

**THE USAGE OF STOCHASTIC AND
MULTICRITERIA DECISION-AID METHODS
EVALUATING GEOTHERMAL ENERGY
EXPLOITATION PROJECTS**

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ABSTRACT

This study is based on three main questions about the utilization of geothermal energy. The first question is how much heat energy the geothermal resource contains? The second one is what the utilization alternatives are for this resource? And the last question is according to which criteria the scenarios formed by integration of the selected utilization alternatives in specified proportions could be assessed, and what the alternative schema obtained could be like?

The method of forming a model by simulations, which is developed as an approach to the solutions of the problems that contain uncertain parameters, like what the heating capacities of the reservoirs are, is used in this study. A model is formed with parameters of the heating capacity of Balçova Geothermal Field by employing Monte Carlo Simulation Technique. Here the aim is to find the amount of the heating energy that could be exploited by sustainable way from the resource. Efforts are given to form the amount of this energy by the help of cumulative probability distribution of the model.

It is emphasized what the estimated heating reserve and the alternatives that could be locally utilized. Here, parameters such as the enthalpy of the geothermal resource, content of the fluid, volume of the geothermal field, pattern of the settlement in the field, ability of the soil, topography and structure of the labor etc. should be considered in the light of reconnaissance and exploration studies done in the geothermal field. From the assessment done for Balçova, it is concluded that geothermal resource could be utilized for heating of the dwellings, greenhouse agriculture, thermal tourism and dehydration of fruit and vegetable.

Having determined the utilization schema of the geothermal resource, the issue of the assessment of the scenarios, which will be formed from these alternatives, comes up. Here begins the decision making process with a political aspect. By determining the criteria that will be considered while selecting the scenarios, and by determining the relative weights of this criteria, an order which shows the desired situation between the scenarios could be obtained. In this study, the scenarios formed in Balçova are assessed by the help of PROMETHEE method –one of the Multicriteria Decision Aid technique. As a result, it is seen that in Balçova tourism related scenarios stand out because of their superiority in employment created and Tons of Petroleum Equivalent energy values.

ÖZ

Jeotermal enerjinin kullanımı ile ilgili üç ana sorudan hareket edilerek bu çalışma hazırlanmıştır. Birincisi, sahip olunan jeotermal kaynağı ısı potansiyeli ne kadardır? İkincisi, bu kaynak ne tür kullanımlar için değerlendirilebilir? Üçüncüsü ise, seçilen bir kullanım veya kullanımların belirli oranlarda birleştirilmesi ile oluşturulan senaryolar hangi kriterlere göre değerlendirilebilir ve nasıl bir kullanım şeması elde edilebilir?

Jeotermal enerji rezervuarlarının ısı kapasitesinin büyüklüğünün ne kadar olduğu gibi çeşitli belirsiz parametreleri içinde barındıran problemlerin çözümüne bir yaklaşım olarak geliştirilen, simülasyonlar ile model oluşturma yöntemi bu çalışmada da kullanılmıştır. Monte Carlo Simülasyon tekniği kullanılarak Balçova sahasının ısı kapasitesine ait parametrelerle bir model oluşturulmuştur. Buradaki amaç kaynaktan sürdürülebilir şekilde kullanılacak ısı enerjisi miktarını bulmaya çalışmaktır. Bu enerji miktarı modelin kümülatif olasılık dağılımı verileri yardımıyla oluşturulmaya çalışılmıştır.

Tahminlenen ısı rezervi ile yerel olarak değerlendirilebilecek kullanımların neler olabileceği üzerinde durulmuştur. Burada jeotermal sahada yapılan keşif ve arama çalışmalarının sonuçları ışığında jeotermal kaynağın entalpisi, akışkanın içeriği, alanın hacmi, topografyası, alandaki yerleşmelerin niteliği, toprak kabiliyeti, işgücü yapısı gibi parametrelerin göz önünde bulundurulması gerekmektedir. Balçova için yapılan değerlendirmeden, jeotermal kaynağın konut ısıtılmasında, sera tarımında, termal turizmde ve sebze-meyve kurutulmasında kullanılabilmesi sonuçları elde edilmiştir.

