PLANNING AND DESIGN OF A NEW GEOTHERMAL DISTRICT HEATING SYSTEM OF 2 X 5000 DWELLINGS IN BALÇOVA

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ABSTRACT

Conceptual planning (technical, economical and politic feasibility) of geothermal district heating systems is the most important step of these projects. In this study, a conceptual planning model developed for geothermal district heating systems is applied to the project of Balcova (Izmir) System-2 Geothermal District Heating System which is on the agenda nowadays in Balçova and the technical, economic and politic feasibilities are investigated. The city section on which the geothermal district heating system will be constructed has a maximum capacity of dwellings having an area of 391,700 m^2 and 80% of them have been built and are in use. The most important parameter that affects the economics of the geothermal district heating systems is the participation ratio of the dwellings in the district. In this study different participation ratio (between 100% and 26%), participation costs (between 1250$ and 1500$) and participation periods (2 or 5 years) are considered and the monthly fixed energy charge which will make the internal rate of return ratio approximately positive values around 0% are calculated.

ÖZ

Jeotermal bölge ısıtma sistemlerinin kavramsal planlaması (teknik, ekonomik ve politik fizibilitesi), bu projelerin en önemli adımıdır. Bu çalışmada, jeotermal bölge ısıtma sistemleri için önerilen kavramsal planlama modeli, Balçova'da(İzmir) gündemde olan Balçova Sistem-2 jeotermal enerji bölge ısıtma sistemi projesine uygulanmış ve sistemin teknik, ekonomik ve politik olabilirliği incelenmiştir. Jeotermal bölge ısıtma sisteminin uygulanacağı bölge, maksimum 3917 konut yapılaşma kapasitesine sahip olup, yapılaşmanın yaklaşık %80'i tamamlanmıştır. Bölgedeki mevcut toplam konut alanı 310.700 metrekaredir. Jeotermal bölge ısıtma sistemlerinin ekonomikliğini etkileyen en önemli faktör, bölgede yer alan konutların yapılacak olan jeotermal bölge ısıtma sistemine katılımlarının oranıdır. Çalışmada, (%100 ile %26 arasında) farklı katılım oranları, (1250 $ ile 1500 $ arasında) katılım payları ve (2 veya 5 yıl) katılım yılları göz önüne alınmış ve iç karlılık oranını sıfıra en yakın pozitif yapan aylık enerji kullanım ücretleri hesaplanmıştır.

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CHAPTER 1

INTRODUCTION

1.1. Geothermal Energy

Heat is a form of energy and *geothermal energy* is, literally, the heat contained within the Earth that generates geological phenomena on a planetary scale. Geothermal energy is often used nowadays, however, to indicate that part of the Earth's heat that can, or could, be recovered and exploited by man, and it is in this sense that we will use the term from now on (Dickson 2004).

It has been used for many centuries for different purposes such as space and water heating, cooking, and medicinal bathing. In fact, usage of geothermal energy was limited by technological improvements and man’s imagination (Dickson 2004, Lund 1998, Satman 2003). In Turkey direct utilization of geothermal energy is more common. The only indirect use of geothermal energy is in Kızıldere/Denizli, has a 20.4 MW installed capacity.

1.2. Direct Use of Geothermal Energy

Direct or non-electric utilization of geothermal energy refers to the immediate use of the heat energy rather than to its conversion to some other form such as electrical energy. The primary forms of direct use include swimming, bathing and balneology (therapeutic use), space heating and cooling including district heating, agriculture (mainly greenhouse heating and some animal husbandry), aquaculture (mainly fish pond and raceway heating), industrial processes, and heat pumps (for both heating and cooling). In general, the geothermal fluid temperatures required for direct heat use are lower than those for economic electric power generation (Lund 1997).

Most direct use applications use geothermal fluids in the low - to moderate – temperature range between 50 °C and 150 °C, and in general, the reservoir can be exploited by conventional water well drilling equipment. Low-temperature systems are also more widespread than high-temperature systems (above 150 °C), so they are more likely to be located near potential users. In the US, for example, of the 1350 known or identified geothermal systems, 5% are above 150 °C, and 85% are below 90 °C (Muffler 1979). In fact, almost every country in the world has some low-temperature systems, while only a few have accessible high-temperature systems, which also describes the situation in Turkey.

Traditionally, direct use of geothermal energy has been on a small scale by individuals. More recent developments involve large-scale projects, such as district heating, greenhouse complexes, or major industrial use. Heat exchangers are also becoming more efficient and better adapted to geothermal projects, allowing use of lower temperature water and highly saline fluids. Heat pumps utilizing very low-temperature fluids have extended geothermal developments into traditionally non-geothermal countries such as France, Switzerland and Sweden, as well as areas of Midwestern and eastern US. Most equipment used in these projects is of standard, off-the-shelf design and need only slight modifications to handle geothermal fluids (Gudmundsson 1985).

The Lindal diagram (Gudmundsson 1985), named for Baldur Lindal, the Icelandic engineer who first proposed it, indicates the temperature range suitable for various direct use activities (Figure 1.1). Typically, the agricultural and aquacultural uses require the lowest temperatures, with values from 25 °C to 90 °C. The amounts and types of chemicals such as arsenic and dissolves gases such as boron, is a major problem with plants and animals, thus heat exchangers are often necessary. Space heating requires temperatures in the range of 50 °C to 100 °C, with 40 °C useful in some marginal cases and ground source heat pumps extending the range down to 4 °C. Cooling and industrial processing normally require temperatures over 100 °C. The leading user of geothermal energy, in terms of market penetration, is Iceland, where more than 90% of the population enjoys geothermal heat in their houses from 27 municipal district heating services, and 44% of the country's total energy use is supplied by direct heat and electrical energy derived from geothermal resources (Ragnarsson 1995).

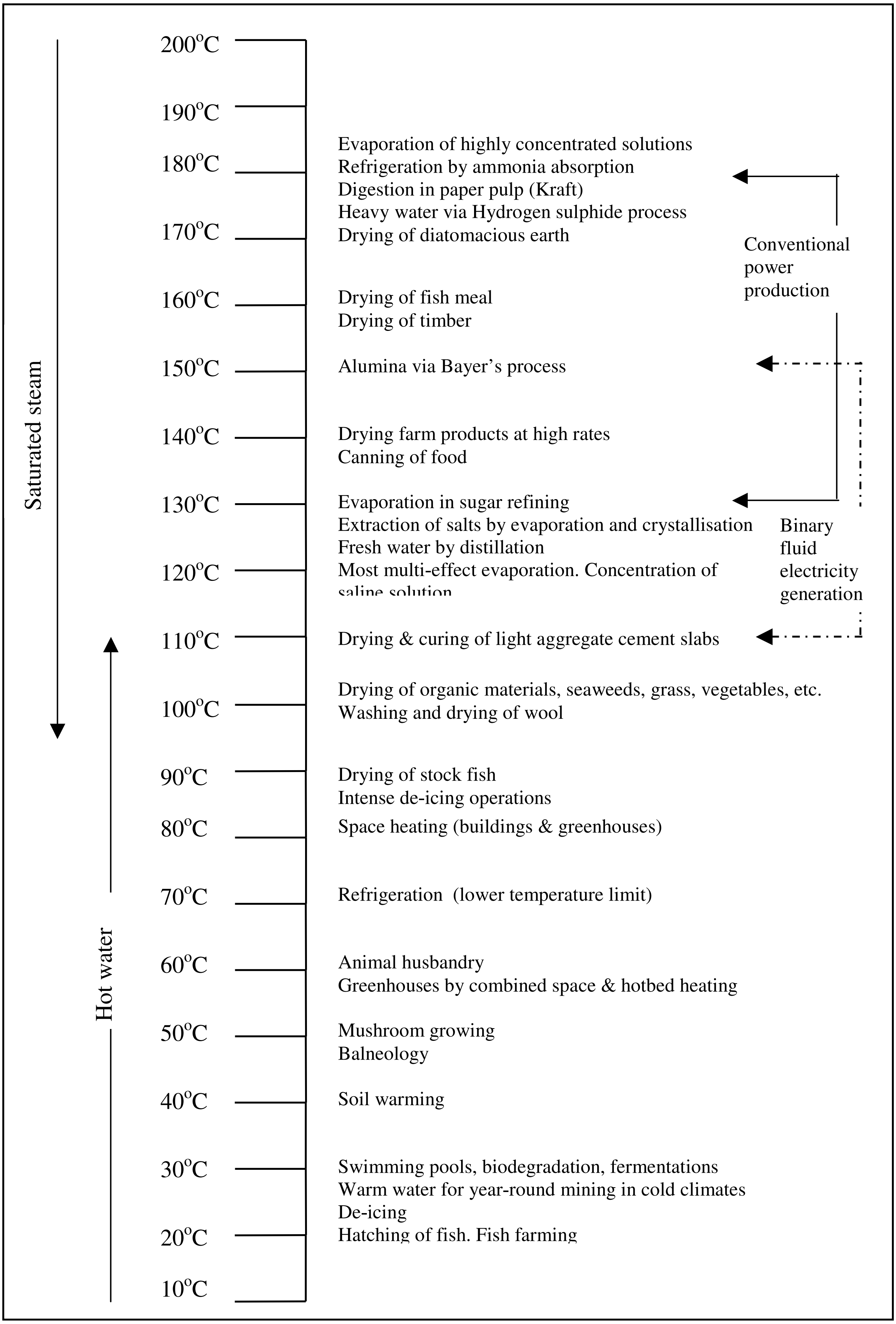


Figure 1.1: Lindal diagram.

1.2.1. Geothermal District Heating

District heating networks are designed to provide space heating to multiple consumers from a single well or from multiple wells or fields. The development of geothermal district heating, led by the Icelanders, has been one of the fastest growing segments of the geothermal space heating industry and now accounts for over 75% of all space heating provided from geothermal resources worldwide (Bloomquist 2003). District heating is also one of the oldest uses of geothermal energy, and the first documented geothermal district heating system was built in Chaudes-Aigues Cantal, France, in the 14th century. In the United States the Boise, Idaho system known originally as the Artesian Hot and Cold Water Company, and later 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 2000a). The early-to-mid 1980’s saw the development of several geothermal district heating systems in Idaho, Oregon, New Mexico and California, and although growth of these systems has continued, no new system has come online since the late 1980’s due to extremely low natural gas prices. Iceland has, however, been the leader in the development of geothermal district heating systems, and as of today over 97% of the inhabitants of the capital city of Reykjavik enjoy the benefits of geothermal district heating, and more than 90% of the total Icelandic population can now count on geothermal district heating to supply their space heating as well as domestic hot water heating requirements. 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 30% of the residences in the country, by 2010 (Lund 2002). Several other countries have also developed or are developing geothermal district heating systems, including Hungary, Romania, France, Poland, China and even Sweden and Denmark, to name just a few.

A geothermal district energy system consists of one or multiple wells or in some cases even well fields, well and circulating pumps, transmission and distribution network, central or individual building heat exchangers, peaking/backup boilers and/or thermal storage units and/or a system for metering. For the individual consumer the equipment is identical or similar to that used in individual systems, i.e. either a forced air or radiant system.

Because of the scale of most geothermal district energy systems, wells will generally be drilled with a larger diameter and often much deeper than would be cost–effective for an individual system. Depths in excess of several hundred meters are not uncommon in many systems, and some may be as deep as 2000–3000 meters or more. Most wells will require pumping to bring the water to the surface and to maintain the pressure so as to prevent release of gases that could result in scale formation. Both line-shaft and downhole pumps have been used successfully, with line-shaft pumps being preferred in the USA and downhole pumps more common in Europe and much of the rest of the world. New advances in downhole pump technology may pave the way for their use in higher temperature wells, and their ability to be used in deviated wells makes them an obvious choice in many applications. Most pumps are equipped with variable speed drives in order to conserve energy as well as better meet system requirements.

Transmission and distribution network generally consists of pre-insulated and jacketed welded steel. However, asbestos cement and some other types of nonmetallic (composite) pipe have been used successfully in some applications. The use of nonmetallic pipe is more common in cooling systems than in heating systems and the pipe may or may not be insulated. Both above and below ground transmission lines are common, but distribution network is almost always underground except in unique applications such as military bases where above-ground piping appears to be much more acceptable and common. When placed above ground, expansion loops and anchors are a necessity and supports must be constructed so as to allow for some pipe movement. When installed below ground, direct burial is preferred and most common. Expansion is accounted for through the use of compensators, and prestressing the pipe before burial is all the more common. During construction, it is vital that welds be thoroughly checked and that water-tight mufflers are used wherever jointing occurs. Once the muffler is installed, the area between the pipe and the muffler jacket is insulated. The muffler ensures that no water will reach the carrier pipe and result in severe external corrosion. In direct buried systems the use of a leak detection system is often employed and although not necessary, the minimal extra cost is often considered to be very inexpensive insurance. A three-wire leak detection system may also double as a signal mechanism for the control of valves. In some below-ground applications, covered trenches or utilidors are used, but their extra cost is very difficult to justify in most applications. They do, however, provide easy access to the piping system for maintenance and repair. If the pipes are installed in covered trenches or utilidors, proper anchors and expansion loops must be used to minimize stress. In larger systems, valves and bypasses are used to reduce the risk of water hammer when flow velocity must be rapidly changed or stopped. Meters installed at critical locations provide data used by operations personnel, and increasingly common real-time computer models provide operators with not only enhanced system control but also reduced operation costs by controlling and optimizing the system to best meet load. Savings may occur in electricity to drive pump motors, in the fossil fuels used in peaking and in a reduction in required personnel (Bloomquist 2002).

Although geothermal fluids may be circulated through the transmission and distribution system directly to end users and in some cases even through the end users' heating system, the practice is discouraged due to the serious risk of corrosion and/or scaling. The heat in the geothermal fluid is instead most often transferred to a secondary fluid for transmission and/or distribution. Such systems are often referred to as closed loop systems. The geothermal fluid is then 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. The heat transfer is accomplished through a heat exchanger. Although both tube-and-shell and plate-and-frame exchangers have been successfully utilized, plate-and-frame exchangers command the largest part of the market due to their better heat transfer characteristics (lower approach temperatures), relatively compact size and the ease with which they can be expanded and cleaned (Figure 1.2).

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. However, despite the availability of thermal storage facilities, meeting peak demand solely with geothermal requires substantially increased flows-sometimes as much as a 50% increase in flow with increased demand. This is because the temperature that is available from the geothermal wells cannot be varied, forcing system operators to meet peak only by increasing flow. Peaking can be provided by fossil fuel boilers, electric boilers or heat pumps. Meeting peak solely by increasing geothermal flow also requires a substantial over-sizing, by 40–60%, of the transmission and/or distribution piping network. Alternatively, peak can be met by varying temperatures while holding flow constant. Since, in an idealized load duration curve, peak demand occurs only 3-5% of the time, the penalty suffered from using fossil fuels to meet peak demand is easily offset by the savings that can be achieved by limiting the number of production and injection wells and the cost savings that result from optimizing (i.e. minimizing) the diameter of the transmission and distribution piping networks. Incorporation of peaking into 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%. Reducing the pipe diameter not only reduces capital cost but also results in savings from reduced thermal losses during a base load system operation (Bloomquist 2003).

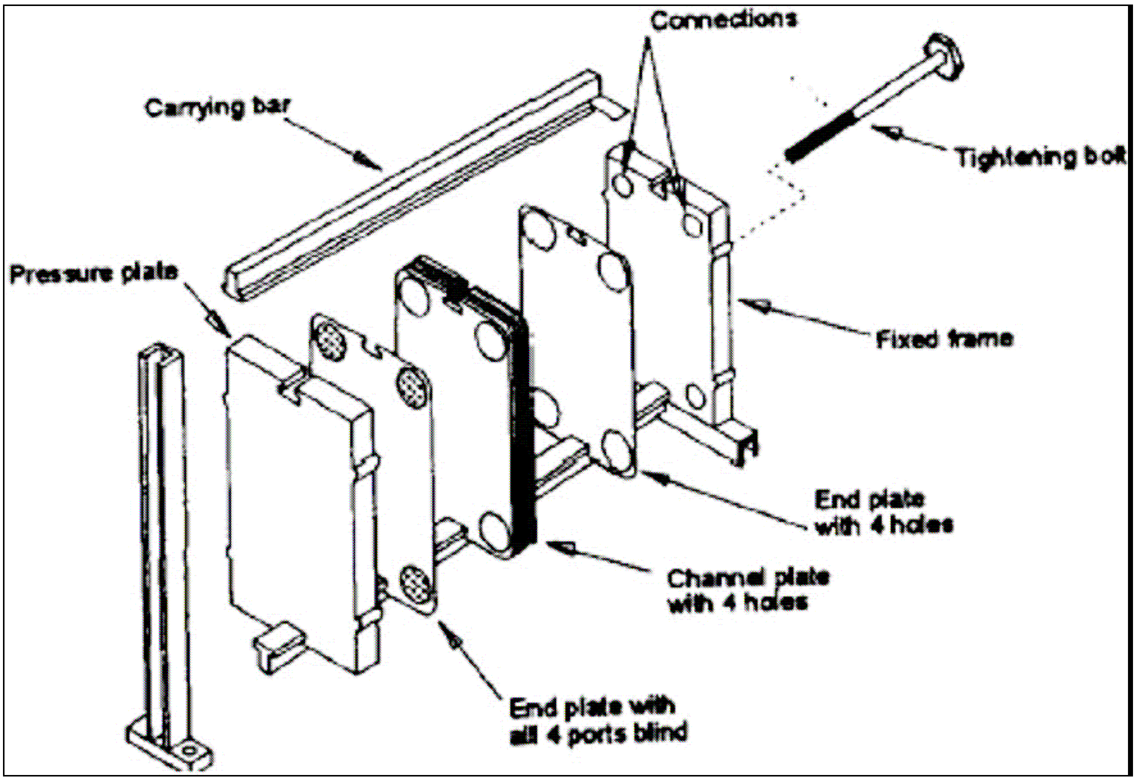


Figure 1.2: Plate and frame heat exchanger.

End users of a district energy system may be connected directly to the distribution network with system distribution fluids circulated directly through the user's HVAC system or 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. Generally users are connected through a plate-and-frame heat exchanger. In some systems, where de-ionized water is circulated through the distribution networks, the heat exchanger may be eliminated and the system circulating fluids carried directly to the in-building equipment. In-building equipment is most common in room radiators, but in the United States forced air or ceiling or floor radiant heat is in common use. Heat exchangers are often a requirement in multiple-storey buildings where additional pumping is required and/or where liability issues preclude direct connections.

Most district energy systems utilize some sort of metering of energy consumption for billing purposes, although some systems use a flat-rate approach based on billing on a per square meter of conditioned space or flow basis. In the case of flat-rate billing on the basis of flow, flow limiters are installed that 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 remotely monitorable may also provide real-time data for system operation as well as eliminating the personnel needed for meter reading and billing, and updating databases and system maps.

CHAPTER 2

DISTRICT HEATING SYSTEMS

2.1. District Heating Systems

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 have to be designed with utmost care (Valdimarsson 2003).

District heating system (DHS) distributes thermal energy from a central source to residential, commercial, and/or industrial consumers for use in space heating, water heating, and/or process heating. The energy is distributed by steam or hot chilled water lines. Thus, thermal energy comes from a distribution medium rather than being generated on site at each facility (ASHRAE 2000).

Whether the system is a public utility or user owned, such as a multi-building campus, it has economic and environmental benefits depending somewhat on the particular application. Political feasibility must be considered, particularly if a municipality or governmental body is considering a DHC installation. Historically, successful district heating systems have had the political backing and support of the community.

District heating systems are best used in markets where the thermal load density is high and the annual load factor is high. A high load density is needed to cover the capital investment for the transmission and distribution system, which usually constitutes most of the capital cost for the overall system, often ranging from 50 to 75% of the total cost for district heating systems.

District heating systems consist of three primary components; the central plant, the distribution network, and the consumer systems. The central source or production plant may be any type of boiler, a refuse incinerator, a geothermal source, solar energy, or thermal energy developed as a by-product of electrical generation.

The second component is the distribution or piping network that conveys the energy. The piping is often the most expensive portion of a district heating or cooling system. The piping usually consists of a combination of preinsulated and field- field-insulated pipe in both concrete tunnel and direct burial applications. These networks require substantial permitting and coordinating with nonusers of the system for right-of-way if not on the owner's property. Because the initial cost is high, it is important to optimize use.

The third component is the consumer system, which includes in-building equipment. When steam is supplied, it may be used directly for heating; it may be directed through a pressure-reducing station for use in low-pressure (0 to 100 kPa) steam space heating, service water heating, and absorption cooling; or it may be passed through a steam-to-water heat exchanger. When hot water or chilled water is supplied, it may be used directly by the building system or isolated by a heat exchanger.

2.2. Benefits of District Heating

"In order for district energy to become a serious alternative to existing or future individual heating and/or cooling systems, it must provide significant benefits to both the community in which it is operated and the consumer who purchases energy from the system. In addition, it must provide major social benefits if federal, state, or local governments are to offer the financial and/or institutional support that is required for successful development" (Lienau 2000).

