,165	**4,282**	4,406	4,536	4,653	4,783
2,500	**4,415**	4,532	4,656	4,786	4,903	5,033

CHAPTER 5

RESULTS AND DISCUSSION

5.1. Results and Discussion of the Conceptual Planning Study

Feasibility studies are one of the important tasks of geothermal district heating system design. Conceptual planning is the stage where the project is evaluated technically, economically and politically. Before this project, it is seen that in Turkey, this important stage of GDHS is not applied sufficiently. The only model for this study was the conceptual planning study applied by Gülşen and Toksoy for Balçova Sytem-2.

In this study, two scenarios (Table 4.13.) are considered for GDHS for Athletes' Village. First of all, it is thought that the geothermal fluid can be brought from Balçova after the drilling of new wells. It is determined that the reservoir will extend to the east according to the iterative development model and there is an expectance to obtain hot water in sufficient temperature and flow rates. If this scenario is considered, then the only disadvantage of it will be the length of geothermal network. Also, because of the elevation between the well and the pumping station, the pressure losses will be high. In this scenario, the length of the geothermal network will be 4500 m, so this long path will result with high investment cost. On the other hand, during the design stage, it is thought that there is a chance of finding a geothermal resource near the village, so it is assumed that a geothermal resource exists at a distance of 1000 m to the village and the analysis is also done for this scenario. It is prominent that second scenario is more feasible in every viewpoint. However, to establish the second alternative, further well exploration would be completed and a sufficient well, which will have sufficient temperature and flow rates, should be found near the village.

Also, the system is analyzed elaborately about the heat losses of the dwellings during the design stage to determine the heat load correctly. The determination of heat load of the system is an important task because, after all, the hot water demand from the well is determined from the heat load. In the beginning of the study, the aim was to replace the fuel-oil firing system with the geothermal district heating system, so firstly, the installation reports were analyzed. In this reports, the value determined for the system capacity was a high value, so some improvements were done to find out an available system capacity. The improvements are done on the calculated heat load in the installation reports according to MMO standards. The differences between these two systems' capacities are given on Table 4.9. and Table 4.10, respectively. Then heat load densities of the system are determined from the modified heat losses. As it is seen on the color coded heat load distribution of the system (Figure 4.3), it is feasible for all existing dwellings.

Another important task in the design is the selection of the diameters in the city network. The best way to choose the proper diameters is to apply optimization in the design. As the diameter increases, the electricity cost of the pumps decreases while the investment cost of the piping increases. Intersection point of these two curves (Figure 4.6) is the optimized value referring to the selection of the diameters. The city network is given on Appendix 3.

Furthermore, to replace the existing system with GDHS, it is planned to change boiler rooms to heat exchanger rooms and provide the distribution of hot water to the blocks from these 12 heat exchanger rooms. Because of these reason, there is no need to put a heat exchanger at each building. The locations for the heat exchanger rooms are shown on Appendix A. The calculations are done according to this design and the sufficient heat exchangers are selected for both heat exchanger rooms and the pumping station. The selected heat exchangers for the city network are listed on Table 4.16.

After determination of the system components, the investment costs and operating costs are calculated for the different well scenarios mentioned above. Also for the operating costs are calculated for the existing heating system to compare the economical feasibility of both systems. It is calculated that if the geothermal hot water is transmitted 4500 m, the investment cost of the system will be $ 3,652,348. However, this value decreases to $ 1,989,255 if a geothermal potential is found near village and it is transmitted 1000 m. Therefore, as expected the well place and the length of the transmission network will highly affect the feasibility of this design.

Finally, the comparison between the existing heating system and the geothermal district heating system is completed for their economical feasibility and a finance model for the geothermal district heating system is suggested in respect of the investment and operating costs. Because of this reason, internal rate of return analysis is applied for different participating costs ($ 1,250 – $ 2500) for both well scenarios and the appropriate operating costs are found which make internal rate of return positive around

0%. The values found vary between $ 16.25- $37 and the results are given on Table 4.30. After this analysis, the net presents worth values are determined for these cost scenarios as well as with the value for the existing system. Since, the annual fuel cost would be so high for the existing heating system; this will influence the operating costs of the existing system in great amounts. Then, it is seen that because the annual expense for existing heating is calculated about $ 1860 for a single consumer, the cost scenarios for the geothermal district heating design are feasible for the consumers.

Therefore, after this conceptual planning study, the exploration of the area for a geothermal resource should be done broadly to find a better well location near village. By this way the investment cost and the operating costs for the design would be lowered, so the consumers would be encountered with better payment scenarios if the project is decided to be applied.

CHAPTER 6

CONCLUSIONS

Geothermal energy is the Earth's interior energy. There are many application areas where this energy can be used. District heating is one of the important application areas. Geothermal district heating design is similar to the central heating system design. The only difference is the temperature regimes.