Jeotermal enerjinin hangi kullanımlarda değerlendirilebileceği belirlendikten sonra, bunlardan oluşturulacak senaryoların değerlendirilmesi konusu gündeme gelmektedir. Burada politik yanı ağır basan karar verme süreci başlamaktadır. Senaryoları seçerken dikkate alınacak kriterlerin ve bu kriterlerin göreceli ağırlıklarının belirlenmesi ile senaryolar arasında istenilen durumu yansıtan bir sıralama elde edilebilir. Bu çalışmada Çoklu Kriterlere Göre Karar Verme Tekniklerinden birisi olan PROMETHEE metodu yardımı ile Balçova özelinde oluşturulan senaryolar değerlendirilmiştir. Sonuç olarak Balçova'da turizm ağırlıklı senaryoların, yarattıkları işgücü ve petrol eşdeğeri enerji kullanımı kriterlerindeki üstünlüğü sebebi ile ön plana çıktıkları görülmüştür.

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CHAPTER 1

INTRODUCTION

1.1 Problem Definition and the Methodology of the Study

When the issue of utilization of geothermal energy resources is examined from economic, environmental and social point of views, one could see that, if this available energy could be used in sustainable way, hypothetically, designated part of energy demand could be met without import dependent resources for many years, and this could have social and environmental effects that could increase the prosperity of the public.

It could be said that, it is impossible to evaluate the energy capacity of the geothermal energy resources with deterministic ways, as there are many parameters that present uncertainty. In case of situations in which these kind of uncertain parameters affect the overall results, the modeling of reservoir could be done by various computer softwares. By the help of these models, estimations about utilization alternatives that will provide the use of the reservoir sustainability –directly related to the probability distribution of the parameters used in the simulation- could be done. Thus, the heat load that the alternatives about the exploitation of the geothermal energy resource will bring to the system could be found and a system suitable for this could be constructed.

According to which criteria that the formed scenarios will be assessed could be qualified as an issue with the political background. Efforts is given to form methodologies in order to clarify and democratize the assessments, that could be tangible or intangible according to the criteria, of the decisions that decision makers are responsible for. By the help of this kind of methodologies, it could be discussed how much the decisions made satisfy the criteria. Additionally, it could be determined what the most suitable scenario(s) would be according to the assessment criteria of the proposed alternatives.

In this study, effort will be given to model heat energy of Balçova geothermal field reservoir with Monte Carlo simulation technique and to estimate sustainable energy capacity of it. While doing this, the result of the studies on Balçova done before will be compared with the result of the model studied in this study.

After this, it will be evaluated what the alternatives about the exploitation of this energy capacity could be, and outputs of these alternatives under the criteria Return on

Investment (ROI), employment created and Tons of Oil Equivalent (TOE) energy will be assessed. Here the aim is to measure efficiency of the scenarios according to economic, social and environmental standpoints that the decision makers would consider. The heating energy that the mentioned alternatives could demand at peak load will be determined. Additionally, it will be discussed what kind of heating system will be necessary and what it would cost.

In the study, scenarios will be formed from utilization alternatives, effort will be given to obtain the complete outrank of the scenarios in the context of the weights that the decision makers will assign to the criteria with the PROMETHEE method, one of the Multicriteria Decision Aid Techniques. Evaluation on the obtained results will be done and the effects of the assumptions on the results will be emphasized.

1.2 Content of the Study

In the first chapter, problem definition and the methodology of the study will be introduced.

In the second chapter, geothermal energy and its application fields will be introduced. Here the purpose is to inform the reader about the issue of geothermal energy. After introducing geothermal energy including technical details, the exploitation schema will be shortly mentioned.

Following this, in the third chapter, the geographical, geological and settlement structure of Balçova geothermal field will be explained. The historical evolution of Balçova geothermal district heating system –as academically most studied geothermal heating project in Turkey- will be introduced.

In the fourth chapter, the Monte Carlo Simulation Technique will be introduced. The exploration studies of petroleum and geothermal field reserve done by using Monte Carlo simulation technique will be summarized. The simulation in the study done by ITU Petroleum and Natural Gas Department, in 2002, will be introduced and evaluated. After this, the simulation done by similar data will be introduced and information about the reserve will be given.