2.2.1. Benefits to Society

If it is to endorse district energy, society must be convinced that district energy will provide an overall net socio-economic benefit in comparison to other thermal supply options. Such a determination must be based on a thorough evaluation of many factors including environmental, economic and employment impacts.

District energy fuel flexibility, coupled with the availability to incorporate indigenous sources of renewable resources such as geothermal, represents an important motivation for district energy development. This ability to use indigenous resources translates directly into a reduction, a reliance on foreign imports and related strategic vulnerability, and an improvement trade imbalance.

District energy can have major impacts on the environment by significantly reducing overall air emissions. Since the need for individual heating and/or cooling systems will be substantially reduced by providing thermal energy from a central source that can more easily control emissions, the emission of sulfur dioxide, nitrous oxide, and dust particulates, will be substantially reduced. For example, if the district heating system relies upon a fossil fuel cogeneration plant, the overall energy efficiency of the plant can increase from approximately 35 to 80%, thus emissions per unit of energy produced will be decreased by 50-60%. If the district heating system can utilize renewable energy such as geothermal or waste heat, emission levels can be even further decreased.

Economic impacts of district heating can range from economic revitalization projects to a major incentive for industrial growth. District energy can often be either a catalyst for, or an adjunct to, urban or neighborhood renewal projects as a central part of a coordinated infrastructure and financial assistance package. It can also provide economic incentives to existing or new industries that are able to increase revenues by selling thermal energy to the district system and at the same time reduce the cost associated with waste heat disposal.

In a less direct but economically as attractive manner, district heating systems result in hundreds of thousands or even millions of dollars of investment in local economics and generate substantial tax revenue. Employment benefits from district system include not only temporary and permanent jobs created from system construction and operation and from retrofitting building systems to be compatible with the district heating system, but also from industrial growth. On a boarder scale, employment opportunities will also be created in the industries that supply equipment used to construct district heating systems.

2.2.2. Community Benefits

A modern district heating system is a useful selling point in retaining and attracting business to a community. District heating can become a catalyst for urban revitalization by providing a reliable, economically-competitive energy source. Systems often allow for the use of energy resources indigenous to the community that cannot be used for other purposes while at the same time providing increased protection from regional or even international energy market fluctuations and ultimately providing for greater economic stability (ASHRAE 2000).

Additional benefits may include: a cleaner environment that makes the community a more desirable place to live, and increased employment opportunities that ultimately result in improving the local tax base. A community-operated district heating system may also become a significant source of income for the community.

2.2.3. Customer Benefits

Local residents, businesses, and industrial customers may receive the greatest benefit from a modern district heating system. Not only do they reap the benefits of all other members of the community, but also the direct benefit of a stable, economically attractive energy supply. Some industries may not only benefit from the reduced energy cost, but may also find a new source of revenue by selling waste energy to the district heating system, and at the same time, reduce operating costs associated with waste heat disposal.

Many customers will, however, receive additional benefits from being connected to a district heating system. These may include:

- Reduced operation costs since a subscriber installation is, in most cases, practically maintenance free
- Safety of operation due to reduced fire hazards as a result of eliminating the need for fuel delivery or fuel storage on the premises
- Potentially lower insurance rates due to the reduced fire hazard
- More space for other purposes because internal floor space previously devoted to heating equipment will no longer be required and can be rededicated to revenue producing uses
- Increased reliability because district heating systems usually consist of several production units and can, thus, provide substantial backup capability.

2.3. Design of District Heating Systems

A district heating system enables the communal power utilities to use heat rejected from industrial processes or from electrical power generation. Heat from unconventional energy sources can also be used, such as natural gas, geothermal energy.

The sole purpose of a district heating system is to supply adequate heat to its consumers. The consumer uses heat to maintain indoor temperature at a reasonably constant level and counter for building heat loss to the surroundings, and for preparation of domestic hot tap water. The benefits of this method of energy distribution are possibilities of centralized heat generation with an associated economy and a low load on the environment.

The most fundamental classification criterion for district heating systems is the type of system heat generation. The most common method of heat generation for district heating in Western Europe 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 district heat system. The heat is distributed to the consumers through a closed loop network, where the hot water is pied to each consumer in the supply network, cooled down by the heat consumer, piped back to the boiler in the return network and re-heated.

The minimum operational demands for a district heating system are:

- Sufficient pressure difference between supply and return pipe at every consumer connection
- Maximum line pressure does not exceed the design value
- Water inlet temperature by every consumer is sufficiently high
- Water temperature in the secondary and tap water system must not exceed a safety limit set for inhabitants and equipment
- Sufficient reliability
- The design and operational policies for a district heating system have to ensure that the operational demands can be fulfilled under normal operation.

The main cost factors of a district heating system are (Valdimarsson 2003):

- Capital costs
- Pumping costs
- Maintenance

- Heat and water loss in the distribution system

2.3.1. Central Plant

The central plant may include equipment to provide heat only, cooling only, both heat and cooling, or any of these three options in conjunction with electric power generation. In addition to the central plant, small so-called satellite plants are sometimes used in situations where a customer's building is located in an area where distribution piping is not yet installed (ASHRAE 2000).

2.3.2. Heat Production

Fire-tube and water-tube boilers are available for gas/oil firing. If coal is used, either package-type coal-fired boilers in small sizes (less than 2.5 to 3 kg/s) or field-erected boilers in larger sizes are available. Coal-firing underfeed stokers are available up to a 4 to 4.5 kg/s capacity; traveling grate and spreader stokers are available up to 20 kg/s capacity in single-boiler installations. Larger coal-fired boilers are typically multiple installations of the three types of stokers or larger, pulverized fired or fluidized bed boilers. Generally, the complexity of fluidized bed or pulverized firing does not lend itself to small central heating plant operation.

2.3.3. Auxiliaries

Numerous pieces of auxiliary support equipment related to the boiler and chiller operations are not unique to the production plant of a DHS and are found in similar installations. Some components of a DHS deserve special consideration due to their critical capture and potential effect on operations (ASHRAE 2000).

Although instrumentation can be electronic or pneumatic, electronic instrumentation systems offer the flexibility of combining control systems with data acquisition systems. This combination brings improved efficiency, better energy management, and reduced operating staff for the central heating plant. For systems involving multiple fuels and/or thermal storage, computer-based controls are indispensable for accurate decisions as to boiler and chiller operation.

Boiler feed water treatment has a direct bearing on equipment life. Condensate receivers, filters, polishers, and chemical feed equipment must be accessible for proper management, maintenance, and operation. Depending on the temperature, pressure, and quality of the heating medium, water treatment may require softeners, alkalizers, and/or demineralizers for systems operating at high temperatures and pressures.

Equipment and layout of a central heating plant should reflect what is required for proper plant operation and maintenance. The plant should have an adequate service area for equipment and a sufficient number of electrical power outlets and floor drains. Equipment should be placed on housekeeping pads.

2.3.3.1. Expansion Tanks and Water Makeup

The expansion tank is usually located in the central plant building. To control pressure, either air or nitrogen is introduced to the air space in the expansion tank. To function properly, the expansion tank must be the single point of the system where no pressure change occurs. Multiple, air-filled tanks may cause erratic and possibly harmful movement of air through the piping. Although diaphragm expansion tanks eliminate air movement, the possibility of hydraulic surge should be considered. On large chilled water systems, a makeup water pump generally is used to makeup water loss. The pump is typically controlled from level switches on the expansion tank or from a desired pump suction pressure.

A conventional water meter on the makeup line can show water loss in a closed system. This meter also provides necessary data for water treatment. The fill valve should be controlled to open or close and not modulate to a very low flow, so that the water meter can detect all makeup.

2.3.3.2. Emission Control

Environmental equipment, including electrostatic precipitators, baghouses, and scrubbers, is required to meet emission standards for coal-fired or solid-waste-fired operations. Proper control is critical to equipment operation, and it should be designed and located for easy access by maintenance personnel.

A baghouse gas filter provides good service if gas flow and temperature are properly maintained. Because baghouses are designed for continuous on-line use, they are less suited for cyclic operation. Heating significantly reduces the useful life of the bags due to acidic condensation. The use of an economizer to preheat boiler feedwater and help control flue gas temperature may enhance baghouse operation. Contaminants generated by plant operation and maintenance, such as wash-down of floors and equipment may need to be contained.

2.3.4. Distribution Design Considerations

Water distribution systems are designed for either constant flow (variable return temperature) or variable flow (constant return temperature). The design decision between constant or variable volume flow affects;

I. Selection and arrangement of the chiller(s),
II. Design of the distribution system,
III. Design of the customer connection to the distribution system.

Unless very unusual circumstances exist, most systems large enough to be considered in the district category are likely to benefit from variable flow design (ASHRAE 2000).

Constant flow is generally applied only to smaller systems where simplicity of design and operation are important and where distribution pumping costs are low. Chillers are usually arranged in series. Flow volume through a full-load distribution system depends on the type of constant flow system used. One technique connects the building and its terminals across the distribution system. The central plant pump circulates chilled water through three-way valve controlled air-side terminal units. Balancing problems may occur in this design when many separate flow circuits are interconnected.

Constant flow distribution is also applied in-building circuits with separate pumps. This arrangement isolates the flow balance problem between buildings. In this case, the flow through the distribution system can be significantly lower than the sum of the flows needed by the terminal if the in-building system supply temperature is higher than the distribution system supply temperature. The water temperature rise in the distribution system is determined by the connected in-building systems and their controls.

In constant flow design, chillers arranged in parallel have decreased entering water temperatures at part load; thus, several machines may need to run simultaneously, each at a reduced load, to produce the required chilled water flow. In this case, chillers in series are better because constant flow can be maintained through the chilled water plant at all times, with only the chillers required for producing chilled water energized. Constant flow systems should be analyzed thoroughly when considering multiple chillers in a parallel arrangement because the auxiliary electric loads of condenser water pumps, tower fans, and central plant circulating pumps are a significant part of the total energy input.

Variable flow design can improve energy use and expand the capacity of the distribution system piping by using diversity. To maintain a high temperature differential at part load, the distribution system flow rate must track the load imposed on the central plant. Multiple parallel pumps or more commonly, variable-speed pumps can reduce flow and pressure, and lower pumping energy at part load. Terminal device controls should be selected to ensure that variable flow objectives are met. Flow-throttling (two-way) valves provide the continuous high return temperature needed to correlate the system load change to a system flow change.

Systems in each building are usually two-pipe, with individual in-building pumping. In some cases, the pressure of the distribution system may cause flow through the in-building system without in-building pumping. Distribution system pumps can provide total building system pumping if the distribution system pressure drops are minimal and the distribution system is relatively short-coupled (1000m or less). To implement this pumping method the total flow must be pumped at a pressure sufficient to meet the requirements of the building with the largest pressure requirement. If the designer has control over the design of each in-building system, this pumping method can be achieved in a reasonable manner. In retrofit situations where existing buildings under different ownerships are connected to a new central plant, coordination is difficult and individual building pumps are more practical.

When buildings have separate circulating pumps, hydraulic isolating piping and pumping design should be used to assure that two-way control valves are subjected only to differential pressure established by the in-building pump. When in-building pumps are used, all series interconnections between the distribution system pump and the in-building must be removed. A series connection can cause the distribution system return to operate at a higher pressure than the distribution system supply and disrupt flow to adjacent buildings. Series operation often occurs during improper use of three-way mixing valves in the distribution to building connection.

In very large systems, a design known as distributed pumping may be used. Under this approach, the distribution pumps in the central plant are eliminated. Instead, the distribution system pumping load is borne by the pumps in the user buildings. In cases where the distribution network piping constitutes a significant pressure loss (system covering a large area), this design allows the distributed pumps in the buildings to be sized for just the pressure loss imposed at that particular location. Ottmer and Rishel (1993) found that this approach reduces the total chilled water pump power by 20-25% in very large systems. It is best applied in new construction where the central plant and distributed building systems can be coordinated.

Usually, a positive pressure must be maintained at the highest point of the system at all times. This height determines the static pressure at which the expansion tank operates. Excessively tall buildings that do not isolate the in-building systems from the distribution system can impose unacceptable static pressure on the distribution system. To prevent excessive pressure in distribution systems, heat exchangers have been used to isolate the in-building system from the distribution system. To ensure reasonable temperature differentials between supply and return temperatures, flow must be controlled on the distribution system side of the heat exchanger.

In high-rise buildings, all piping, valves, coils, and other equipment may be required to withstand high pressure. Where system static pressure exceeds safe or economical operating pressure, either the heat exchanger method or pressure sustaining valves in the return line with check valves in the supply line may be used to minimize pressure. However, the pressure sustaining/check valve arrangement may over pressurize the entire distribution system if a malfunction of either valve occurs.

2.3.5. Design Guidelines

Guidelines for plant design and operation include the following (ASHRAE 2000):

- Variable-speed pumping saves energy and should be considered for distribution system pumping.

- Limit the use of constant flow systems to relatively small central chilled water plants.
- Larger central chilled water plants can benefit from primary/secondary or primary/secondary/tertiary pumping with constant flow in central plant and variable flow in the distribution system. Size the distribution system for a low overall total pressure loss. Short-coupled distribution systems (1000m or less) can be used for a total pressure loss of 60 to 120 kPa. With this maximum differential between any points in the system, size the distribution pumps to provide the necessary pressure to circulate chilled water through the in-building systems, eliminating the need for in-building pumping systems. This decreases the complexity of operating central chilled water systems.
- All two-way valves must have proper close-off ratings and a design pressure drop of at least 20% of the maximum design pressure drop for controllability. Commercial quality automatic temperature control valves generally have low shutoff ratings; but industrial valves can achieve higher ratings.

2.3.6. Hydraulic Considerations

Although the distribution of a thermal utility such as hot water encompasses many of the aspects of domestic hot water distribution, many dissimilarities also exist; thus the design should not be approached in the same manner. Thermal utilities must supply sufficient energy at the appropriate temperature and pressure to meet consumer needs. Within the constraints imposed by the consumer's end use and equipment, the required thermal energy can be delivered with various combinations of temperature and pressure. Computer-aided design methods are available for thermal piping networks (Bloomquist 1999). The use of such methods allows the rapid evaluation of many alternative designs.

2.3.6.1. Water Hammer

The term water hammer is used to describe several phenomena that occur in fluid flow. Although these phenomena differ in nature, they all result in stresses in the piping that are higher than normally encountered. Water hammer can have a disastrous effect on a thermal utility by bursting pipes and fittings and threatening life and property.

In steam systems, water hammer is caused primarily by condensate collecting in the bottom of the steam piping. Steam flowing at velocities 10 times greater than normal water flow picks up a slug of condensate and accelerates it to a high velocity. The slug of condensate subsequently collides with the pipe wall at a point where flow changes direction. To prevent this type of water hammer, condensate must be prevented from collecting in steam pipes by the use of proper steam pipe pitch and adequate condensate collection and return facilities.

Water hammer also occurs in steam systems due to rapid condensation of steam during system warm-up. Rapid condensation decreases the specific volume and pressure of steam, which precipitates pressure shock waves. This form of water hammer is prevented by controlled warm-up of the piping. Valves should be opened slowly and in stages during warm-up. Large steam valves should be provided with smaller bypass valves to slow the warm-up.

Water hammer in hot water distribution system is caused by sudden changes in flow velocity, which causes pressure shock waves. The two primary causes are pump failure and sudden valve closures. Preventive measures include operational procedures and special piping fixtures such as surge columns.

2.3.6.2. Pressure Losses

Friction pressure losses occur at the interface between the inner wall of a pipe and a flowing fluid due to shear stresses. In steam systems, these pressure losses are compensated for with increased steam pressure at the point of steam generation. In water systems, pumps are used to increase pressure at either the plant or intermediate points in the distribution system.

2.3.6.3. Pipe Sizing

Ideally, the appropriate pipe size should be determined from an economic study of the life-cycle cost for construction and operation. In practice, however, this study is seldom done due to the effort involved. Instead, criteria that have evolved from practice are frequently used for design. These criteria normally take the form of constraints on the maximum flow velocity or pressure drop. Noise generated by excessive flow velocities is usually not a concern for thermal utility distribution systems outside of buildings. For steam systems, maximum flow velocities of 60 to 75 m/s are recommended. For water systems, Europeans use the criterion that pressure losses should be limited to 100 Pa per meter of pipe. Recent studies indicate that higher levels of pressure loss may be acceptable and warranted from an economic stand-point (Bohm 1988, Koskelainen 1980, Phetteplace 1989).

When establishing design flows for thermal distribution systems, the diversity of consumer demands should be considered (for example, the various consumers' maximum demands do not occur at the same time). Thus, the heat supply and main distribution piping may be sized for a maximum load that is somewhat less than the sum of the individual consumers' maximum demands. For steam systems, Geiringer (1963) suggests diversity factor of 0.8 for space heating and 0.65 for domestic hot water heating and process loads. It is also suggested that these factors may be reduced by approximately 10% for high-temperature water systems. Werner (1984) conducted a study of the heat load on six operating low-temperature hot water systems in Sweden and found diversity factors ranging from 0.57 to 0.79, with the average being 0.685.

2.3.6.4. Network Calculations

Calculating the flow rates and pressures in a piping network with branches, loops, pumps, and heat exchangers can be difficult without the aid of a computer. Methods have been developed primarily for domestic water distribution systems (Jepsson 1977, Stephenson 1981). These may apply to thermal distribution systems with appropriate modifications. Computer-aided design methods usually incorporate methods for hydraulic analysis as well as for calculating heat losses and delivered water temperature at each consumer. Calculations are usually carried out in an iterative fashion, starting with constant supply and return temperatures throughout the network. After initial estimates of the design flow rates and heat losses are determined, refined estimates of the actual supply temperature at each consumer are computed. Flow rates at each consumer are then adjusted to ensure that the load is met with the reduced supply temperature, and the calculations are repeated.

2.3.7. Thermal Considerations

Three thermal design conditions must be met to ensure satisfactory system performance:

I. The “normal” condition used for life-cycle cost analysis determines appropriate insulation thickness. Average values for the temperatures, burial depth, and thermal properties of the materials are used for design. If the thermal properties of the insulating material are expected to degrade over the useful life of the system, appropriate allowances should be made in the cost analysis.

II. Maximum heat transfer rate determines the load on the central plant due to the distribution system. It also determines the temperature drop, which determines the delivered temperature to the consumer. For this calculation, the thermal conductivity of each component must be taken at its maximum value, and the temperatures must be assumed to take on their extreme values, which would result in the greatest temperature difference between the carrier medium and the soil or air. The burial depth will normally be at its lowest value for this calculation.

III. During operation, none of the thermal capabilities of the materials (or any other materials influenced thermally by the system) must exceed design conditions. To satisfy this objective, each component and the surrounding environment must be examined to determine whether thermal damage is possible. A heat transfer analysis may be necessary in some cases.

The conditions of these analyses must be chosen to represent the worst-case scenario from the perspective of the component being examined. For example, in assessing the suitability of a coating material for a metallic conduit, the thermal insulation is assumed to be saturated, the soil moisture is at its lowest probable level, and the burial depth is at its maximum value. These conditions, combined with the highest anticipated pipe and soil temperatures, give the highest conduit surface temperature to which the coating could be exposed.

Heat transfer in buried systems is influenced by the thermal conductivity of the soil and the depth of burial, particularly when the insulation has low thermal resistance. Soil thermal conductivity changes significantly with moisture content; for example Bottorf

(1951) indicated that soil thermal conductivity ranges from 0.14 W/(m.K) during dry soil conditions to 2.16(W/m.K) during wet soil conditions.

CHAPTER 3

DESIGN OF GEOTHERMAL DISTRICT HEATING SYSTEMS

3.1. Geothermal Unique Technical Design Considerations

Geothermal district energy systems present the developer with some uniquely difficult design considerations that are seldom if ever found by developers of other district energy systems (Lienau 2000).

Both the nature of the geothermal resource, e.g., the potential for scaling and/or corrosion, and locational constraints can dramatically affect design, component selection, and operational strategy.

In its most simplified form, a geothermal system will consist of a production well or wells, including, if needed, pumps, a transmission and distribution network, and a means of disposing of the geothermal fluid, e.g., surface disposal or reinjection. In this case, the geothermal fluid is supplied directly to the consumer's end use equipment. The advantage is minimum capital cost, simplicity of design, minimum cost to the end user, and simplicity of operation. The disadvantages include high potential for corrosion and/or scaling in the transmission and distribution network as well as the customer's end use equipment; inability to vary distribution temperature, therefore requiring that both peak demand and back-up must be supplied by the geothermal system; and, if surface disposal is employed or injection is at a considerable distance from the production area, an inability to maintain reservoir pressures and potentially fluid volumes.

A slight variation on the above design would be to install heat exchangers at each individual consumer. This provides a high level of protection for the consumers in building equipment, but will add cost, although those costs may be offset by reductions in maintenance of the in-building system. This type of system is employed by the Oregon Institute of Technology (OIT) in Klamath Falls, Oregon, and has proven to be highly successful and extremely cost effective. The installation of heat exchangers was a design change after 10+ years of operation where the geothermal fluids were circulated through the user's in-building equipment. Back-up and peaking for the OIT system is provided through the use of three wells, of which only one is needed to meet base load demand, and a second for peak requirements, always leaving a third well for back-up.