The goal of this study is to compare the existing fuel-firing heating system in Athletes' Village with the geothermal district heating system. This study was modeled after conceptual planning study prepared for Balçova System-2. In this study, the technical, economical and political phases of conceptual planning are applied to Athletes' Village. After the design stage, the price proposals for the components of the geothermal district heating system are taken from related companies. Therefore, all the factors which will affect the investment and operating costs of the design are determined. In regard of these costs, the monthly fixed charges, which make internal rate of return positive around zero, are determined and payment scenarios for different participating costs are calculated. For the first alternative of geothermal district heating design, when it is assumed that $ 1500 is taken from the consumers as a participating cost, a monthly fixed charge of $ 36 is calculated at the end of the internal rate of return analysis. For the same participating cost, $ 20.4 is found for the monthly fixed charge at the end of the economical analysis of the second alternative of the design. When the high annual fuel-oil costs are considered for the existing conventional system, these values are sensible prices for the consumers. As a result, the project seems feasible for the customers when the economies of both existing system and the geothermal district heating system are compared for the same comfort conditions.

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APPENDIX A

THE LOCATIONS OF THE HEAT EXCHANGER ROOMS

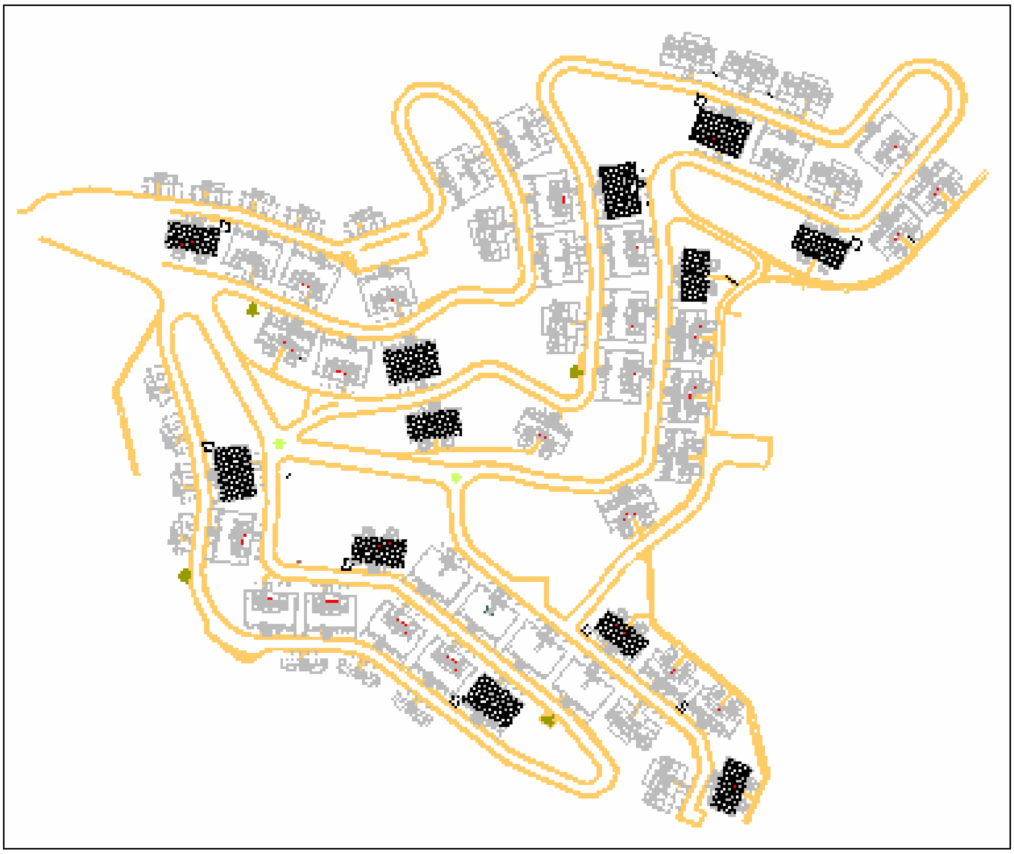

Figure A1. The Locations of the Heat Exchanger Rooms

The distribution of 64 blocks over the village area can be seen on the above figure. The hatched places are the blocks where the heat exchanger rooms are located.