In the fifth chapter, Multicriteria Decision Aid and its methods will be introduced. The advantage of PROMETHEE method over the other methods will be listed, and the use of the method will be explained in detail. The possible exploitation schema of Balçova Geothermal Field reserve will be determined and the economic, environmental

and social benefit analysis will be done (corresponding benefits are ROI, TOE and employment created). Scenarios will be formed by proportioning the utilization alternatives of Balçova Geothermal Field reserve according to various percentages based on the peak load of the heating system. For each scenario, ROI, TOE and employment created will be calculated. Here, three drying facilities will be attached to each scenario, and effort will be given to determine how the utilization of the system in low season will affect the output of the scenarios. Following this, the scenario that will satisfy the hypothetical decision maker most –according to the weights he will assigned to the criteria- will be determined and evaluated.

In the sixth chapter, the assessments concerning the model proposed, which is about how to exploit the Balçova Geothermal Field reserve according to the scenarios, will be gathered and presented together. The strong and the weak aspects of the model proposed will be emphasized.

CHAPTER 2

GEOTHERMAL ENERGY AND APPLICATION FIELDS

2.1 Introducing Geothermal Energy

Geothermal energy, basically, is the thermal energy within the earth's interior and recognized as an important and viable source of renewable energy. It has been used for many centuries for different purposes such as space and water heating, cooking, and medicinal bathing.

The *geothermal gradient* expresses the increase in temperature with depth in the Earth's crust. Down to the depths accessible by drilling with modern technology, i.e. over 10,000 m, the average geothermal gradient is about 2.5-3 °C/100 m. For example, if the temperature within the first few meters below ground-level, which on average corresponds to the mean annual temperature of the external air, is 15 °C, then we can reasonably assume that the temperature will be about 65°-75 °C at 2000 m depth, 90°-105 °C at 3000 m and so on for a further few thousand meters. There are, however, vast areas in which the geothermal gradient is far from the average value. In areas in which the deep rock basement has undergone rapid sinking, and the basin is filled with geologically 'very young' sediments, the geothermal gradient may be lower than 1 °C/100 m. On the other hand, in some 'geothermal areas' the gradient is more than ten times the average value (WEB_1 2005).

The difference in temperature between deep hotter zones and shallow colder zones generates a conductive flow of heat from the former towards the latter, with a tendency to create uniform conditions, although, as often happens with natural phenomena, this situation is never actually attained. The mean *terrestrial heat flow* of continents and oceans is 65 and 101 mWm⁻², respectively, which, when really weighted, yield a global mean of 87 mWm⁻² (Pollack et al. 1993).

The temperature increase with depth, as well as volcanoes, geysers, hot springs, etc., are in a sense the visible or tangible expression of the heat in the interior of the Earth, but this heat also engenders other phenomena that are less discernible by man, but of such magnitude that the Earth has been compared to an immense 'thermal engine'. It will be tried to describe these phenomena, referred to collectively as the *plate tectonics* theory, in simple terms, and their relationship with geothermal resources (WEB_1 2005).

The outermost shell of the Earth, known as the *lithosphere*, is made up of the crust and the upper layer of the mantle. Ranging in thickness from less than 80 km in oceanic zones to over 200 km in continental areas, the lithosphere behaves as a rigid body. Below the lithosphere is the zone known as the *asthenosphere*, 200-300 km in thickness, and of a 'less rigid' or 'more plastic' behaviour. In other words, on a geological scale in which time is measured in millions of years, this part of the Earth behaves in much the same way as a fluid in certain processes (WEB_1 2005).

Because of the difference in temperature between the different parts of the asthenosphere, convective movements and, possibly, convective cells were formed some tens of millions of years ago. Their extremely slow movement (a few centimetres per year) is maintained by the heat produced continually by the decay of the radioactive elements and the heat coming from the deepest parts of the Earth. Immense volumes of deep hotter rocks, less dense and lighter than the surrounding material, rise with these movements towards the surface, while the colder, denser and heavier rocks near the surface tend to sink, re-heat and rise to the surface once again; very similar to what happens to water boiling in a pot or kettle (WEB_1 2005).