A more common is to separate the geothermal fluids form the circulating loop through the use of a plate and frame heat exchanger prior to transmission or, at a minimum, prior to distribution. Once having passed through the heat exchanger, the spent geothermal fluid is either injected back into the reservoir or disposed of at the surface. The primary advantage is to avoid potential for corrosion or scaling resulting from the circulation of the geothermal fluid. A second major advantage is the ability to site injection wells at an optimum distance from the production wells without the need for an extensive and potentially costly return line. Disadvantages include a slightly more complex system, cost of the primary heat exchanger, and the continued requirement to meet both peaking and back-up requirements with the geothermal fluid. Depending upon the demands of the system and the volume and temperature of the geothermal fluids available, peak demand may require up to twice as many wells as is required for base load supply, and transmission and distribution pipelines may have to be up to 30 percent larger than if peak demand could be met through increases in send-out temperature rather than strictly through increased flow..

The addition of peaking and back-up boilers and potentially thermal storage to the above system design greatly enhances flexibility of design and operation, minimizes the number of production and injection wells required, minimizes transmission and distribution pipeline diameters, and adds security of operation due to the availability of fossil-fueled or electric back-up. Although the boiler will, in all likelihood, require the availability of fossil fuel and possible fossil fuel storage, operating cost will not be greatly affected as the boiler will not be expected to be used more than 5 to 15 percent of the time, although it may meet 50 percent or more of the peak demand.

For larger systems, incorporation of a primary heat exchanger to separate the geothermal fluids from the distribution loop and inclusion of fossil fuel peaking and back-up boiler should always be given serious consideration both as a means of minimizing capitol expenditure and as a means of ensuring maximum possible operational flexibility and system security.

If the geothermal resource area is located at some distance from the district energy service area, the cost of a transmission piping loop required to transmit the geothermal fluid to and from the service area may be excessively expensive. In such cases, consideration should be given to instead using a single transmission pipe through which heated surface water or near surface, non-geothermal groundwater is used as the heat transmission medium. A second primary heat exchange could then be accomplished at the service area prior to distribution or the transport medium could be used as the distribution medium as well. Incorporation of storage and fossil fuel boilers to meet peak demand could significantly reduce the required diameter of both the transmission and distribution piping system, minimizing capital cost. The transport medium would then be rejected to some surface water source or injected. Because the temperature of the rejected water will be significantly above the ambient temperature of the receiving water, the risk for significant thermal pollution must be carefully considered and mitigation measures adopted where ever necessary. Consideration of long-distance transmission would only be justified where the customer base justifies the added cost associated with constructing the transmission pipeline.

In Reykjavik, Iceland, heated non-geothermal water is transported some 30 km from the Nesjavellir field through a 900 mm transmission pipe to the outskirts of the city where both storage and fossil fuel-fired peaking is available.

Material selection is also a major consideration in the design of a geothermal district energy transmission and/or distribution system. The corrosiveness or high potential for scaling of many geothermal fluids requires that at least some consideration be given to the use of nonmetallic pipe. When available, asbestos concrete was an ideal choice but, unfortunately, is no longer available. Polybutelene and reinforced fiberglass are other possible choices, although both have temperature limitations. Ductile iron is another possible choice, but concerns related to the nature of the mechanical joints make it less than ideal. In its least expensive form, ductile iron is uninsulated, causing concern related to heat loss and possible environmental unacceptability. In most situations, the preferred alternative, at least for large diameter transmission and distribution piping, is preinsulated, jacketed, welded steel pipe with insulated and sealed mufflers at the joints. In smaller diameter, many of the preinsulated and jacketed, nonmetallic, flexible piping systems, primarily available from Europe, should be given careful consideration. The flexibility and nonmetallic nature of the piping system could make it the ideal solution for use in many geothermal systems, especially if the geothermal fluids are used as the distribution medium. Even when the geothermal fluid is not distributed, these flexible piping systems can considerably reduce the cost of installing the distribution network.

Although seldom given serious consideration, geothermal can also serve as a basis for providing cooling, either as a separate district cooling service or as an adjunct to district heating service. Thermally-activated absorption equipment may be located in a central plant and distribution of chilled water provided through a district distribution system or located at each individual user with thermal energy provided through the heat distribution system. Another alternative would be to use centrally-located, steam-driven, centrifugal chillers if the geothermal fluid temperature is adequate for steam production. The turbine drive of a binary system could also serve as a means to drive centrifugal chillers. Incorporation of storage can greatly improve the economics of most cooling systems because of the ability to schedule production during nonpeak power periods. Because cooling is often of greater economic value than heating, where ever cooling is needed and geothermal fluids of adequate temperature are available, it should be evaluated.

3.2. Capabilities of an Ideal District Energy Model

In determining the technical and economic feasibility of a new geothermal district heating system, the key questions are;

- What are the actual building loads; when do these loads occur; and what are the heating load densities of a given area?
- What are the best technical solutions for providing heating production, e.g., is the system based on cogeneration or trigeneration with excess steam; are there waste heat streams from industry that can be incorporated?
- Do daily or seasonal electrical rate schedules or other factors encourage or even necessitate the inclusion of storage?
- Will the system require multiple production plants or can all of the equipment be located in a central facility?
- What is the planned build-out of the system; will it be constructed in phases; what is the likely penetration rate based on marketing surveys?
- What is the economic trade-offs in terms of production cost and varying send-out temperatures vs cost of the distribution network?

- What is the most economical routing for the distribution system, taking into account the placement of existing utility services and opportunities to use existing pathways, e.g., through basements or below-ground parking garages?
- How should the distribution system be laid out to provide maximum operational security and customer assurance?
- How economics are affected by using various piping materials, flow rates, and/or send-out and return temperature?
- Are there tax incentives or utility programs that can improve the economics of a system that accomplish certain policy or operational goals?
- What financing options are available and how can multiple financing options be packaged to obtain the most cost-effective package?

3.3. Applications in Turkey

The use of medium temperature (30-150 °C) geothermal resources as a heat source in Turkish district heating systems has been accelerating since 1980's. Considering the geothermal district heating projects, which are in the phase of conceptual planning and construction, it is obvious that geothermal energy is being started to use widely for the heating purposes in the next decade. Following cities own district heating systems:

- Balçova-Narlıdere (İzmir)
- Simav (Kütahya)
- Kırşehir
- Kızılcahamam (Ankara)
- Kozaklı (Nevşehir)
- Afyon
- Sandıklı (Afyon)
- Diyadin (Ağrı)
- Gönen (Balıkesir)
- Salihli (Manisa)

In addition to these district heating systems, several district heating systems are in planning or construction phase. Moreover constructed systems have been expanding each year (Toksoy 2001).

Although there are many district heating systems in Turkey none of those systems had a feasibility phase, or the feasibility studies conducted in the related area are covering just a few number of issues which a feasibility study should have. Because of this reason at least for the city of İzmir a regulatory draft named "Geothermal Energy Regulations for the City of İzmir (Draft)" was prepared and it covers the whole subject starting with exploration and ending with construction phase.

3.3.1. The Geothermal Energy Regulations for İzmir (Draft)

In these regulations there is a part related to the district heating applications and in this section that part is going to be discussed. In the Draft for geothermal district heating systems following documents are asked:

1. The region plan
2. Well characteristics
3. Physical and chemical properties of the geothermal fluid
4. Population density
5. Nationalization or usage permissions
6. Climatic data
7. System developing profile
8. Seasonal heat load
9. Heat load density based on peak load
10. Heat load factor
11. Meeting the peak load requirements
12. The minimum heat load for the system operating properly
13. Fluid flow rates
14. Working temperatures
15. Thermal design of the system
16. The agreements done by the consumers
17. Application project
18. Costs
19. Feasibility study
20. Timetable of the project
21. Legal permissions for the application

With these documents Draft forces the applicant to make a full study to design and plan the district heating system. It should be noted that the applicant also will benefit from these studies. Although the district heating systems in Turkey are designed and owned by the municipalities the system constructions are adjudicated and private companies complete the systems' construction in the name of municipalities. So they have to make a study for being able to offer a price. And the study they should do is well summarized with the above headings listed. Without completing any of those studies the company can also be damaged economically. Although this Draft is introduced for the city of İzmir it should be argued and applied for the whole country in a very short time.

CHAPTER 4

DESIGN OF SYSTEM-2 GEOTHERMAL DISTRICT HEATING SYSTEM

4.1. Introduction to System-2

Although qualitatively aren't defined properly, Turkey has many geothermal energy resources and besides the traditional spa applications, in recent 10-15 years many cities have geothermal district heating system (GDHS) projects on their agenda. These projects that are the subject to use Turkey's own geothermal energy resources in regional heating systems have a great lack of materializing the stages of conceptual planning properly as well as other problems (Toksoy 2001). By foreseeing the usage of reservoirs of which the characteristics aren't properly defined and completing technical and economical analysis with the rough data, these projects passes through the planning stage: Results are the geothermal district heating systems with extreme technical and economical problems faced by the owner and operator (Aksoy 2003, Şener 2003a, Erdoğmuş 2003a, Toksoy 2003a). Although in recent years some technical and administrative standards have been developed (Serpen 2001) these haven't turned into an obligatory statute.

The very first step of the geothermal district heating system projects is conceptual planning (Aksoy 2003) which includes technical, economical and political feasibility like the other systems (ASHRAE 2000). Completion of conceptual planning which is sensitive to the known characteristics and possible improvements of the reservoir and economic parameters (such as participation ratio and cost) can lead to make best decisions for the investment. Otherwise, risky investments can be encountered.

The aim of this study is to apply the developed conceptual planning model (Toksoy 2003b) to the geothermal district heating system called System-2 which is planned to use the same reservoir with the existing system[i] with a new pumping and control center and to discuss the results.

Due to lack of necessary information about the geothermal reservoir and especially of the financial resource (potential users) taken into account in Turkey, some uncertainties appear for evaluation of technical and economic possibility of geothermal district heating system projects. Searching for technical and economical possibility with deterministic methods become impossible on the contrary to the examples in the literature but it is suggested to use stochastic approaches as seen in a research done for electricity production using geothermal energy (Goumas 1999). In this study the conceptual planning model developed by Toksoy and Şener (2003) for geothermal district heating systems is applied and the uncertainties in the financial model (participation ratio, participation cost, and monthly fixed energy charge) were overcome by parametric approach using different scenarios.

In the projects of geothermal district heating systems, financing the investment by the geothermal energy users is a widespread model in Turkey. However at the beginning of the projects the participation ratio, participation cost and monthly fixed energy charge for the energy users that accommodate in the district where the geothermal heating system will be constructed are unknown parameters. Another uncertainty is participation calendar of the conventional energy users into the geothermal system; in other words the time history of total number of the dwellings integrated in the geothermal district heating system. However, in this research by observing the existing geothermal district heating systems, different scenarios are introduced for participation ratios, participation cost and participation period. For all of these scenarios the monthly fixed energy charge making the internal rate of return (IRR) value positive nearest to zero is calculated. Naturally, results are a large interval of choice for the investors. In the district where the project will take place, a public survey determining the economical preferences of the potential users as suggested by the applied conceptual planning helps to narrow the interval of choice and making the most economical investment possible.

According to the results of the analysis; for 20 years of system life with the participation cost of $1250, monthly fixed energy charge of $20, it is possible to reach

[i] Balçova-Narlıdere(İzmir) Geothermal District Heating System

positive IRR values, down to the 50% and %59 participation ratio with the average well cost and with the cost of recently drilled BD-9 well, respectively.

Balçova System-2 GDHS is a sub-system which will be integrated to Turkey's the biggest geothermal district heating system called Balçova-Narlidere GDHS (Hepbaşlı 2003)). The district heating system was installed in 1999-2000 and with drilling new wells and rehabilitation of existing ones, the production of geothermal fluid and re-injection flow rate are increased and in parallel to these improvements system capacity is also increased. The total heated spaces in square meters per each heating season and projection for the 2004-2005 is given in Table 4.1. As seen; the system enlarged 103.7 % from 1999-2000 heating season to 2003-2004 heating season. With joining of Air Force Complex and System-2 this increase will reach to 245%. Another increase that is not given in the Table 4.1 is the greenhouses, which are heated using return water from heating system (re-injection fluid). Almost 100 acres greenhouse area is within the system and the development of this application is among the foresights of the system management.

Table 4.1. The development of heating capacity of Balçova - Narlıdere Geothermal District Heating System (m^2).

	Heating Seasons					
	99-00	00-01	01-02	02-03	03-04	04-05
Heating Capacity	515,711	751,460	946,524	950,286	1,050,286	1,781,986
Rate Of Increase (%)		45.7	83.5	84.3	103.7	245.5

Balçova System-2 geothermal district heating system is the first step planned for the enlargement of the existing geothermal district heating system on the east direction which is independent from the present system as a city network but it is a system planned to take the required energy from the same geothermal reservoir. Its geographical location is on the west of Ata Street and on the south of Sakarya Street (Figure 4.1). The region plan seen in the Figure 4.1 is the aerial view 2001 of existing buildings taken at August on the city plan. District has an area of almost 244,600 m^2. The architectural properties and information on energy system and consumption of the district in which district heating system will be implemented are given in section 4.3, briefly. Detailed information can be found in the literature WEB_1 (2003).

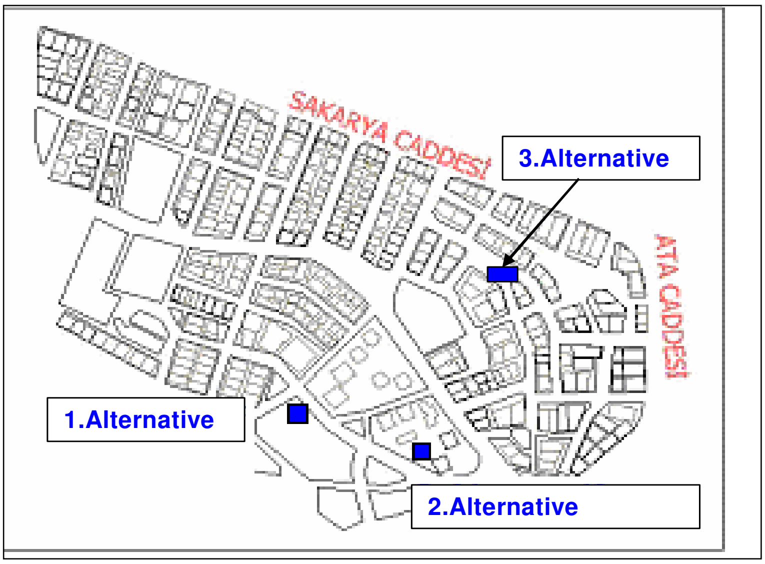


Figure 4.1. Balcova System-2 GDHS city plan and pumping station alternative locations.

4.2. Applied Model of Conceptual Planning

Conceptual planning is a search on technical, economical and political feasibility of any project. Political feasibility is concerning whether the administration and the society support the project or not. Traditional spa applications, low heating costs seen in the operating geothermal district heating systems, being a national resource and relatively less environmental negative impact create political support for these projects. The technical and economical feasibility of geothermal district heating systems projects have some differences from the conventional district heating system.

The source of these differences is the uncertainties about the reservoir and financial model. Searching for technical and economical feasibility with deterministic methods become impossible on the contrary to the examples in the literature (Agioutantis 2000, Karytsas 2003) but it is suggested to use stochastic approaches as seen in a research done for electricity production using geothermal energy (Goumas 1999). In this study the conceptual planning model (Toksoy 2003b) developed for geothermal district heating systems is applied and the uncertainties in the financial model (participation ratio, participation cost, and monthly energy usage fees) were overcome by parametric approach using different scenarios.

One of the components of conceptual planning for geothermal district heating systems is the database about the geothermal reservoir and the district (Climatic data, district plan etc.); the other one is the social-economical public survey (consisting statistics of energy consumption and economical parameters) which helps to form the financial scenarios for the project and the other components are the technical design and economical analysis that use all of these data.

4.3. Database

For the design of the geothermal district heating systems the first step should be collecting the data about the region, climate, reservoir and the social and economical analysis should be carried out.

4.3.1. Characteristics of Geothermal Reservoir

An important element affecting the investment and operating cost of a GDHS is the number of the wells that will supply the required energy and their corresponding costs. Balçova-Narlıdere Geothermal Reservoir is the only one for which reservoir performance project (Satman et al. 2002) is completed and the best-known reservoir in Turkey. To be able to construct new geothermal district heating systems, new production and re-injection wells are to be drilled and connected to the existing geothermal pipeline network. The first assumption about the capacities of new wells is that the new wells will have the same capacity with the average capacity of existing ones. The average flow rate of the production wells used in 2003 is 33 l/s and the weighted average temperature is 130°C[ii] (Table 4.2). The first method for calculating the cost of the wells is to use this average performance and calculate the required number of wells for System-2. However in the same reservoir the well named BD9 has been drilled as the conceptual planning stage has been going on, the capacity of the well BD9 has been more over the average capacities of the existing wells (100 l/s and 139°C) and this well has been planned to be the production well of System-2. In the economical

[ii] In Balcova-Narlidere region according to the production and re-injection strategies flow rates and weighted average supply temperature changes. Given averages are calculated according to well performances after the usage of BD-8 as re-injection well.

feasibility calculations, the properties of both of average wells (Scenario A) and the well BD9 (Scenario B) have been considered.

Table 4.2. Data of Balçova production wells.

Name	Depth	Capacity	Temperature
	m	(l/s)	(ºC)
B4	125	20	114
B5	125	45	124
B10	125	30	114
BD2	677	45	133
BD3	750	25	137
BD4	624	40	140
BD5	1100	25	117
BD6	606	40	135
BD7	700	25	117
Average Well:		**33**	**130**

4.3.2. District Information

The building inventory of the district where System-2 GDHS will be developed is given in Table 4.3. Region is a dwellings area and growth is almost (80%) completed. The maximum dwelling number in the region is calculated according to the existing dwellings, available land and city regulations for construction for this land.

Table 4.3. The number and area of dwellings in the region of System-2.

	Number	Area (m^2)
Area of the region	-	244,600
Maximum dwelling capacity	3,249	391,700
Existing dwellings	2467	310,700
New dwellings to be constructed	782	81,000

4.3.3. Climatic Data

4.3.3.1. Outdoor Design Temperature and Typical Year

The outdoor design temperature is taken as 1.6^{o}C with 99% percentile value for System-2 and as typical year 1993 is chosen (Şen et al. 2000).

4.3.3.2. Balance Temperature

The balance temperature used for estimation of energy consumption is chosen as 18.3^{o}C. According to 18.3^{o}C balance temperature and typical year data total number of heating days is 188, and heating hours is 4700 hours. Energy consumption calculations are done according to hourly outdoor temperatures.

4.3.4. Social and Economical Analysis: Survey Results

The questionnaire given in the Appendix 1a is applied to all of the dwellings by a 10 person group charged by the Mechanical Engineering Association Izmir Branch and done by face-to-face interactions. In the questionnaire the following questions are asked:

1. House address and the place in the building,
2. House area,
3. Heating system type (stove, flat heating system, etc.),
4. Annual amount and cost of the fuel used,
5. For flat heating systems existence of installation project,
6. For flat heating systems radiator types,
7. For flat heating systems radiator lengths,
8. Annual period of heating season (months),
9. Existence of thermometer in the houses,
10. The indoor temperature during the heating season,
11. Window type,
12. Glass type,
13. Hot water source,
14. Number of LPGs used for hot water source,
15. Desire of participating in the geothermal district heating system,
16. Paying the fee implied for participating in the geothermal district heating system,
17. Installing flat heating system if not existing.

4.3.4.1. The Number of Dwellings Survey Applied

The public survey has been applied on 2049 dwellings out of 2467 dwellings present in the area (Table 4.4). Some of the questions in the survey haven't been answered because of an information lack or not making a decision (for being a tenant) or the unused dwellings. However, the number of dwellings answering different questions is quite high and changes from 83% to 85% of existing number of dwellings.

Table 4.4. Number of dwellings to which survey applied.

	Amount	Area (m^2)
Existing dwellings	2,467	310,700
Dwellings information taken	2,049	218,584
Dwellings information not taken	418	44,591

4.3.4.2. Building and Storey Numbers in the Region

The number of the buildings in which 2467 dwellings take place is 313 in the region. Approximately half of these buildings have 4 stories. The distribution of the number of stories in the buildings is given in Table 4.5.

Table 4.5. Number of stories and buildings.

Stories	Buildings	Stories	Buildings
1	19	6	20
2	2	7	38
3	8	8	1
4	148	9	3
5	74	**Total**	**313**

4.3.4.3. Dwelling Areas

One of the necessary inputs which will be used in conceptual planning is the areas of the dwellings. One of the methods that can be used for the prediction of the areas of the dwellings is the servicing maps prepared by the aerial photographs; the other one is getting the needed information from the residents by questionnaires. Both of the methods were used and the results were compared.