APPENDIX B

THE GEOTHERMAL LOOP

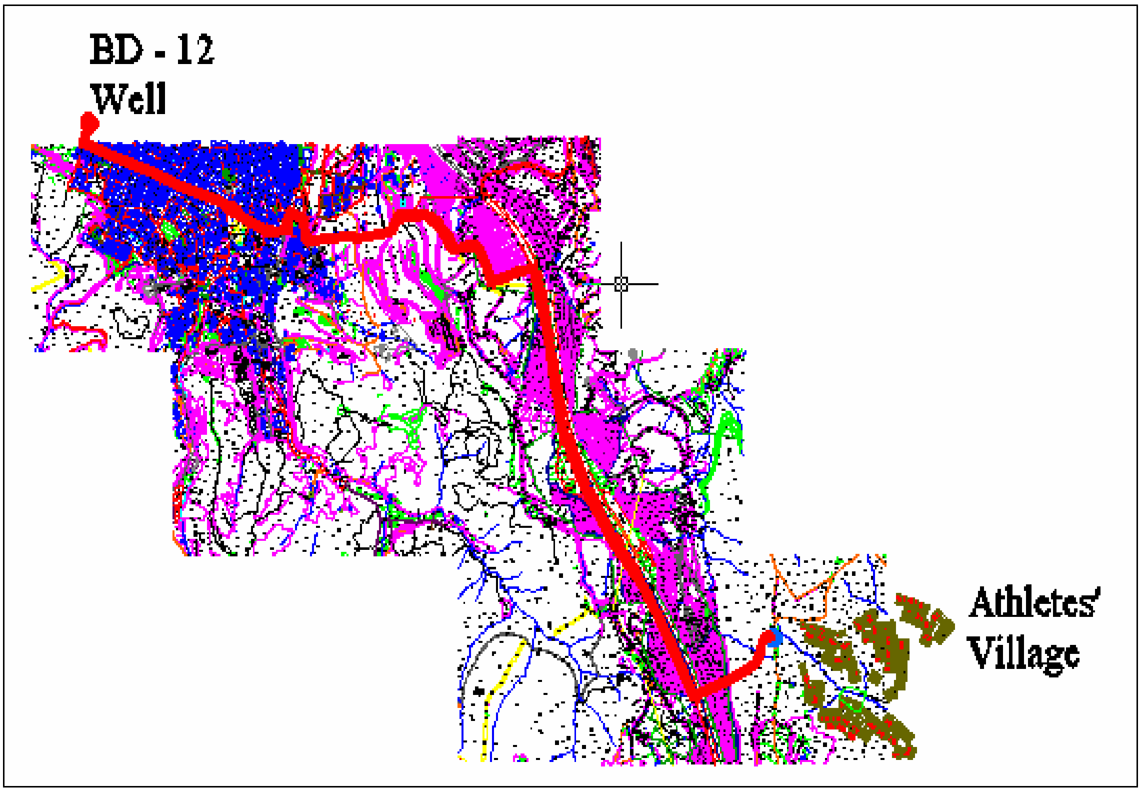

Figure B.1. The Geothermal Loop

APPENDIX C

CITY NETWORK

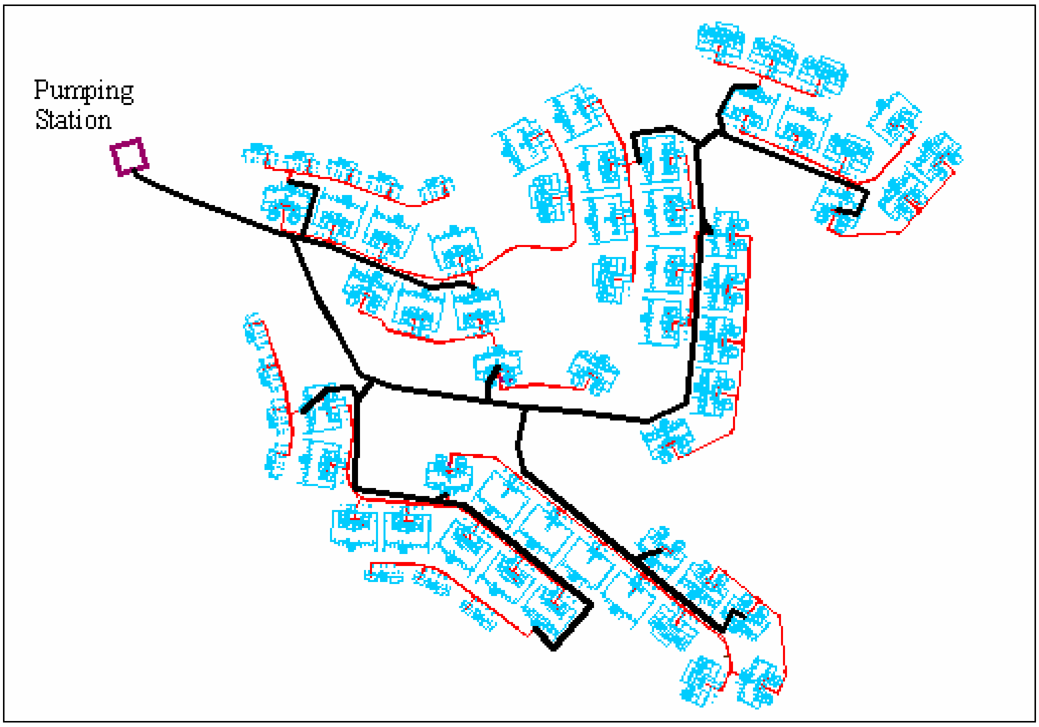

Figure C.1. City Network