Geothermal systems can therefore be found in regions with a normal or slightly above normal geothermal gradient, and especially in regions around plate margins where the geothermal gradients may be significantly higher than the average value. In the first case the systems will be characterized by low temperatures, usually no higher than 100 °C at economic depths; in the second case the temperatures could cover a wide range from low to very high, and even above 400 °C (WEB_1 2005).

To sum up, the terms that are basic to a discussion of the nature and distribution of geothermal energy are *geothermal gradient*, *heat flow* and *geothermal anomaly*. *Geothermal gradient* refers to the increase of temperature as the depth increases: the deeper into the earth, the higher the temperature. Normally the temperature increases 1°C in 33 m. However, the increase may exceed 5°C in 33 m because geologic setting and rock types differ. Thermal energy moves toward the earth's surface by conduction of heat through solid rock, by movement of molten rock (magma), or by movement of water. The vertical movement of thermal energy by conduction is called *heat flow*.

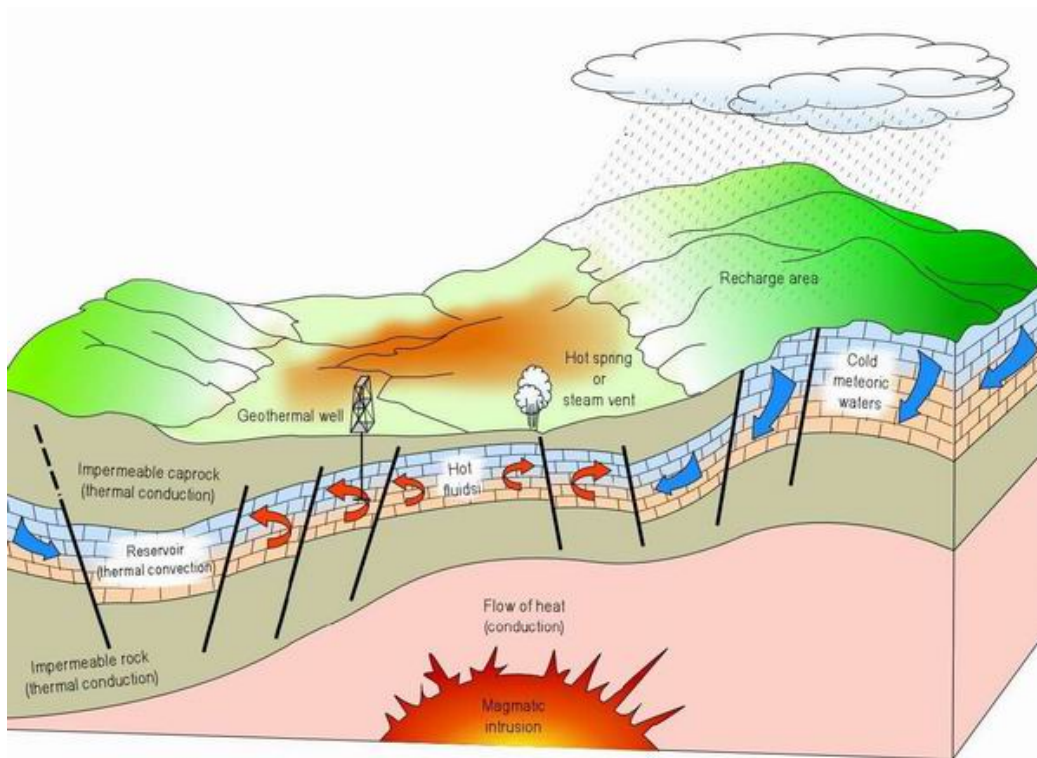
In some geothermal areas, temperatures at some depths are higher or lower than temperatures in nearby terrain. This temperature irregularity, called a *geothermal anomaly*, may be limited to a small area and only a single hot spring may indicate the

anomaly. On the other hand, the area may be a region of thousands of square miles. Because drilling, developing and maintaining wells that will produce warm or hot water is expensive, geothermal exploration involves locating positive geothermal anomalies with relatively high temperatures close to the surface (WEB_1 2005).