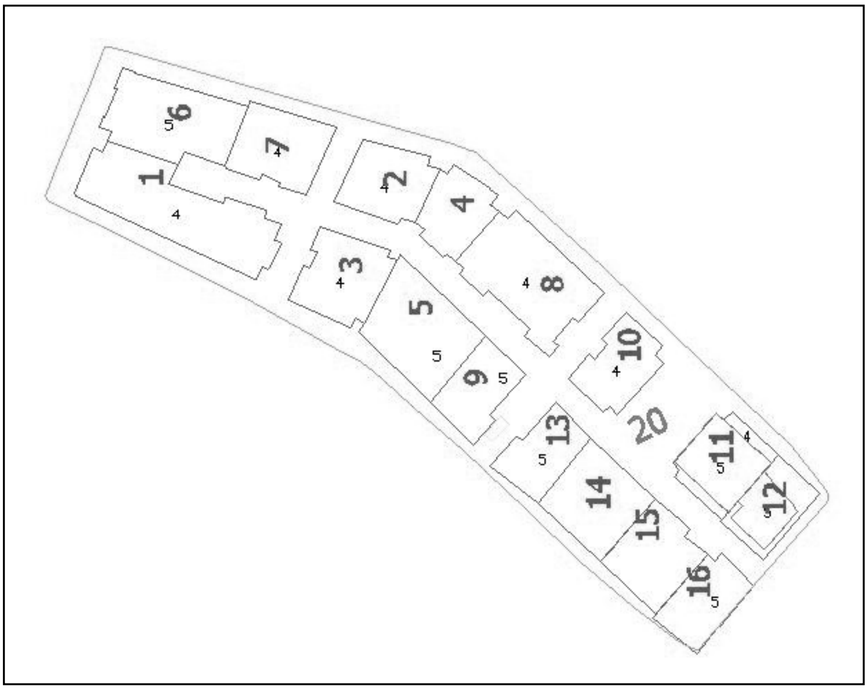


Figure 4.2. The aerial photograph of the example block (number 20).

Table 4.6. The comparison of the areas of the dwellings with two different methods.

Building number	Dwelling area from aerial photo m^2	Stories	Building area from aerial photo m^2	Building area from questionnaires m^2	Difference %
1	229	4	916	863	6.14
2	105	4	420	340	23.53
3	118	5	590	525	12.38
4	87	5	435	297	46.46
5	168	5	840	765	9.80
6	164	5	820	775	5.81
7	115	4	460	333	38.14
8	189	4	756	741	2.02
9	90	5	450	425	5.88
10	91	4	364	320	13.75
11	113	5	565	410	37.80
12	91	5	455	340	33.82
13	87	5	435	440	-1.14
14	131	5	655	552	18.66
15	113	5	565	525	7.62
16	90	4	360	360	0.00
Total Area			**9,086**	**8,011**	**13.42**

A block (Figure 4.2) in the region is taken as an example and for the all buildings on this block the areas calculated by the help of the aerial photographs and the answers about the areas obtained by the questionnaire were listed in Table 4.6.

Using the servicing maps prepared by using the aerial photographs, the areas of the dwellings are found larger than their existing sizes because some of the building components as balconies can't be distinguished from the interior areas. On the other hand the answers about the areas of the dwellings in the questionnaire sometimes don't give the correct information. For example, residents living in different stories but in the same building can give different values about the area of the identical dwellings. On the example block the difference between the two areas is about 13%. There can be averagely from 13% to 50% difference seen between the results of both methods; the results of the aerial photographs are higher. In the aspect of conceptual planning, it is seen that the results of the questionnaire is more appropriate than the results of the aerial photographs. However the areas of the dwellings must be defined accurately as the application projects are prepared.

4.3.4.4. Heating Systems Used in the Region

In the region of interest the heating systems being used are listed with the amounts in the Table 4.7. As seen from this table usage of stove is the most general one. Although individuals having flat heating systems in the dwellings, because of economic reasons, also use stoves or other kinds. In the region there is no central heating system in any building.

4.3.4.5. Fuel Types and Costs

Table 4.8 shows the fuel types used in the region of interest. Some houses are heated by one kind of fuel while some use more than one kind. Of course according to the type of fuels used heating systems also differ (electrical, LPG, coal, etc. stoves). The total cost of the fuels in the region of 2049 houses is 512,416$ and this is calculated by using the prices of the fuels[iii] and US dollar prices in TL[iv] (Table 4.9).

[iii] Fuel Costs. Fuel-oil: 1.416.000 TL/lt; Kerosene : 1.305.000 TL/lt; LPG : 21.500.000 TL/tube; Coal : 175.000 TL/kg; Wood: 150.000 TL/kg; Electricity : 150.000 TL/kWh.
[iv] 1 $ = 1.600.000 TL

Table 4.7. Heating systems used in the region.

Type	Number of Dwellings	%
Stove	1513	74
Flat Heating System	398	19
F.H.S + Stove	61	3
Air Conditioner	54	3
A.C. + Stove	16	1
F.H.S. + A.C.	4	0.1
F.H.S. + A.C.+ Stove	3	0.2
Total	**2049**	**100**
Dwellings information not taken	418	-

Table 4.8. Fuel types used in the region.

Fuel types	Number of Dwellings	%
Coal	504	25
Electricity	487	24
Fuel-oil	353	17
Wood & Coal	270	13
Lpg	137	7
Lpg & Electricity	73	4
Kerosene	66	3
Wood & Coal & Electricity	47	2
Fuel-oil & Electricity	28	1
Coal & Electricity	18	1
Fuel-oil & Coal	22	1
Kerosene & Electricity	14	1
Wood	7	0.3
Coal & Lpg	5	0.2
Fuel-oil & Lpg	4	0.2
Kerosene & Coal	4	0.2
Fuel-oil & Electricity & Lpg	3	0.1
Coal & Electricity & Lpg	2	0.1
Lpg & Coal & Wood & Electricity	2	0.1
Wood & Coal & Lpg	2	0.1
Lpg & Kerosene	1	0.05
Total	**2049**	**100**
Dwellings information not taken	418	

By calculating the average house area (107 m^2) and converting this to 100 m^2 to be able to compare the price with the geothermal district heating system monthly fee since this is calculated by using 100 m^2 unit house area. This calculation results are given in the Table 4.9.

4.3.4.5.1. Fuel Cost of the Flat Heating System Owners

As can be seen from Table 4.11 the dwellings heated by flat heating systems pay 986,721,711 TL ($ 617) per year. This amount is for the weighted average of 120 m^2 house area. When the house area is supposed to be 100 m2 the fuel cost becomes 822,854,888 TL ($ 514). To be able to compare, the fee applied in BNGDHS (380,000,000 TL=$ 240) is also given in the Table 4.11. As seen from the numbers the flat heating system owners pay 2 times more than the BNGDHS participants. The cost in the flat heating systems with coal seems to be 68% cheaper but there is no detailed information about the heating system and thermal comfort conditions. With the reported values in those dwellings 1.3 tones coal is fired to heat 230 m^2 house area which implies it is impossible to maintain the thermal comfort conditions.

Table 4.9: The annual fuel cost of the region ($).

		2049 Dwellings Survey Applied		Existing Dwellings (2467)		Maximum Number of Dwellings (3247)	
Dwelling Area→ Fuel Type↓	(m^2)	218,584		310,700		388,700	
		$	%	$	%	$	%
Fuel-oil		239,252	47	340,078	47	425,453	47
Electricity		104,252	20	148,186	20	185,388	20
Coal		90,911	18	129,223	18	161,664	18
LPG	($)/%	45,918	9	65,269	9	81,654	9
Kerosene		20,734	4	29,472	4	36,871	4
Wood		10,740	2	15,266	2	19,099	2
Total		**512,416**	**100**	**727,493**	**100**	**910,128**	**100**

Table 4.10. For average house area and 100 m^2 house area annual average fuel cost.

	TL	**$**
For a 107 m^2 average house area annual fuel cost	400,129,834	250
For a 100 m^2 average house area annual fuel cost	375,081,390	234
Monthly fee in BNGDHS for 100 m^2 house area	384,000,000	240

4.3.4.5.2. Fuel Cost of the No Flat Heating System Owners

The average and weighted average annual heating costs of dwellings using stove in the district where System-2 GDHS developed are summarized in Table 4.11 for different type of fuel. Weighted average of heating cost of the stove using dwellings is less than geothermal energy cost.

Table 4.11. Annual fuel cost for the dwellings heated by flat heating system.

Used Fuel	Houses	Total Dwelling Area	Average Dwelling Area	Average Heating Cost	Average Heating Cost ($100m^2$)
		m^2	m^2	TL	TL
Fuel-oil & Coal	2	224	112	1,606,000,000	1,433,928,571
Fuel-oil & Lpg	4	431	108	1,270,700,000	1,179,303,944
Fuel-oil	353	42,453	120	1,000,354,901	831,802,888
Fuel-oil & Electricity	28	3,295	118	933,128,571	792,946,889
Fuel-oil & Electricity & Lpg	3	320	107	903,166,667	846,718,750
LPG	17	1,862	110	721,294,118	658,539,205
BNGDHS			**100**		**384,000,000**
Coal	2	460	230	525,000,000	228,260,870
Weighted Average			120	986,721,711	822,854,888

But stove using in a dwelling means uncontrollable heating of one space(usually living room) at a certain time of period and no thermal comfort is in the remaining spaces (bedroom, kitchen, bathroom, sleeping rooms, etc.)

4.3.4.6. Radiator Types in the Dwellings Using Flat Heating System

In most of the dwellings where flat heating system installation is existing panel radiators are used (Table 4.13). Only one dwelling has floor heating installation. The integration of heating systems with radiators to the geothermal district heating system is easy especially if the temperature regime does not create a requirement for the changing of the radiator lengths. But floor heating system's integration won't be so easy since the suggested system will work with higher temperatures. That dwelling will require an extra heat exchanger in the dwelling.

Table 4.12. Annual heating cost for the dwellings not using flat heating system.

Fuel Type	Number of Dwellings	Total Dwelling Area	Average Dwelling Area	Heating Cost for Average Dwelling	Average Heating Cost for Dwelling of 100 m^2
		m^2	m^2	$	$
LPG & Coal & Wood & Ele	2	230	115	457	398
Kerosene&Coal	4	405	101	394	389
LPG&Kerosene	1	85	85	268	316
Kerosene & Electricity	14	1,445	103	296	287
LPG&Electricity	73	7,615	104	284	273
Coal&LPG	5	517	103	260	251
Kerosene	66	6,849	104	252	242
Geothermal			**100**		240
Coal&Electricity &LPG	2	226	113	228	201
LPG	120	12,108	101	202	200
Wood & Coal & Electricity	47	5,094	108	206	190
Coal&Electricity	18	2,039	113	208	184
Electricity	487	50,498	104	173	167
Wood & Coal & LPG	2	175	88	132	151
Wood&Coal	270	27,316	101	131	129
Coal	502	51,862	103	107	104
Wood	7	731	104	105	101
Fuel-Oil&Coal	20	2,344	117	115	98
Weighted Average			103	159	153

Table 4.13. Used radiator types and total surface areas.

Radiator Type	Number of Dwellings	Total Surface Area m^2	%
Panel	514	1,923	95.2
Aluminum	12	58	2.2
Peak	10	34	1.9
Panel & Aluminum	2	5	0.4
Panel & Peak	1	5	0.2
Floor Heating	1	-	0.1
Total	**540**	**2,025**	**100**
Dwellings information not taken	33		**-**

4.3.4.7. Heating Season Period

One of the questions in the questionnaire is about the heating season period. Actually the answers for this question bring out the result for the former doubts about the thermal comforts. With geothermal district heating system for almost 6 months and 24 hours/day the houses will be heated and same thermal comfort can be maintained for such a long period in only 29 (1%) houses. Almost in half of the houses just 4 months, and in 39% 5 months is seen as heating season period (Table 4.14).

Table 4.14. Heating season period.

Heating Season	Number of Dwellings	%
4 Months	989	48.5
5 Months	790	39
3 Months	205	10
6 Months	29	1
2 Months	11	0.5
Total	**2,024**	**100**
Dwellings information not taken	443	

4.3.4.8. Indoor Temperatures

First of all to the individuals it is asked if they have a thermometer in their houses or not, and only in 17% of the total houses existence of thermometer is faced. But just after that question another one is asked this time about the indoor temperatures. Surprisingly almost all individuals answered this question and most (81%) answered 18-22 ºC (Table 4.15). This shows that the temperatures told are just guesses and not measured. Another former result said that most houses are heated by stoves meaning that these guesses of temperatures are just for some part of the house and this is actually seemed to be a deficiency of this questionnaire and it is decided to be asked the heated area for all houses in a future survey.

Table 4.15. Indoor temperatures.

Average Indoor Temperatures	Number of Dwellings	%
Below 18	54	3
18-22	1,638	81
Above 22	326	16
Total	**2,018**	**100**
Dwellings information not taken	449	

4.3.4.9. Window and Glass Types

Almost the half of the windows in the region is wooden made and the rest aluminum or metal types (Table 4.16). This shows that isolation is not so good in the region. Another implication of bad isolation is about glasses. In the region about 75% of the glasses are single type (Table 4.17).

Table 4.16. Window types in the region.

Window Type	Number of Dwellings	%
Wood	960	46
Metal	577	28
Plastic	499	24
Wood & Metal	16	1
Wood & Plastic	18	1
Wood & Plastic & Metal	2	0.1
Plastic & Metal	3	0.1
Total	2,075	100
Dwellings information not taken	392	

Table 4.17. Glass types of windows in the region.

Glass type	Number of Dwellings	%
Single	1,572	76
Double	476	23
Single & Double	23	1
Total	2,071	100
Dwellings information not taken	396	

4.3.4.10. Hot Tap Water Source

According to the information taken from 2014 dwellings 70% of them obtain their hot tap water from gas (LPG) heaters. This is followed by electrical heaters (19%) and flat heating system boilers (5%). Remaining 6% obtains their hot tap water from different sources such as sun (Table 4.18).

Table 4.18. Hot tap water sources.

Fuel Types	Number of Dwellings	%
Gas Heater	1,418	70
Electrical Heater	384	19
Flat heating system boiler	93	5
Sun % Gas Heater	43	2
Sun	28	1
LPG (small)	15	0.7
Kombi	7	0.3
Sun & Electrical Heater	7	0.3
Sun & Boiler	7	0.3
Boiler & Gas Heater	5	0.2
Bath Stove	3	0.1
Bath Stove (wood)	1	0.05
Sun (electrical support)	1	0.05
Boiler & Sun & Gas Heater	1	0.05
Heater (Gas & Electrical)	1	0.05
Total	**2014**	**100**
Dwellings information not taken	453	
Average usage of LPGs (days)	32	

4.3.4.11. Householders Desire for Being an Energy Consumer in Geothermal District Heating System

The region of System-2 GDHS is at the border of the existing geothermal district heating system. For this reason residents are familiar with the GDHS. When asked if they would like to take place unconditionally in the district of geothermal heating system, the answer is mostly yes (89 %, Table 4.19). However when the residents are asked if taking place in geothermal district heating system cause a participation fee about 1000 to 1500 $ and unless they have got a central heating system there will be an additional investment cost about 1000 $ also, desire to use geothermal energy decreases to 74% (Table 4.20).

After erection, how the ratio and process (in time scale) of participation will occur is not known and the subject requires scenarios except beyond the ones given in Table 4.18 and 5.19. As its examples seen in the literature (Summer et al. 2003) the scenarios of 100%, 75%, 50%, and 33% participation rate have been suggested for the foresights of investment and management costs. Experience from the other GDHS projects suggest that maximum participation ratio can reach a maximum value between 75% and 80% in a long time period (~5 years) after the erection completed. In this study, 10 participation ratios between 100% and 26% were used.

Table 4.19. Participating unconditionally.

Answers	Number of Dwellings	%
Yes	1839	89
No	122	6
Tenant	99	5
No decision	15	1
Total	**2075**	**100**

Table 4.20. Participating under economic conditions defined.

Answers	Number of Dwellings	%
With credit	1469	71
Cash	70	3
Tenant	296	14
No	182	9
No decision	58	3
Total	**2075**	**100**

The assumption of participation ratio being homogeneous seems correct since almost all of the buildings in the district are dwellings. This leads to homogeneous distribution of investment and operating cost in the presence of participation ratio scenarios.

4.3.4.12. Installation of Radiator Systems

One of the questions in the questionnaire was about installation of the radiator system in the house needed for being a participant of geothermal district heating system. The distribution of the answers is given in Table 4.21.

Table 4.21. Answers for installation of radiator system if not existing.

Answers	Number of Dwellings	%
Yes	741	36
Existing	688	33
Tenant	296	14
Cannot afford	292	14
No decision	58	3
Total	**2,075**	**100**
Dwellings information not taken	392	-

4.4. Heat Load Density

The heat load density which is calculated from heat load inventory of dwellings affects the investment and operating costs of the pipeline network and is another critical parameter of economical evaluation of geothermal district heating system (Bloomquist 2000b).

It's not possible to obtain an inventory about energy consumption of buildings in the region of System-2. For this reason; the load densities were calculated by using the average peak heating load 54.9 kcal/h.m^2 determined from heating load of 40 buildings in the district by the static heat loss method. By using the economic criterion (Table 4.22), color coded economic evaluation of the distribution of load density for different participation scenarios were shown on the total and the parts of district in Figure 4.3 and distribution ratios were shown in Table 4.23 and 4.24. As it is seen by the figures and tables; the economical availability increases as the participation ratio increases. Economical feasibility becomes possible for all participation ratios in the case of maximum dwelling.

Table 4.22. Economic availability related to heat load density.

Construction type	Heat load density		Availability for District Heating System
	MW/ha	Kcal/h.m^2	
City center, skyscrapers	Over 0.70	Over 60	Very available
City center, buildings with many floors	0.51-0.70	44-60	Available
City center, commercial buildings, buildings with many dwellings	0.20-0.51	18-44	Applicable
Buildings with 2 dwellings	0.12-0.20	10-18	Questionable
Single houses	Less than 0.12	Less than 10	Impossible

Table 4.23. Heat load density distribution for existing construction and different participation scenarios.

Criterion	Participation Ratio (%)			
	89	75	50	33
Very available	63.7	57.2	34.6	16.3
Available	7.6	7.8	20.6	18.4
Applicable	6.5	12.8	18.5	32.3
Questionable	0.0	0.0	4.1	10.8
Impossible	3.9	3.9	3.9	3.9
Green area	18.3	18.3	18.3	18.3

Table 4.24. Heat load density distributions for maximum dwelling capacity and different participation scenarios (Bloomquist 2000b).

Criterion	Participation Ratio (%)			
	89	75	50	33
Very available	78.3	78.3	64.4	26.0
Available	3.4	0.0	8.5	33.1
Applicable	0.0	3.4	8.7	22.6
Questionable	0.0	0.0	0.0	0.0
Impossible	0.0	0.0	0.0	0.0
Green area	18.3	18.3	18.3	18.3

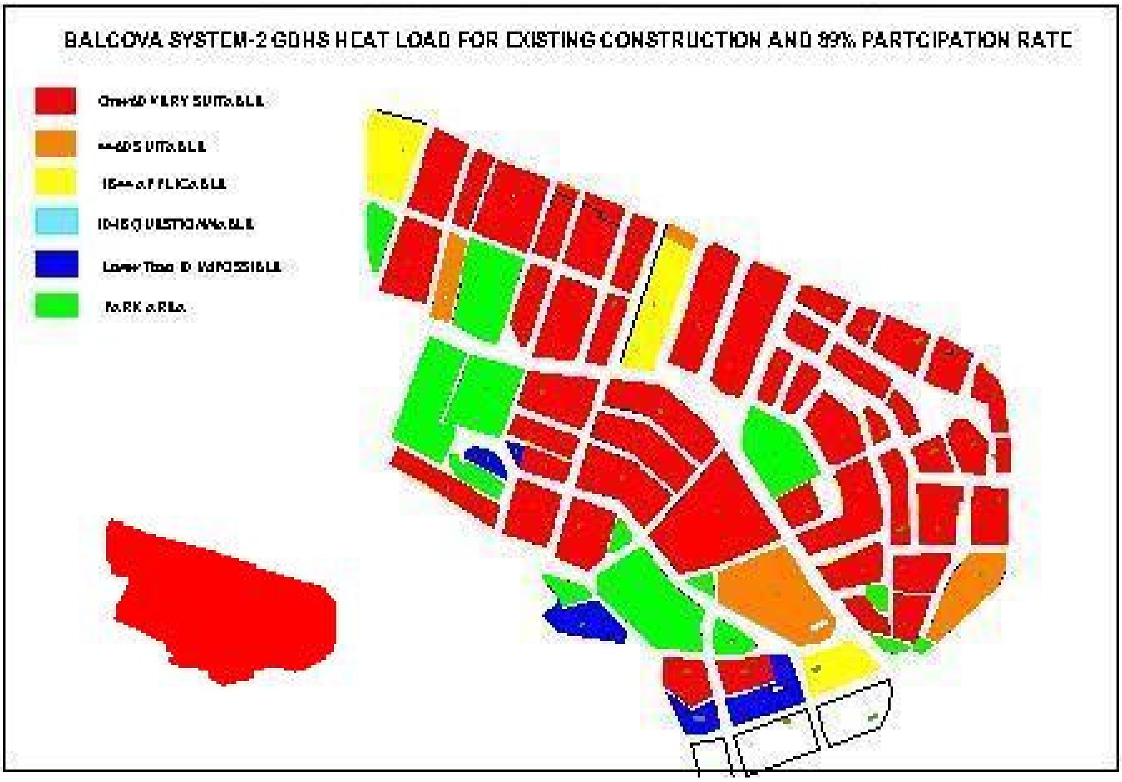


Figure 4.3a. Heat load density distribution for existing buildings and 89% participation rate.

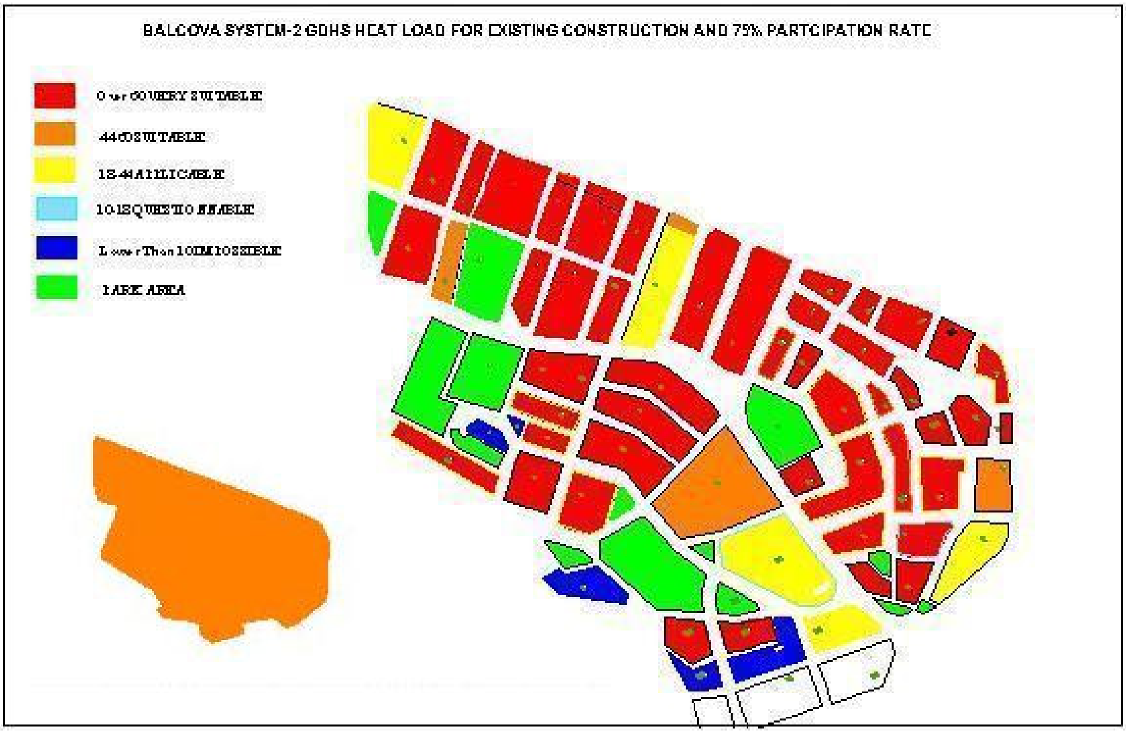


Figure 4.3b. Heat load density distribution for existing buildings and 75% participation rate.

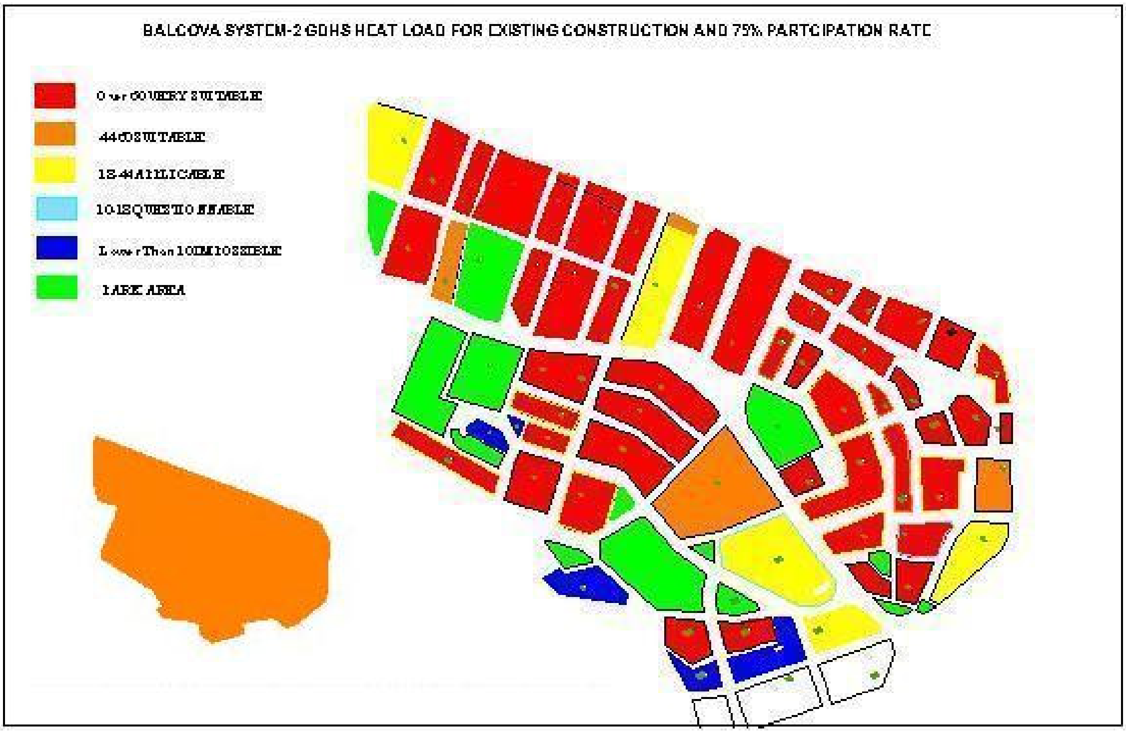


Figure 4.3c. Heat load density distribution for existing buildings and 50% participation rate.

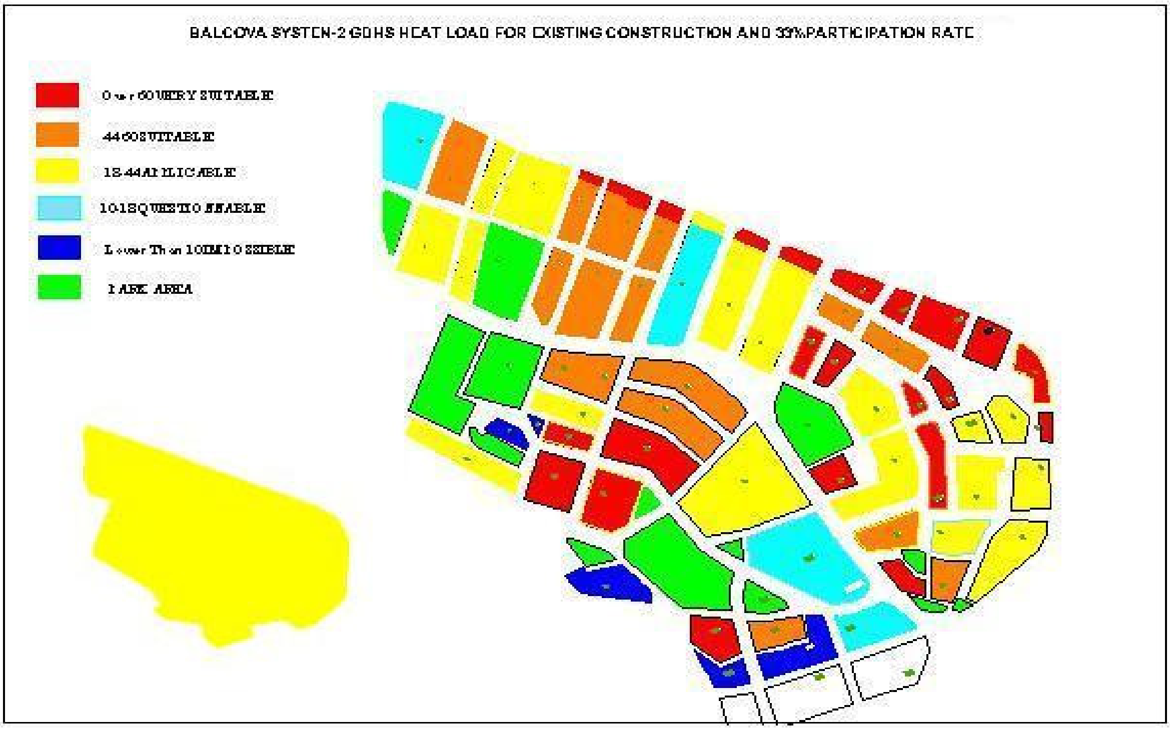


Figure 4.3d. Heat load density distribution for existing buildings and 33% participation rate.

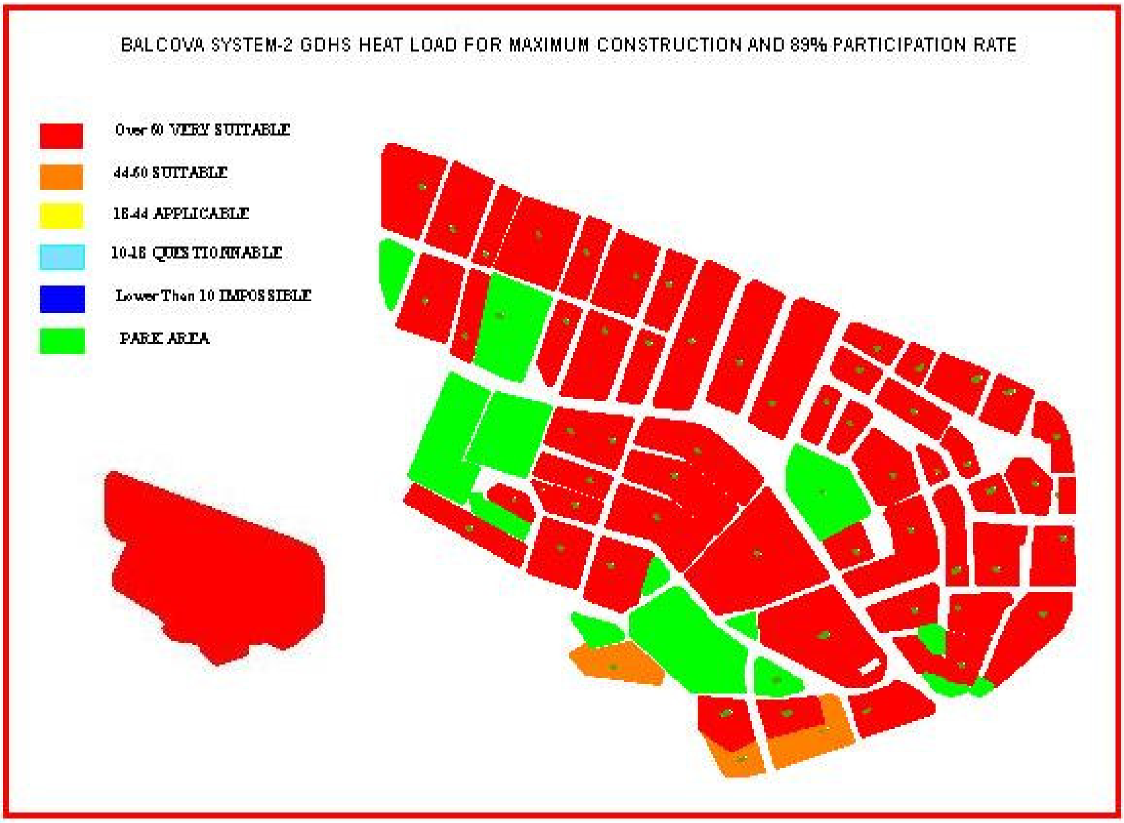


Figure 4.3e. Heat load density distribution for maximum buildings and 89% participation rate.

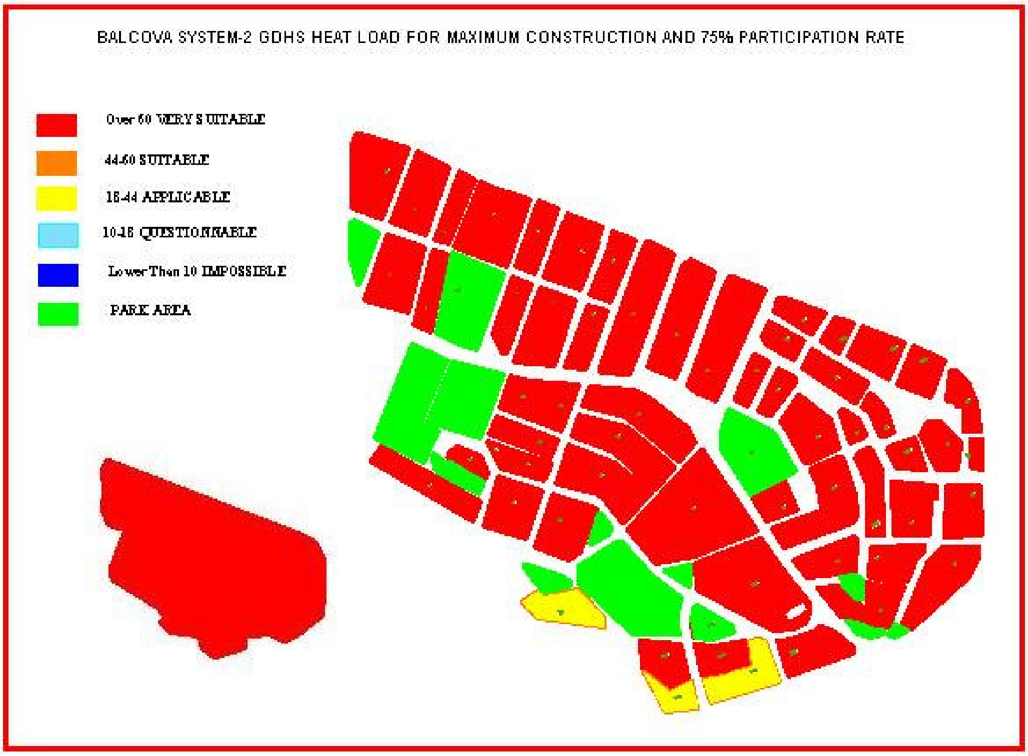


Figure 4.3f. Heat load density distribution for maximum buildings and 75% participation rate.

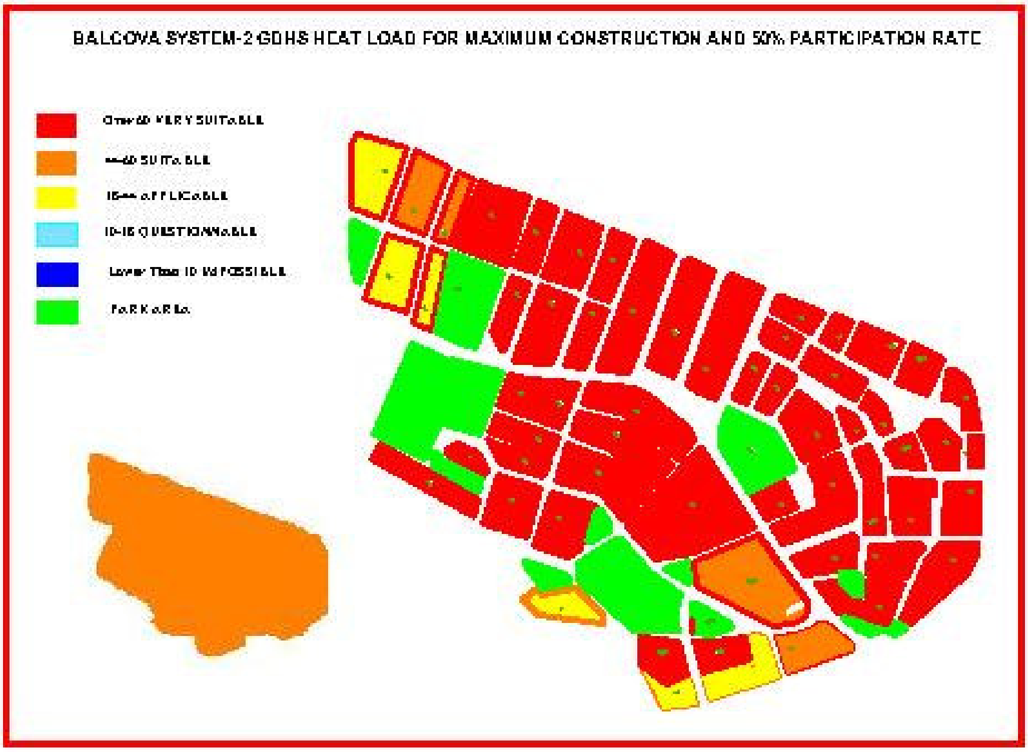


Figure 4.3g. Heat load density distribution for maximum buildings and 50% participation rate.

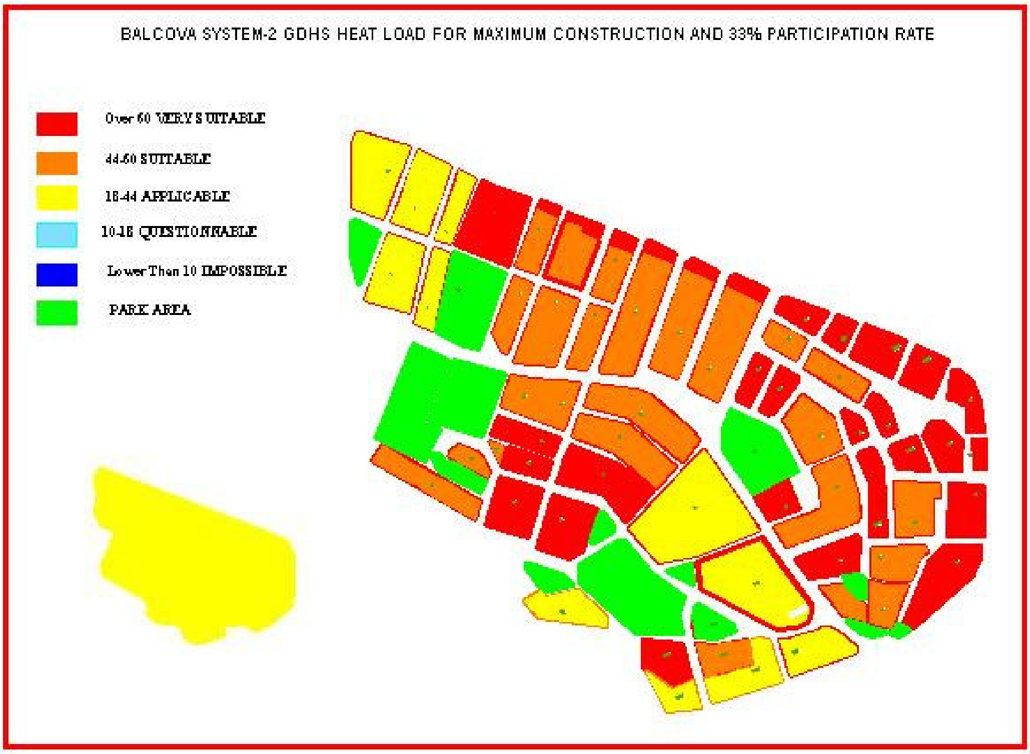


Figure 4.3h. Heat load density distribution for maximum buildings and 33% participation rate.

4.5. System Capacity

The capacity of the geothermal district heating system is accepted as 391,700 m^2 according to the assumed development scenario (maximum dwelling area) and the system design has been done according to this value. The peak load of the existing buildings in the region of interest is calculated as 19.7 MW$_t$, and the peak load is assumed to be 24.9 MW$_t$ after the development completed. These values are calculated according to the average heat loads of 40 different buildings, calculated using static heat load method, of 54.9 kcal/h.m^2 (Toksoy et al. 2001) and this value does not include the hot tap water load. But taking into account two factors this value can be accepted as the total peak heat load including the hot tap water load. The first one is that 54.9 kcal/h.m^2 value is calculated taking the outdoor design temperature as 0 °C. In addition to this indoor design temperature is taken as 22 °C. A new climatic analysis shows that the outdoor design temperatures used in Turkey are not correct (Arısoy et al. 2000). According to this new analysis taking the outdoor design temperature as 1.6 °C is appropriate for Izmir. If this peak heat load value is modified according to new outdoor design temperature the value becomes 51.41 kcal/h.m^2. The second factor is that according to the statistics in the Balçova-Narlıdere GDHS only half of the energy consumers have hot tap water installations. Keeping these two factors in mind it can be said that:

- Due to the modification of the outdoor design temperature peak load value decreases by 3.49 kcal/h.m^2. For a 100 square meters dwelling this decrease is 349 kcal/h.
- According to the Installation Project Preparation Guide prepared by the Mechanical Engineering Association hot tap water per a house is 775 kcal/h. Noting that one of two houses will use geothermal energy for hot tap water 775/2=387.5 kcal/h amount of load per house should be added.