Main mechanism of the geothermal energy resources could be summarized as follow. Geothermal resources have three main components: a heat source, a reservoir, and a fluid. The heat source can be either a very high temperature (>600 oC) magmatic intrusion that has reached relatively shallow depths (5-10 km) or, as in certain low-temperature systems, the Earth's normal temperature, which is, increases with depth. Geothermal fluid is the carrier that transfers the heat. Circulating fluids extract heat from the reservoir, which is a volume of hot permeable rocks. Reservoirs may contain hot water and/or steam. In many, but not all cases, the reservoir is connected to a surface recharge area that replenishes all or part of the fluids emerging naturally (for example in springs) or extracted in wells.

High heat flow zones may be located close to the surface where convective circulation plays a significant role in bringing the heat close to the surface. Convection occurs because of the heating and consequent thermal expansion of fluids in a gravity field. Heated fluid of lower density tends to rise and to be replaced by colder fluid of high density, coming from the margins of the system. Deep circulation of groundwater along fracture zones will bring the heat to shallower levels, collecting the heat flow from a broad area and concentrating it into shallow reservoirs or discharging as hot springs. By drilling into reservoirs, the hot water and/or steam are piped to the surface. The schematic representation of an ideal geothermal system is given in the figure below. Main mechanism and the movements of the geothermal components of the geothermal reservoir could be seen in the figure.

Figure 1. Schematic representation of an ideal geothermal system



Source: WEB_1 2005

The most common criterion for classifying geothermal resources is that based on the enthalpy of the geothermal fluids that act as the carrier transporting heat from the deep hot rocks to the surface. *Enthalpy*, which can be considered more or less proportional to temperature, is used to express the heat (thermal energy) content of the fluids, and gives a rough idea of their 'value'. The resources are divided into low, medium and high enthalpy (or temperature) resources, according to criteria that are generally based on the energy content of the fluids and their potential forms of utilization. Table below reports the classifications proposed by a number of authors. A standard method of classification, as with terminology, would avoid confusion and ambiguity but, until such a method exists, it would be indicated that the temperature values or ranges involved case by case, since terms such as low, intermediate and high are meaningless at best, and frequently misleading (WEB_1 2005).

Table 1. Classification of geothermal resources (°C) (WEB_1 2005)

	(a)	(b)	(c)	(d)	(e)
Low enthalpy resources	< 90	<125	<100	≤150	≤190
Intermediate enthalpy resources	90-150	125-225	100-200	-	-
High enthalpy resources	>150	>225	>200	>150	>190

Source: (a) Muffler and Cataldi (1978).
(b) Hochstein (1990).
(c) Benderitter and Cormy (1990).
(d) Nicholson (1993).
(e) Axelsson and Gunnlaugsson (2000)

2.2 Exploration of Geothermal Energy

According to the wide literature on this subject indicates that there are nine main objectives of geothermal exploration (Lumb 1981). These are:

1. To identify geothermal phenomena.
2. To ascertain that a useful geothermal production field exists.
3. To estimate the size of the resource.
4. To determine the type of geothermal field.
5. To locate productive zones.
6. To determine the heat content of the fluids that will be discharged by the wells in the geothermal field.
7. To compile a body of basic data against which the results of future monitoring can be viewed.
8. To determine the pre-exploitation values of environmentally sensitive parameters.
9. To acquire knowledge of any characteristics that might cause problems during field development.

The relative importance of each objective depends on a number of factors, most of which are tied to the resource itself. These include anticipated utilization, technology available, economics, as well as situation, location and time, all of which affect the exploration program. For example, the preliminary reconnaissance of geothermal manifestations assumes much greater importance in a remote, unexplored area than in a

well-known area; estimating the size of the resource may be less important if it is to be used in a small-scale application that obviously requires much less heat than is already discharging naturally; if the energy is to be used for district-heating or some other application needing low-grade heat, then a high-temperature fluid is no longer an important objective (Lumb 1981).