At these conditions the new peak heat load becomes 54.9-3.49+3.875=55.28 kcal/h.m^2. Noting the indoor temperatures varying between 18 and 26 °C using 54.9 kcal/h.m^2 value seems to be acceptable. Of course it should be kept in mind that this value can only be used at conceptual planning phase. During application project preparation phase heat loads for all buildings should be carried out.

4.6. Energy Transfer System

The energy transfer system chosen for System-2 is a two-stage system (Toksoy 2003b). The produced geothermal fluid will return to the re-injection wells after it transfers its energy at the main heat exchangers in pumping station (usually called heating center) to the working fluid in the city circuit. The city circuit will transfer the energy from the main heat exchangers to the heat exchangers in the building. The reason for choosing the two-stage system instead of one-stage system is to prevent the effects of high pressures (6-7 bars) in the city circuit and to have automatic control convenience.

4.7. Service Life of Materials

While making a choice of material for a system components (heat exchanger, pipe, gasket etc.) in the design stage of geothermal district heating systems, mechanical behaviors of materials in contact with the geothermal fluid (temperature and corrosion effects) and how the mechanical properties of the materials change by the time in working conditions must be considered and finally the materials that minimizes the total cost must be chosen.

One of the main components of GDHS is the geothermal and city (pipeline) network. For these networks pre-insulated pipes are used. These pipes are formed in three parts: Inner pipe (steel or FRP), insulation material (polyurethane) over the inner pipe and protecting jacket (polyethylene) over all. One of the most critical properties of these materials is thermal endurance. In Table 4.25 simple and combined technical life of the various pipe materials are given for different temperatures.

Table 4.25. The simple and combined technical life of several materials in the system at different temperatures[v].

Material	Simple life (years)						
	80ºC	90ºC	100ºC	110ºC	120ºC	130ºC	140ºC
Steel (St37) pipe	10-15	10-15	10-15	10-15	10-15	10-15	10-15
PUR insulation	50	50	50	50	28	8	3
PE jacket	30	30	20	20	10	10	10
Gasket (EPDM)	20	20	20	15	10	7	4
FRP pipe	20	20	20	20	20	20	20
Isophtalic FRP pipe	20	20					
Pre-insulated Pipes	Combined life (years)						
	80ºC	90ºC	100ºC	110ºC	120ºC	130ºC	140ºC
ST37-PUR-PE	10-15	10-15	10-15	10-15	10	8	3
FRP-PUR-FRP	20	20	20	20	20	8	3
I.FRP-PUR-I.FRP	20	20	3	3	3	3	3

Combined life is the smallest one of all components for the operating temperature. For example the combined life of Steel (St37) pipe, polyurethane insulation and polyethylene jacket for 140 °C is 3 years. The critical component for this example is the polyurethane's life of 3 years at 140°C. In the design of previous system, Balçova-Narlıdere GDHS, this property is not considered and in the pipes carrying 130°C - 140°C geothermal fluid, polyurethane is used. This material is burned and lost its properties in a short time (Figure 4.4).

The technical life of material also affects the economical analysis as changing replacement time, cost of amortization and salvage value.

[v] For 7 bar pressure.

Figure 4.4. Deformation of polyurethane insulation in Balçova-Narlıdere GDHS.

4.8. Operating Temperatures

For determination of the operating temperatures the main heat exchangers in the heating center, heat exchangers in the buildings, and dwelling radiator areas are to be considered. With these considerations the operating temperatures of the geothermal circuit, city network and the in-building temperatures are determined.

a. Geothermal Circuit: Using BD9 well as the production well for System-2 and keeping in mind the material service lives the geothermal fluid produced from the BD9 well at 139 °C will be cooled down to 120 °C (Figure 4.5) and then sent to the pumping station of the System-2 GDHS. At the pumping station some of the geothermal fluid (21 l/s) coming out of the heat exchanger at 55 °C will mix with geothermal fluid at 139 °C and the remaining (72 l/s) will return to re-injection well. The reason to decrease the temperature of the fluid produced in the geothermal line to 120 °C is the rapid decreasing of service life of polyurethane at higher temperatures. Including the heat losses on the geothermal line, the amount of fluid that must be produced for System-2 from BD-9 well at the peak load of 25.4 MW will be 72 l/s. Producing geothermal fluid up to 100 l/s from BD-9 well is possible. The production over the requirements of System-2 will be used to foster the Balçova-Narlıdere geothermal district heating system.

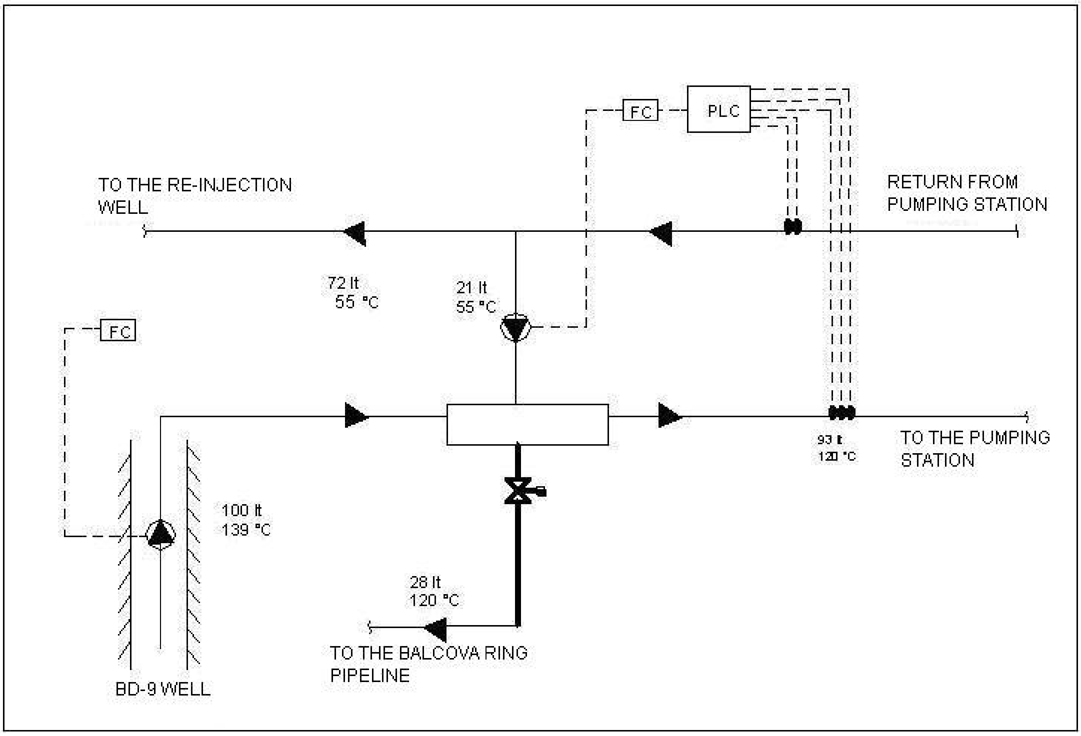


Figure 4.5. Schematic of mixing and control system at the BD-9 wellhead.

b. City Network: In order to determine the temperature regime of the water that will circulate in the city network, the analysis of investment and management cost of the pipe circuit is made according to the pipe types, maximum operation temperatures and compound technical life. As a result the most appropriate temperature regime is found as 90 °C / 50 °C (Appendix 2).
c. In-building Temperatures: The temperature regime in the building network is chosen as 70 °C / 45 °C considering the costs of the heat exchangers of the buildings (Appendix 2).

4.9. Location of the Pumping Station

Within the boundaries of System-2 district, there are three alternative locations for the pumping station (Figure 4.1). In order to make the most appropriate location selection for the pumping station;

- In the aspect of the investment cost, the distance of the pumping station from the geothermal fluid production and re-injection area,

- In the aspect of the management cost of the well pump, the topographic elevation difference between the pumping station and the geothermal fluid production and re-injection area,
- In the aspect of the network pressures and the management cost of city network circulation pumps, the topographic characteristics of the city network

are considered. There is no difference between three alternatives in the aspect of the investment cost. Because of the topographic characteristics, high pressures wil be in the city network for Alternative 1 and 2. For these two alternatives it is not possible to create zones in the region. In Alternative 3, by zoning, the operation pressure on the city network can be decreased. By taking target head loss as 15 mm/m (in Pipelab Software) for all alternatives the investment and management costs of the well pump have been calculated for single zone Alternative 1 and 2 and two-zone Alternative 3. As a result it is seen that the minimum management cost belonged to Alternative 3 (Table 4.26). Although investment and operating cost depend on pipe material, results of calculation of the operating cost for alternative pumping stations will be similar for every pipe materials. Consequently it is decided that Alternative 3 is the most convenient location through the others.

Table 4.26. City network and well pump annual operating costs for pumping station alternatives.

Pumping Station	Geothermal Pipe Length	City Network Investment Cost	Geothermal Pipe Circuit Losses	Height Diference	Well Pump Annual Operating Cost
	m	**$**	**mSS**	**m**	**$**
Alternative 1	1,231	286,388	13.68	92	49,985
Alternative 2	1,390	298,785	15.46	80	44,984
Alternative 3	1,153	286,394	12.81	66	33,549

4.10. Geothermal and City Network Pipe Materials

Considering all of the pre-insulated pipes alternatives given in Table 4.25, the pipe types which will minimize the total cost is selected for the pipe network of the geothermal district heating system.

4.10.1. Geothermal Network

The alternative pipe types taken into consideration for the geothermal network (Figure 4.6) are pre-insulated (polyurethane and polyethylene) steel (St37) and FRP. The isopthalic FRP cannot stand 120 °C operating temperature. The total investment costs (net present value) for 20 years system life are presented in Figure 4.7 for different pipe materials. Total head loss in this loop is given in Table 4.27.

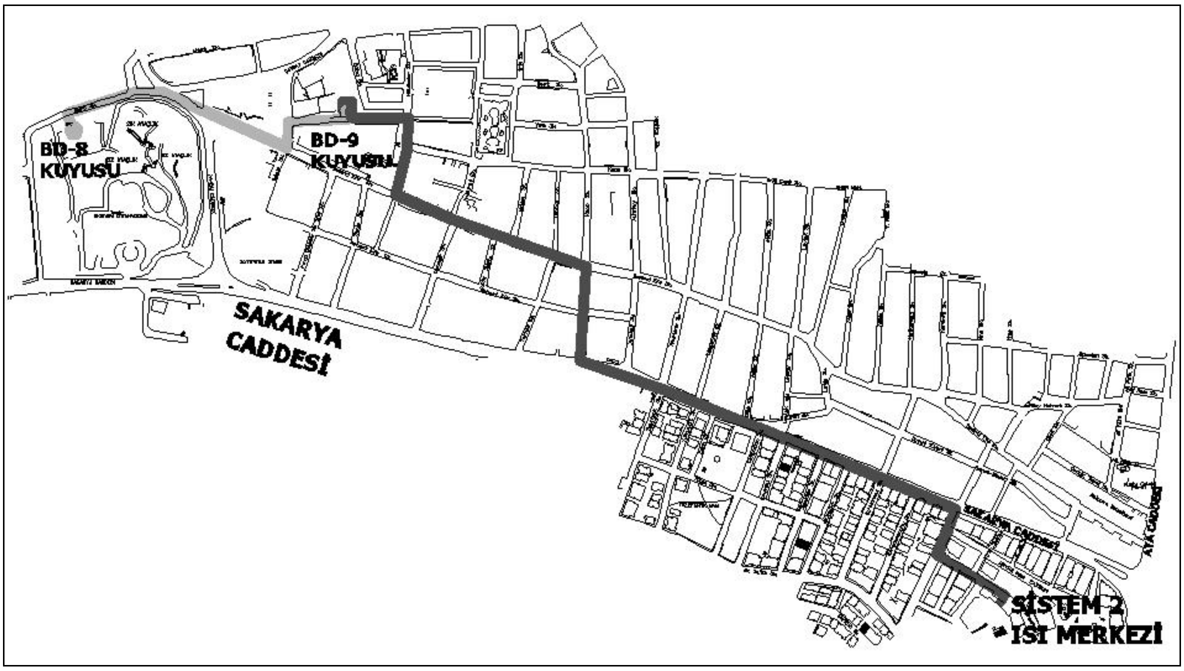


Figure 4.6. Geothermal Network

Table 4.27. Geothermal Loop Head Loss.

Flow Rate	Flow Rate	Diameter	Velocity	Re	Friction Factor	Unit Friction Loss	Length	Total Friction Loss
Q	Q	DN	V					
l/s	m3/h	mm	m/s		f	h=fxV2/(2.g.D)	l	
						mmSS/m	m	mSS
95.8	**344.9**	**250**	**1.95**	**1364577.2**	**0.014**	**11.11**	**1153**	**12.81**

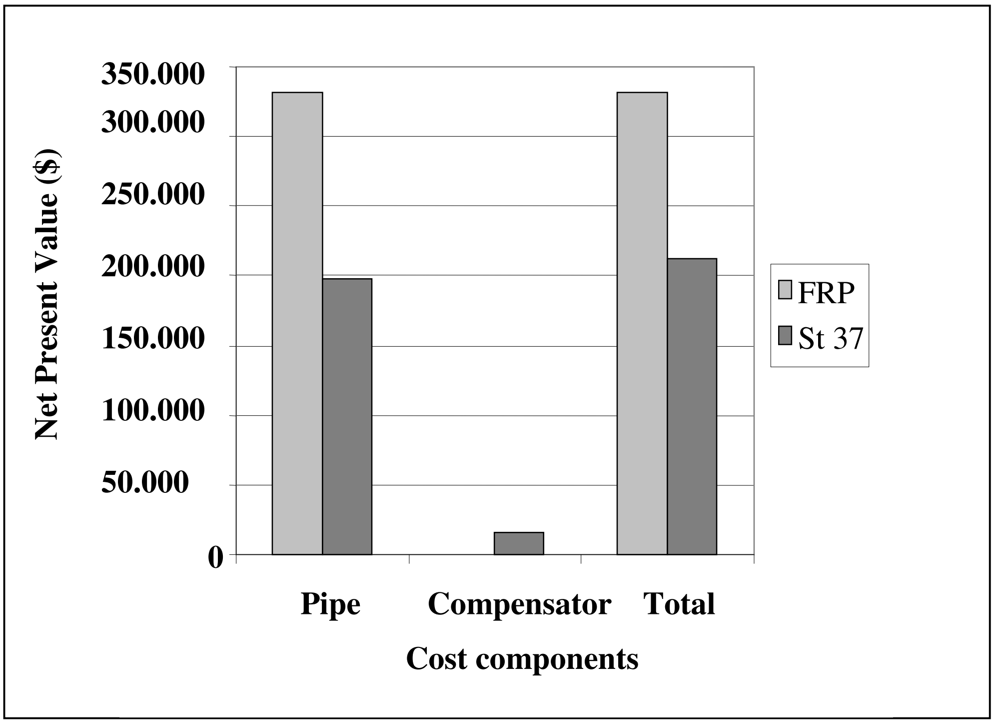


Figure 4.7. Total costs of geothermal network

4.10.2. City Network

Three pre-insulated pipe types are taken into account (steel, isophtalic FRP and FRP) for the city network and investment and operating costs are calculated for different system temperatures (Figure 4.8). Investment cost includes pipe, pipe installation and excavation. Operating cost is including the electricity consumption of circulating pumps and cost of inhibitor for corrosion. One can see on the Figure 4.8 that there are two results for the steel pipe with different service life. Observations done in Balçova-Narlıdere GDHS show that for small diameter (<250 mm) pipes the service life is much lower than 10 years and for large diameter (>250 mm) pipes it is about 10 years due to improper installation. Observation of previous system suggests 10 years service life for steel pipe system, but the proper installation will result longer service life as much as 15 years. The costs are net present values for 20 years time period.

As seen in Figure 4.8, if isophtalic FRP is used, the entire network with the temperature regime of 80 ^{o}C / 50 ^{o}C is reaching the minimum cost. However the temperature regime of 80 ^{o}C / 50 ^{o}C increases the costs of heat exchangers of the buildings and the radiators (heaters) in the dwellings. Because of this reason, the nearest alternative with the minimum cost of pipe material (FRP for the supply line, isophtalic

FRP for the return line) becomes the most appropriate pipe material with the temperature regime of 90°C / 50°C.

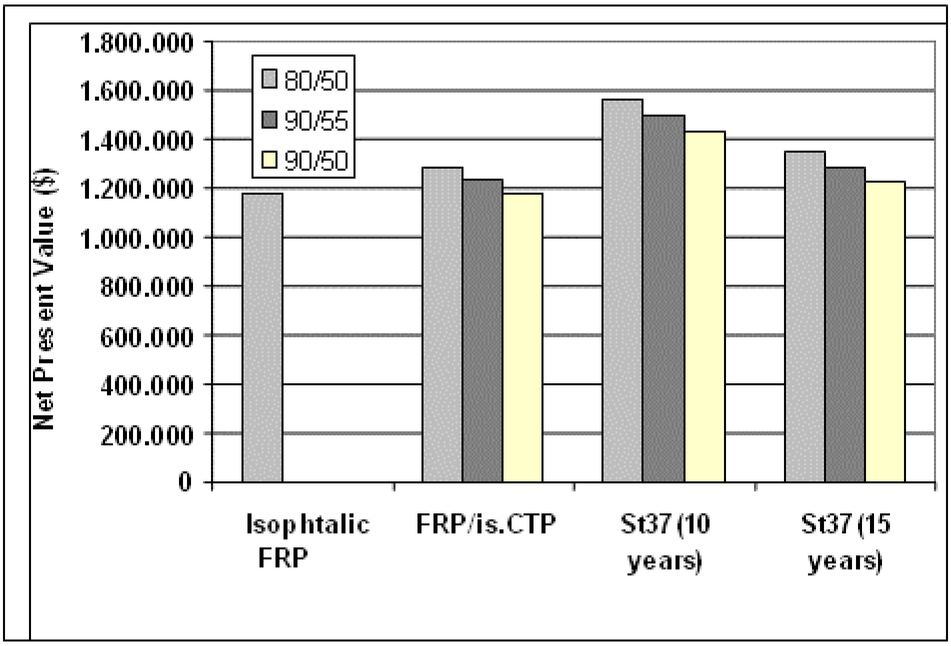


Figure 4.8. Total costs of city network

4.11. Heat Exchangers

For System-2, plate-type heat exchangers are selected because of their convenience for periodical services (for cleaning) and small volumes. At the pump station, for the lower zone 2 units of heat exchanger with the capacity of 4.93 MW and for the upper zone 2 units of heat exchanger with the capacity of 7.55 MW are considered to be used. The plates of the heat exchangers in the buildings are selected as stainless steel; the plates of the heat exchangers at the pumping station are selected as titanium because the geothermal fluid has the chlorine content which is on the edge of the corrosion value for stainless steel.

4.12. Diameters in the City Network

Investment cost is increasing while operating cost is decreasing with an increase at pipe diameters and an optimization required for the selection of diameters. The diameters of the pipes which make total cost minimum around 17.7 mm/m target head lost in the city network are selected by using Pipelab program (Figure 4.9). Resulting head losses in lower and upper zone are given in Figure 4.10.

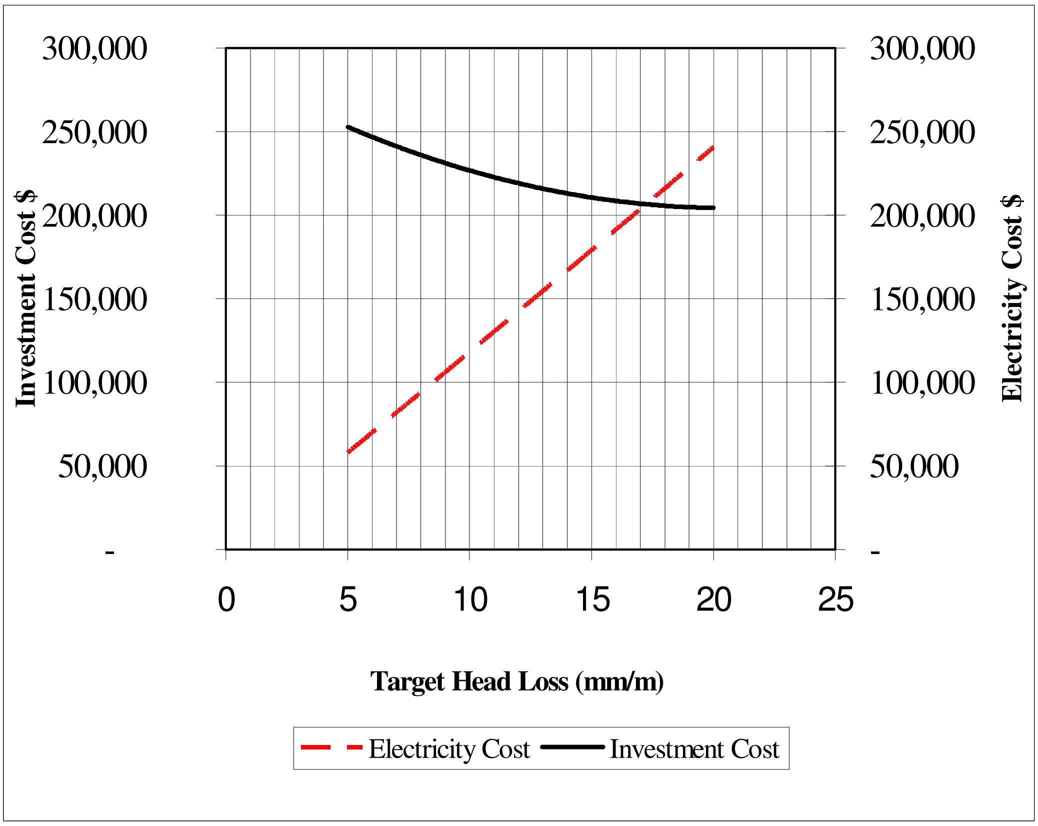


Figure 4.9. Change of Investment and Electricity Cost with target head loss.

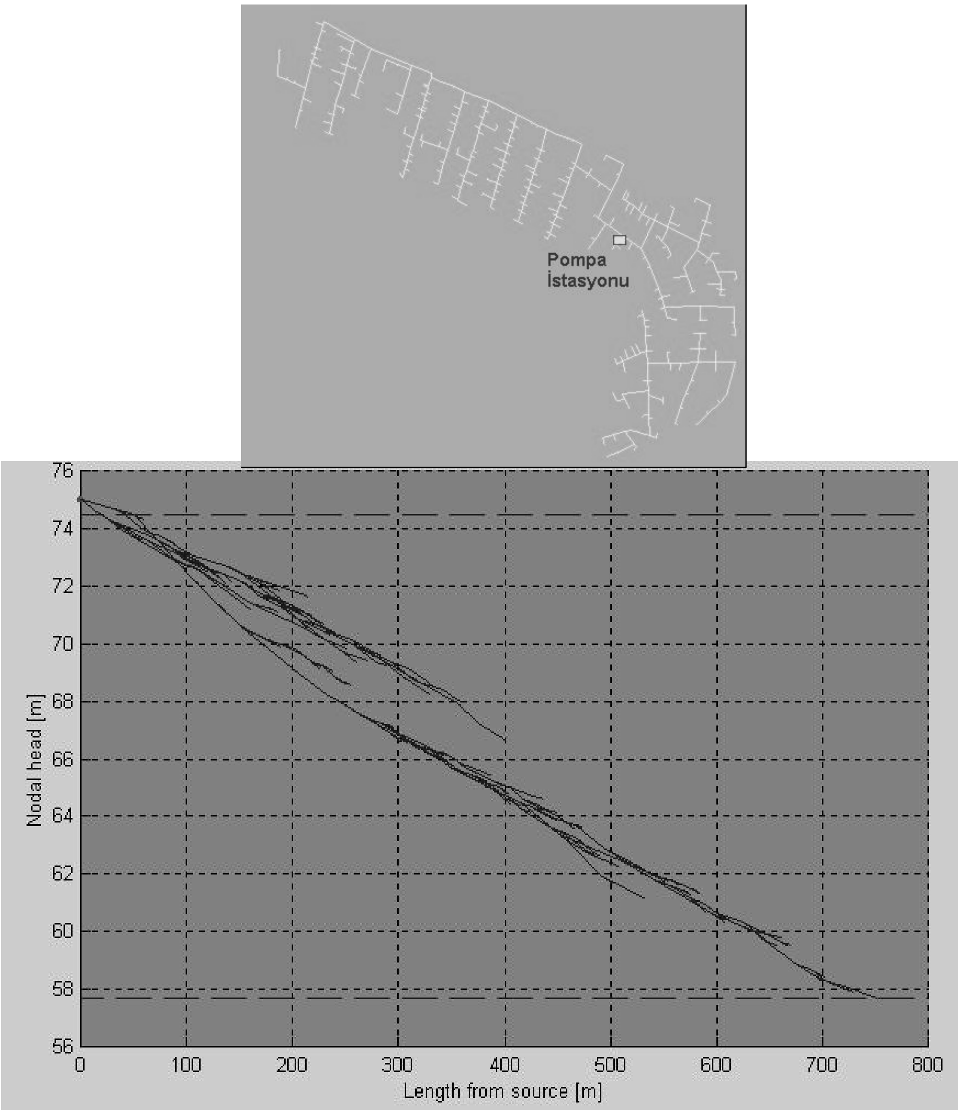
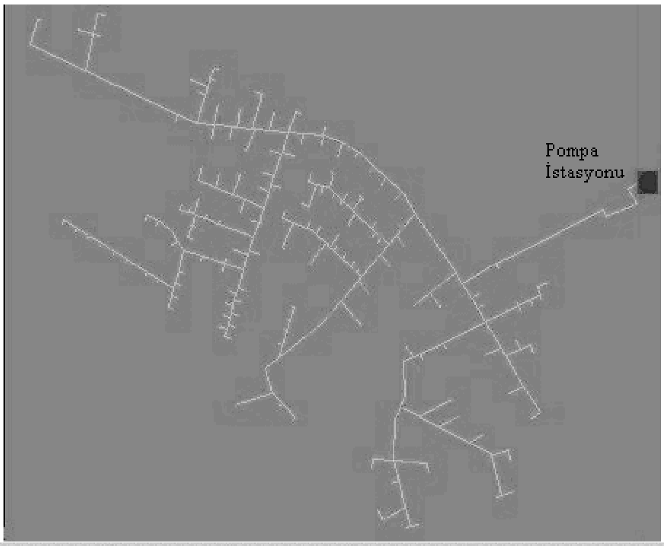


Figure 4.10a. Lower Zone distribution network and head losses.



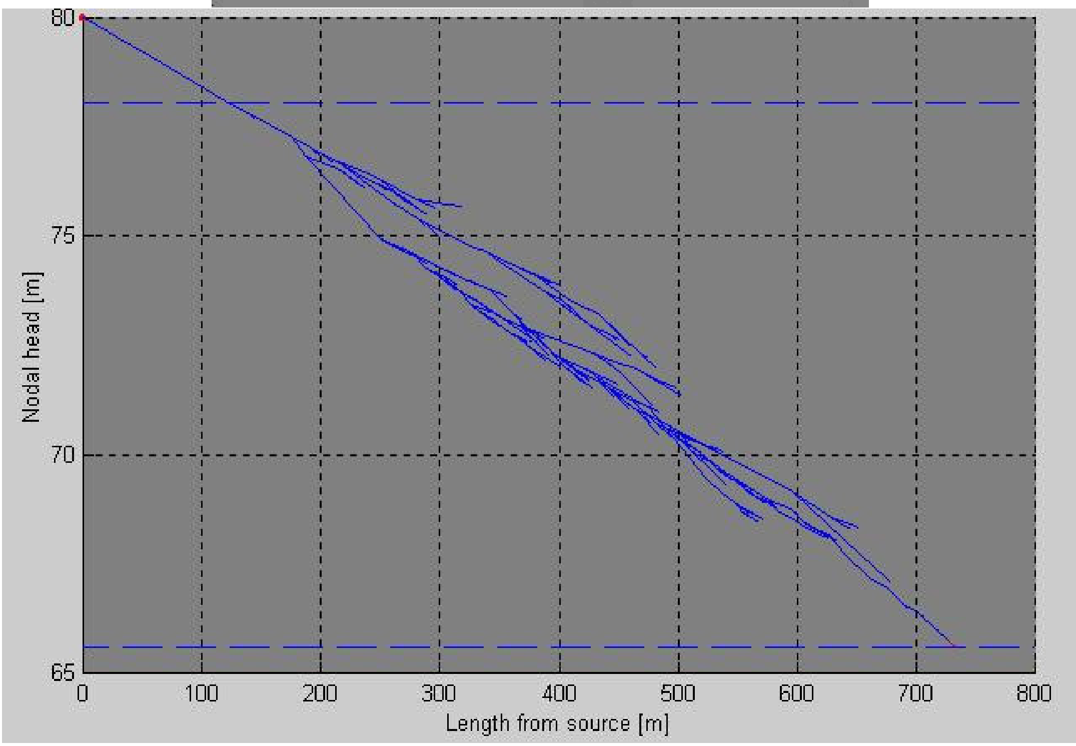


Figure 4.10b. Upper Zone distribution network and head losses.

4.13. Circulation Pumps

After determining the system characteristic (Figure 4.11) according to the changing outdoor temperatures (Table 4.28), the most efficient pumps are chosen from the manufacturer catalogues. Since for partial and peak load it is desired that the pump is working with a high efficiency, two in line-type pumps are planned to work in parallel with an efficiency of 70% - 80%. To adopt changing outdoor temperatures the pumps are of adjustable speed driven type.

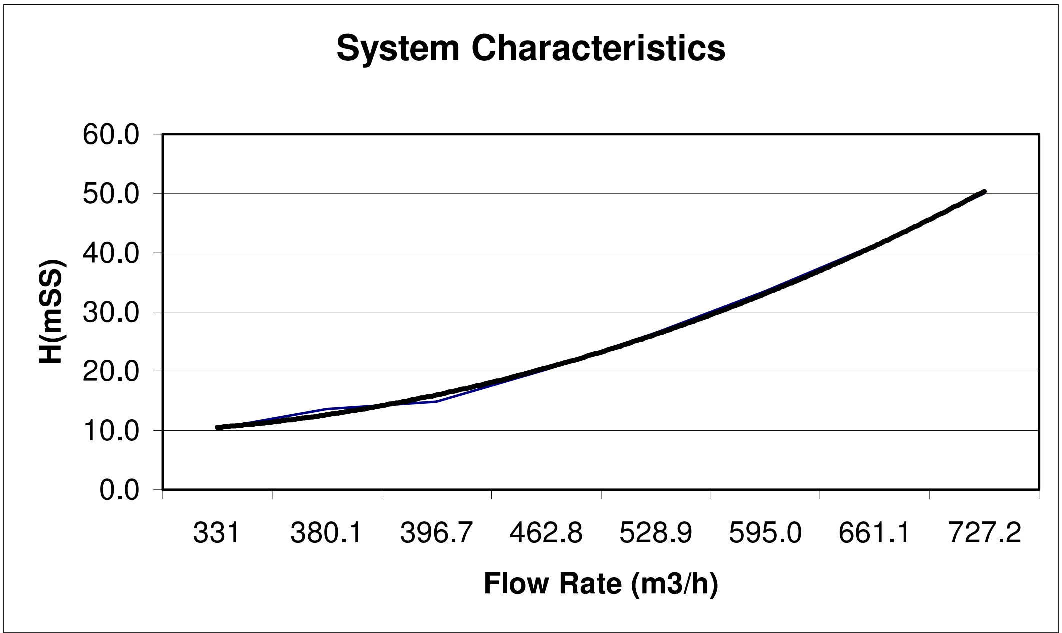


Figure 4.11. System Characteristics

Table 4.28. System Characteristics with changing outdoor temperature.

Outdoor Temperature	°C	12	10.5	10	8	6	4	2	0
Flow Rate	m^3/h	331	380.1	396.7	462.8	528.9	595.0	661.1	727.2
Head Loss	mSS	10.3	13.7	14.9	20.2	26.4	33.5	41.3	50.0

4.14. Valves

On the city network to obtain maintenance ease and at a problematic case making minimum users to be affected with this problem valves are positioned and the details are given in Table 4.28. Also for the all branches valves are suggested (Table 4.30).

Table 4.29. Valves on the city network.

Diameters	Amount
40	1
50	8
65	9
80	12
100	11
125	6
150	5
200	3
250	3
Total	**58**

Table 4.30. Valves at the branches.

Diameters	Amount
20	6
25	128
32	144
40	62
50	32
65	3
Total	**375**

4.15. Control System

For observation and control aims, an automatic control system is designed to control the system load with constant temperature and variable flow. This system will measure the temperatures, flow rate, parameters of frequency converters in networks and then control the pumps according to heat load simulation. Variable flow rate will be achieved by changing pump speed with frequency converters.

4.16. Economical Analysis

The most important factors affecting the investment cost are the number of production and re-injection wells and according costs. As mentioned in section 4.3.1 two different scenarios are considered; first scenario (Scenario A) considers the average well properties calculated using the BNGDHS 2003 data, and the second scenario (Scenario B) considers BD9 as the production well of System-2. During the economical analysis one of the most important factors is the participation rates. For different participation rates some of the investment components differ and accordingly the operating costs may change. Keeping these in mind for different participation rates and well scenarios economical analysis are carried out and finalized with Internal Rate of Return calculations.

4.16.1. Investment Cost

The investment cost of the geothermal district heating systems includes the phases starting with exploration of the geothermal reservoir and ending with the start of the usage of geothermal energy. While calculating the investment cost of the System-2 GDHS no reservoir related costs are included because of the existence of every data from the BNGDHS. Preparation of the project and documentation cost are included in the investment cost. If the district heating system is going to be erected on a new geothermal field of course the cost of research wells, geologic and geophysical studies should be included in the investment cost.

System-2’s investment cost distribution according to Scenario A can be seen in Figure 4.12. The costs shown in this figure are according to 100% participation (388.700 m^2). As can be seen from Figure 4.12 drilling of wells, transporting the geothermal fluid and city network costs are of great importance. Drilling of wells and well equipment costs are calculated using the Bergama case WEB_2 (2003).

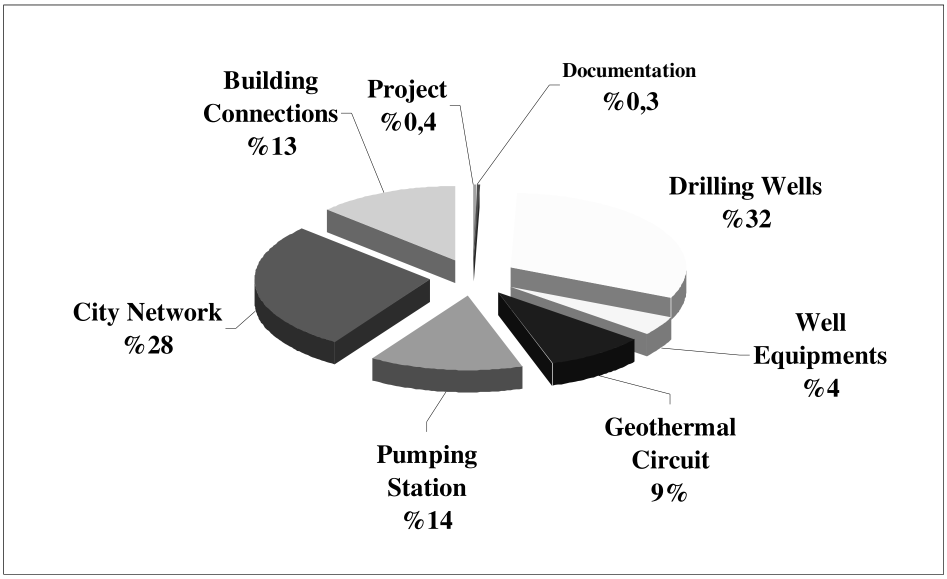


Figure 4.12. Distribution of investment cost for 100 % participation rate for Scenario A.

In Table 4.31 the investment costs changing with participation rates and well scenarios are shown. While internal rate of return analysis are carried out investment costs are changed for the marked components. Table 4.32 shows the investment cost values according to different participation rates and well scenarios.

Table 4.31. Investment components of System-2 GDHS.

Components	Cost changing with well scenarios	Cost changing with participation ratio		Components	Cost changing with well scenarios	Cost changing with participation ratio
Geothermal network				Well equipments	X	
City network				Flow control pump		X
Branch connections		X		Building connections		X
Pumping Station build.				P.S. miscellaneous		
P.S. Heat exchangers		X		Service vehicle		
Automatic control				Office equipments		
Conceptual planning				Electrical misc.		
Project+Documentation				Questionnaire		
Circulation pumps	X			Control + Test		
Frequency Converters	X			Asphalt restoration		
Well pump	X					

Table 4.32. Variation of investment cost with participation ratio and wells scenarios ($).

Participation Ratio (%)	Number of Dwellings	Scenario A	Scenario B
100	3,917	3,874,442	3,008,077
89	3,468	3,819,135	2,952,771
79	3,094	3,768,856	2,902,492
75	2,938	3,748,745	2,882,380
71	2,781	3,728,633	2,862,269
59	2,311	3,181,539	2,801,934
50	1,959	3,136,288	2,725,140
40	1,567	2,630,793	2,674,862
33	1,293	2,595,597	2,639,666
26	1,018	2,560,402	2,604,471

4.16.2. Operating Cost

Geothermal district heating systems include 8 main components:

1. Cost of Personnel
2. Electricity Consumption
3. Water Consumption
4. Cost of Inhibitor
5. Cost of Chemicals
6. Maintenance Cost
7. Marketing Cost
8. General Expenses

The details of the foreseen operating costs of the System-2 are given in this section and the results are listed in Table 4.38. The operating costs are foreseen according to the realized costs in 2002 in Balçova-Narlıdere GDHS. Because the year of 2002 simulates the ideal case for Balçova-Narlıdere GDHS. The biggest component of the operating costs in System-2 is calculated to be the personnel cost. While calculating the annual personnel cost in System-2 10 personnel are assumed including 1 manager. The personnel costs are calculated using the personnel cost of Balçova-Narlıdere in 2003. The administration committee included in BNGDHS is also assumed to be included in the personnel cost of System-2 and related according to the system capacity and calculated to be $ 3277. Monthly personnel cost is summarized in Table 4.33.

Table 4.33. Monthly personnel cost of Balçova System-2.

			Gross Salary (TL)	Total (TL)	Total (US $)
1	Operator	4	500,872,286	2,003,489,144	1,382
2	Manager	1	888,497,276	888,497,276	613
3	Accountant	1	465,108,164	465,108,164	321
4	Maintenance Personnel	2	324,881,388	649,762,776	448
5	Public Relations	1	741,887,647	741,887,647	512
6	Servant	1	324,881,388	324,881,388	224
7	Administrative Committee				3,277
	TOTAL				**6,776**

The electricity consumption is of great importance in the operating costs of the geothermal district heating systems. The monthly electricity consumption is calculated using the hourly temperature data for 1993 and the Conventional Energy Coefficient (CER_0) (Şener 2003) for optimized production (Table 4.34).

Table 4.34. Monthly electricity consumption.

Month	Energy Production (kWh)	Energy Production according to CER_o (kWh_e)	Electricity Cost (USD for 100% Participation)
1	12,282,920	91,837	7,107
2	11,647,306	87,084	6,739
3	9,239,595	69,082	5,346
4	5,935,257	44,377	3,434
5	3,864,359	28,893	2,236
6	2,519,865	18,840	1,458
7	2,603,418	19,465	1,506
8	2,599,843	19,438	1,504
9	2,778,182	20,772	1,607
10	3,354,147	25,078	1,941
11	7,943,722	59,393	4,596
12	8,440,429	63,107	4,883
Total	**73,209,043**	**547,367**	**42,357**

No welding at the pipe connections in the city network and correct installation will be applied and no leakages are assumed. Thus, no enormous water cost as in Balçova-Narlıdere GDHS will be faced and energy loss problem is to be prevented. The amount of water needed in System-2 is calculated by summing up the volumes of:

- City network pipes (distribution line, branches and building connections),
- Building and pumping station heat exchangers,
- Pipes and expansion tank in the pumping station.

In Table 4.34 the calculated volumes of the city network and in Table 4.36 the volumes of the heat exchangers are listed. The amount of water needed in the first filling is calculated to be 92 m^3 and the total volumes of the all equipments are listed in Table 4.37.

While calculating the water consumption for general maintenance purposes the system is assumed to be emptied and refilled twice in a year. Noting this and for the system working at full capacity the required amount of water is calculated as 184 m^3/year. At pumping station assuming a consumption of 10 liters per person 36 m^3 is added to 184 m^3 and a total amount of 220 m^3 water consumption is found. The unit cost of water is taken from the IZSU's price list. According to the work site price list unit price is 5,287,000 TL. Taking the rate of dollar exchange 1,450,000 TL a total of $

802 is found to be paid for water consumption. As seen no leakage will lead to a very low cost for water opposite to Balçova-Narlıdere GDHS.

Table 4.35. The pipe volumes in the city network.

Diameter (mm)	Length (m)	Unit Volume (m^3/m)	Total (m^3)
20	570	0.00031	0.179
25	3380	0.00049	1.658
32	3392	0.00080	2.727
40	2066	0.00126	2.595
50	2422	0.00196	4.753
65	1864	0.00332	6.182
80	1910	0.00502	9.596
100	1048	0.00785	8.227
125	792	0.01227	9.714
150	684	0.01766	12.081
200	782	0.03140	24.555
250	114	0.04906	5.593
300	24	0.07065	1.696
Total			**89,6**

Table 4.36. Volumes of the heat exchangers.

Placement	Capacity (kcal/h)	Amount	Unit (m^3/amount)	Total (m^3)
Building	10,980	1	0.001	0.001
Building	16,470	4	0.001	0.004
Building	21,960	10	0.0012	0.012
Building	27,450	62	0.0014	0.0868
Building	32,940	39	0.0015	0.0585
Building	38,430	32	0.0017	0.0544
Building	43,920	21	0.0020	0.0420
Building	49,410	38	0.0021	0.0798
Building	54,900	25	0.0023	0.0575
Building	60,390	27	0.0026	0.0702
Building	65,880	24	0.0028	0.0672
Building	71,370	9	0.0030	0.0270
Building	76,860	11	0.0031	0.0341
Building	82,350	20	0.0052	0.1040
Building	87,840	16	0.0052	0.0832
Building	98,820	14	0.0069	0.0966
Building	109,800	10	0.0069	0.0690
Building	120,780	9	0.0085	0.0765
Building	1,037,610	3	0.0365	0.1095
Pumping Station	750,000	2	0.1135	0.2270
Pumping Station	500,000	2	0.0757	0.1513
Total				**1.5116**

Table 4.37. Filling amount of water for Balçova System-2 (m^3).

	Volume (m^3)
City network pipe volume	89.6
Building heat exchangers volume	1.13
Pumping station heat exchangers	0.38
Expansion tank volume	0.6
Total	**91.7**

The cost of chemicals and maintenance costs are thought to be linearly changing with Balçova-Narlıdere GDHS. So the according to capacities the costs for System-2 are calculated and listed in Table 4.38. The administrative committee, marketing cost and general expenditures are thought to be shared and distributed to two systems according to their capacity and the costs for System-2 are listed in Table 4.39.

Table 4.38. The operating costs for System-2 calculated according to BNGDHS 2002's costs.

	Balçova - Narlıdere GDHS (Erdoğmuş 2003b)	Balçova System-2 GDHS
Heating Capacity (m^2)	1,150,000	310,700
Inhibitor Cost (US $)	3,753	1,014
Other Chemicals (US $)	1,912	517
Maintenance Costs (US $)	53,417	14,432

Table 4.39. Annual operating costs for Balçova System–2 for 100% participation rate.

		Operating Cost (US $ / year)	%
1	Cost of Inhibitor	1,014	0.56
2	Cost of Chemicals	517	0.28
3	Water Consumption	802	0.44
4	Personnel Cost	81,317	44.62
5	Electricity Consumption	42,357	23.24
6	Cost of Maintenance	14,432	7.92
7	Marketing Cost	3,197	1.75
8	General Expenditures	38,617	21,19
Toplam		**182.253**	**100**

4.16.3. Finance Model

One of the important steps of economical analysis in conceptual planning is figuring out the finance model. The investment finance of Balçova Sistem-2 geothermal district heating system is suggested to be supplied from the participation cost of the dwellings and the monthly fixed energy cost charged to the dwellings which will benefit from the geothermal district heating system, as it's practiced in the other applications in Turkey. The internal rate of return for different participation costs ($1250, $1350, $1500) is analysed by finding the monthly fixed energy costs which make internal rate of return positive around 0%.

Another parameter in the finance model is the integration schedule of dwellings into geothermal district heating system. Two different periods, 2 and 5 years, has been taken into consideration (Figure 4.13). For any participation ratio, the increase of the number of the dwelling in the geothermal district heating system assumed linear in each period.

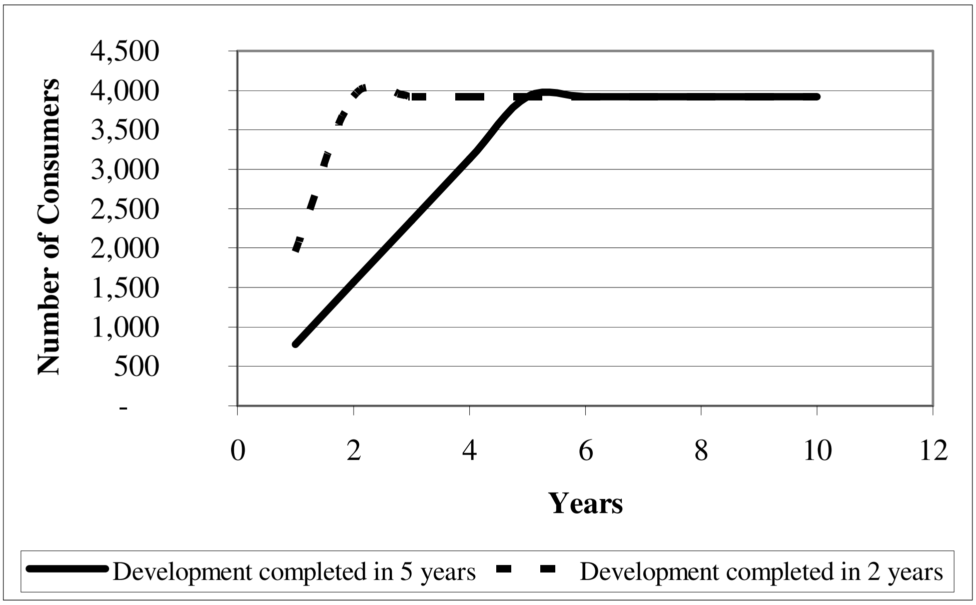


Figure 4.13. Development scenarios for participation schedule.

4.16.4. Internal Rate of Return Analysis

The internal rate of return analysis has been carried out by different well scenarios (A and B), participation schedule (2 and 5 years) and participation costs ($1250, $1350,

$1500) in order to define monthly fixed energy charge which make internal rate of return positive around 0%. Results are presented in Table 4.40.

The values in shaded area in Table 4.40 are most acceptable economic figures for the householders since participation cost of $1250 and monthly fixed energy charge around $20 are in practice in existing geothermal district heating system nearby. Attention must be given to that, monthly fixed energy charge bigger than any value presented in Table 4.40 will make the internal rate of return positive, so the investment profitability better.

Although investment costs of wells in two scenarios are different, participation ratio interval for these two scenarios are quite similar.

Table 4.40. The monthly fixed energy charge which make internal rate of return positive around 0%.

Participating Period	**Participation Ratio**	**Scenario A Energy Usage Fee $**			**Scenario B Energy Usage Fee $**		
Years	**%**	**$ 1250**	**$ 1350**	**$ 1500**	**$ 1250**	**$ 1350**	**$ 1500**
5	100	17.0	17.0	17.0	17.0	17.0	17.0
	89	17.0	17.0	17.0	17.0	17.0	17.0
	79	17.0	17.0	17.0	17.0	17.0	17.0
	75	17.0	17.0	17.0	17.0	17.0	17.0
	71	18.1	17.6	17.0	17.0	17.0	17.0
	59	23.2	22.6	21.7	17.8	17.2	17.0
	50	28.5	27.9	27.1	22.2	21.6	20.7
	40	37.3	36.7	35.8	29.3	28.7	27.8
	33	44.4	44.1	43.7	37.0	36.4	35.5
	26	45.6	45.7	45.7	44.9	44.7	44.4
2	100	17.0	17.0	17.0	17.0	17.0	17.0
	89	17.0	17.0	17.0	17.0	17.0	17.0
	79	17.0	17.0	17.0	17.0	17.0	17.0
	75	17.0	17.0	17.0	17.0	17.0	17.0
	71	17.0	17.0	17.0	17.0	17.0	17.0
	59	20.9	20.3	19.4	17.0	17.0	17.0
	50	26.3	25.7	24.7	20.0	19.4	18.5
	40	35.1	33.8	33.5	27.2	26.5	25.6
	33	43.2	42.8	42.2	34.5	33.2	33.3
	26	45.2	45.2	45.1	44.1	43.8	42.9

CHAPTER 5

RESULTS AND DISCUSSION

5.1. Results and Discussion of the Survey

The region of interest is composed of dwellings only. So the results of the survey can be extrapolated through the whole region although information from all dwellings could not be taken. According to the answers taken from the householders it is observed that there are many tenants. It sholud be noted that the application of survey must be announced some time before the application and people should be informed about the importance of the survey. As known people in Turkey when see surveyors generally don't want to answer the questions or misinform them. Because of this reason the surveyors had some difficulties in telling householders the importance of the survey. A good solution to this may be arranging a meeting a week before the survey application starts to inform the householders. This way tenants can talk with the house owners and can have an idea about participating in the district heating system.

Another solution can be a special subscription method for the tenants which actually started to be applied. The first connection fee is paid back to the tenants if they participate in the district heating system and then leave the dwelling.

The surveyors should be chosen carefully. Like the ones in the System-2 survey they can be chosen from the Mechanical Engineering Association since they can realize the importance of the survey easily and can behave accordingly.

In the survey answers to the area of the dwellings showed that householders don't know the area of the dwelling they are living in. The areas reported by the householders and the ones calculated using aerial photographs may differ much. Also another fact supporting this discussion is that in the same building the dwelling areas are much different from each other which is suspicious. If possible seeing the deeds of the dwellings should be wanted from the surveyors.

Answers and analysis about the heated area showed that in the next survey the heated area, especially to the stove using householders, should be asked and if needed should be measured.

To the choices for the question of the heating season period 6 months should be added. These modifications and the new format of the survey can be seen in Appendix 1b.

5.2. Results and Discussion of the Design

The number of production and re-injection wells is one of the important components of investment cost of geothermal district heating systems. Two scenarios (A and B) are considered for two approximations in the estimation of wells number and their investment costs. The effects of these two approximations on investment cost can be noticed in Table 4.29. Although investment costs are different, effect of wells scenarios on internal rate of return are not so striking in the case of System-2 (Table 4.40). Scenario B assumes only one injection well to be drilled with the re-injection capacity similar to BD-9. If the number of re-injection wells increases due to lower re-injection capacity reached in drilled wells, investment cost will also increase and the interval given in Table 4.39 for this scenario get closer to interval of the Scenario A (Table 4.40, shaded areas).

System-2 Geothermal District Heating System is feasible for both existing and maximum dwelling in terms of heat load density (Figures 4.3). Although the criterion used in this assessment is not developed for Turkey, researches similar to this one will give more information on the validity of the criterion for Turkey.

Weighted average of conventional heating energy cost of the dwellings in the System-2 district is quite equal to the cost of geothermal energy with current energy price policy. Moreover thermal comfort conditions will be more developed in the dwellings which will take place in the geothermal district heating system.

In the Balcova-Narlidere GDHS to which System-2 will be integrated the participating cost is $ 1250, and monthly fixed energy charge is $ 20 during this study. The social and economical structure of the area on which the System-2 is planned to be is same as the area where the Balçova-Narlıdere GDHS is developed. In addition to this information; existing applications and the results of the questionnaire show that $1250 for participation cost and $20 for monthly fixed energy charge will be acceptable for the potential users in the System-2 project.

As can be seen from the shaded areas in Table 4.40, up to 59% participation ratio for Scenario A and up to 50% participation ratio for Scenario B, the internal rate of return value is positive for $ 1250 participation cost and $ 20 monthly fixed energy charge or less. In the similar applications it is observed that after price based bids, the investment costs of projects decreases by 10-20%. If this decrease in the investment cost is taken into account, it can easily be said that for lower participation ratio, lower monthly fixed energy charge will make the internal rate of return value positive. Obviously in this case project will be realized with low participation ratio which is critical decision parameter in investment.

5.3. Geothermal Energy Regulations (Draft) for Izmir

As listed in the section 3.3.1 the Regulations for Izmir seems to be applicable in terms of geothermal district heating system design. Actually the applied conceptual model is somewhat similar to the suggested one in the Regulations.

In the Draft the population density is desired for the next 25 years, but this study showed that the service life of a geothermal district heating system is about 20 years and after 20 years all of the equipments will be renewed. Thus, the population for coming 20 years could be enough instead of 25 years.

Some headings like heat load density should be clarified and explained in more details. The designer may not know that kind of studies, so examples could be attached to the Draft for this kind of documents.

An important point not to miss is that as applied in this study a detailed survey application and results of that survey should be a required document since because as happened in this study the survey results are crucial.

CHAPTER 6

CONCLUSION

At the very beginning of the study it was aimed to design the new geothermal district heating system in Balçova as en extension to the existing district heating system. This study is the first example in Turkey for such as a design procedure. In the study concptual planning phase is completed. And at the end the all parameters of the geothermal district heating system named System-2 are known including investment, operating costs and the internal rate of return analysis. As can be seen from the Table 4.40, up to 59% participation ratio for Scenario A and up to 50% participation ratio for Scenario B, the internal rate of return value is positive for $ 1250 participation cost and $ 20 monthly fixed energy charge or less. And it is noted that the actual prices will be determined by a price based bid. This bid was concluded at the ending period of this study and the investment cost revealed as $ 1,500,000 instead of the calculated value of $ 3,000,000 (Scenario B, 100% participation). The values are too different from each other because some items in the calculated cost are not included in the bid such as the cost of the wells, pumping station building. But since this value can be viewed as the real investment cost the system will be very economic if the same prices are continued to be applied.

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APPENDICES

Appendix 1a. The Original Survey

Date: ... / ... / ....

Our company started a new project for extending the existing geothermal district heating system which uses economic and environment friendly energy source. Being a national and clean energy source it is aimed to design perfect system for you. If you desire so please fill in this survey correctly and fully.

Sincerely
Balçova Geothermal Energy
Ltd. Sti.

1. Address Information
Name / Surname / Tel :
Dwelling Owner Name / Surname / Tel (Empty if owner)
District :
Street :
Building Name / No :
Storey : Ground Roof Ground + ... Storey
Daire No :
Stories in the Building :
Building Administrator :(if existing Name / SUrname / Tel)

Area of your dwelling? (According to deed)

2. Which option you use for heating ?

(A) Flat Heating System (LPG / Fuel-Oil)
(B) Central Heating System (Coal / Fuel-Oil / LPG)
(C) Stove (Wood / Coal / Electricity)
(D) Air Conditioner
(E) Others :

3. How much is your annual fuel cost?
(A) LPG :
(B) Coal :
(C) Fuel-oil :
(D) Electricity :
(E) Wood :
(F) Others :

4. If answer to the 2nd question is A or B do you have:
Flat Heating System Installation Project? YES □ NO □

5. If answer to the 2nd question is A or B:
Which heating elements do you have?
□Panel radiator (PR) □Peak radiator (DR) □Aluminum radiator (AR)
□Floor Heating (FH) □Fan-Coil (FC)

6. If answer to the 2nd question is A or B:
Radiator type/ total length :

Lounge	: .... /	Kitchen	:......... /	Living Room	: .... / ....
Bedroom	: .... /	Bedroom	:......... /	Corridor	: .... / ....
Bathroom	: .... /	Other	: .... /	Other	: .... / ....

7. How long do you heat your dwelling? (Months) (A) 1 (B) 2 (C) 3 (D) 4 (E) 5
8. Do you have thermometers (temperature measuring device) in your dwelling? (A) Yes (B) No
9. What is the average indoor temperature at winter? (A) Below 18°C (B) Between 18°C - 22°C (C) Above 22°C
10. What are your window frame types? (A) Wooden frame (B) Plastic frame (C) Metal frame
11. What are your glass types? (A) Single glasses (B) Double glasses
12. How do you obtain your hot tap water? (A) Central Heating (B) Kombi (C) Water heater (LPG) (D) Water heater (electrical) (E) Sun Energy (F) Others :
13. If answer to the 12th question is C : How long do you use one LPG tube ?
14. Do you want to participitate in the Geothermal District Heating System? □YES □NO
15. Geothermal District Heating Systems have two main costs per dwelling. First one is the participation cost which is in the range of $ 1000-1500. The second one is if an radiator system does not exist in your dwelling you should install one of which cost is about $ 1000. The foreseen participation cost is about $ 1000-1500 for your district. Can you pay this amount in cash or with credits in 12 months? □Yes I can pay in cash □I can pay with credits □No I cannot afford If you don't have a radiator system can you install this and pay about $ 1000? □YES □NO
NOTES and OPINIONS:

Appendix 1b. The Modified Survey

Date: ... / ... / ....

Our company started a new project for extending the existing geothermal district heating system which uses economic and environment friendly energy source. Being a national and clean energy source it is aimed to design perfect system for you. If you desire so please fill in this survey correctly and fully.

Sincerely
Balçova Geothermal Energy
Ltd. Sti.

---

1. Address Information

Name / Surname / Tel :
Dwelling Owner Name / Surname / Tel (Empty if owner)
District :
Street :
Building Name / No :
Storey : Ground Roof Ground + ... Storey
Daire No :
Stories in the Building :
Building Administrator :(if existing Name / SUrname / Tel)

Area of your dwelling? (According to deed):

---

2. Which option you use for heating ?

(A) Flat Heating System
- LPG
- Fuel-Oil
- Others

(B) Stove
- Coal
- Electricity
- LPG
- Kerosene
- Others

(D) Air Conditioner
(E) Others :

---

3. How much is your annual fuel cost?

(A) Amount (B) Cost

---

4. How much area do you heat?

---

5. If answer to the 2nd question is A or B do you have:

Flat Heating System Installation Project? YES □ NO □

---

6. If answer to the 2nd question is A:

Which heating elements do you have?

□Panel radiator (PR) □Peak radiator (DR) □Aluminum radiator (AR)
□Floor Heating (FH) □Fan-Coil (FC)

---

7. If answer to the 2nd question is A or B:

Radiator type/ total length :

Lounge	: .... /	Kitchen	:......... /	Living Room	: .... / ....
Bedroom	: .... /	Bedroom	:......... /	Corridor	: .... / ....

Bathroom	: .... /	Other	: .... /	Other	: .... / ....

8. How long do you heat your dwelling? (Months)
(A) 1 (B) 2 (C) 3 (D) 4 (E) 5 (F) 6

9. Do you have thermometers (temperature measuring device) in your dwelling?
(A) Yes (B) No

10. What is the average indoor temperature at winter?
(A) Below 18°C (B) Between 18°C - 22°C (C) Above 22°C

11. What are your window frame types?
(A) Wooden frame (B) Plastic frame (C) Metal frame

12. What are your glass types?
(A) Single glasses (B) Double glasses

13. How do you obtain your hot tap water?
(A) Boiler
(B) Kombi
(C) Water heater (LPG)
(D) Water heater (electrical)
(E) Sun Energy
(F) Others :

14. If answer to the 12th question is C :
How long do you use one LPG tube ?

15. Do you want to participitate in the Geothermal District Heating System?
□YES □NO

16. Geothermal District Heating Systems have two main costs per dwelling. First one is the participation cost which is in the range of $ 1000-1500. The second one is if an radiator system does not exist in your dwelling you should install one of which cost is about $ 1000.

The foreseen participation cost is about $ 1000-1500 for your district. Can you pay this amount in cash or with credits in 12 months?

□Yes I can pay in cash
□I can pay with credits
□No I cannot afford

If you don’t have a radiator system can you install this and pay about $ 1000?

□YES □NO

NOTES and OPINIONS:

Appendix 2

Comparison of the Temperature Alternatives.								
GEOTHERMAL LOOP			**GEOTHERMAL LOOP**			**GEOTHERMAL LOOP**		
T_1 =	120	°C	T_1 =	120	°C	T_1 =	120	°C
T_2 =	55	°C	T_2 =	55	°C	T_2 =	55	°C
LMTD 1=	13,95		LMTD 1=	16,83		LMTD 1=	18,20	
CITY LOOP			**CITY LOOP**			**CITY LOOP**		
T_1 =	90	°C	T_1 =	80	°C	T_1 =	90	°C
T_2 =	50	°C	T_2 =	50	°C	T_2 =	50	°C
BUILDING LOOP			**BUILDING LOOP**			**BUILDING LOOP**		
T_3 =	70	°C	T_3 =	70	°C	T_3 =	80	°C
T_4 =	45	°C	T_4 =	45	°C	T_4 =	45	°C
LMTD 2=	10,82	°C	LMTD 2=	7,21	°C	LMTD 2=	7,21	°C
PIPE COST	994.100	$	PIPE COST	1.230.034	$	PIPE COST	994.100	$
PUMPING STATION HEAT EXCHANGER COST								
54.954	**$**		**46.980**	**$**		**54.954**	**$**	
826	m^2		1239	m^2		1239	m^2	
21.504.330	kcal/h		21.504.330	kcal/h		21.504.330	kcal/h	
k=	2406							
RADIATOR COST								
21.504.330	kcal/h		21.504.330	kcal/h		21.504.330	kcal/h	
RADIATOR EFFICIENCY		0,52	RADIATOR EFFICIENCY		0,48	RADIATOR EFFICIENCY		0,47
18.964	m^2		18.964	m^2		17.299	m^2	
BUILDING HEAT EXCHANGERS TOTAL COST								
134.508	$		115.250	$		190.000	$	
TOTAL COST			**TOTAL COST**			**TOTAL COST**		
1.183.562		**$**	**1.392.264**		**$**	**1.239.054**		**$**