2.2.1 Exploration Methods

Geological and hydrogeological studies are the starting point of any exploration program, and their basic function is that of identifying the location and extension of the areas worth investigating in greater detail and of recommending the most suitable exploration methods for these areas. Geological and hydrogeological studies have an important role in all subsequent phases of geothermal research, right up to the siting of exploratory and producing boreholes. They also provide the background information for interpreting the data obtained with the other exploration methods and, finally, for constructing a realistic model of the geothermal system and assessing the potential of the resource. The information obtained from the geological and hydrogeological studies may also be used in the production phase, providing valuable information for the reservoir and production engineers. The duration and cost of exploration can be appreciably reduced by a good exploration program and an efficient coordination of the research (WEB_1 2005).

Geochemical surveys (including isotope geochemistry) are a useful means of determining whether the geothermal system is water- or vapor-dominated, of estimating the minimum temperature expected at depth, of estimating the homogeneity of the water supply, of inferring the chemical characteristics of the deep fluid, and of determining the source of recharge water. Valuable information can also be obtained on the type of problems that are likely to arise during the re-injection phase and plant utilization (e.g. changes in fluid composition, corrosion and scaling on pipes and plant installations, environmental impact) and how to avoid or combat them. The geochemical survey consists of sampling and chemical and/or isotope analyses of the water and gas from geothermal manifestations (hot springs, fumaroles, etc.) or wells in the study area. As the geochemical survey provides useful data for planning exploration and its cost is relatively low compared to other more sophisticated methods, such as the geophysical surveys, the geochemical techniques should be utilized as much as possible before proceeding with other more expensive methodologies (WEB_1 2005).

Geophysical surveys are directed at obtaining indirectly, from the surface or from depth intervals close to the surface, the physical parameters of deep geological formations. According to the Dickson and Fanelli (2004), these physical parameters include:

- 1 Temperature (thermal survey)
- 2 Electrical conductivity (electrical and electromagnetic methods)
- 3 Propagation velocity of elastic waves (seismic survey)
- 4 Density (gravity survey)
- 5 Magnetic susceptibility (magnetic survey).

Some of these techniques, such as seismic, gravity and magnetic, which are traditionally adopted in oil research, can give valuable information on the shape, size, depth and other important characteristics of the deep geological structures that could constitute a geothermal reservoir, but they give little or no indication as to whether these structures actually contain the fluids that are the primary objective of research. These methodologies are, therefore, more suited to defining details during the final stages of exploration, before the exploratory wells are sited. Information on the existence of geothermal fluids in the geological structures can be obtained with the electrical and electromagnetic prospectings, which are more sensitive than the other surveys to the presence of these fluids and to variations in temperature; these two techniques have been applied widely with satisfactory results. The magnetotelluric method, which exploits the electromagnetic waves generated by solar storms, has been greatly improved over the last few years, and now offers a vast spectrum of possible applications, despite the fact that it requires sophisticated instrumentation and is sensitive to background noise in urbanized areas. The main advantage of the magnetotelluric method is that it can be used to define deeper structures than are attainable with the electric and the other electromagnetic techniques. The Controlled Source Audiomagnetotelluric method (CSAMT) developed recently uses artificially induced waves instead of natural electro-magnetic waves. The penetration depth is shallower with this technique, but it is quicker, cheaper, and provides far more detail than the classic MT method.

Thermal techniques (temperature measurements, determination of geothermal gradient and terrestrial heat flow) can often provide a good approximation of the temperature at the top of the reservoir.

Drilling of *exploratory wells* represents the final phase of any geothermal exploration program and is the only means of determining the real characteristics of the geothermal reservoir and thus of assessing its potential (Combs and Muffler 1973). The data provided by exploratory wells should be capable of verifying all the hypotheses and models elaborated from the results of surface exploration and of confirming that the reservoir is productive and that it contains enough fluids of adequate characteristics for the utilization for which it is intended.

2.2.2 Exploration Program

Before drawing up a geothermal exploration program all existing geological, geophysical and geochemical data must be collected and integrated with any data available from previous studies on water, minerals and oil resources in the study area and adjacent areas. This information frequently plays an important role in defining the objectives of the geothermal exploration program and could lead to a significant reduction in costs (WEB_1 2005).

The exploration program is usually developed on a step-by-step basis: *reconnaissance*, *pre-feasibility* and *feasibility*. During each of these phases the less interesting areas are eliminated gradually. The methods used also become progressively more sophisticated and more detailed as the program develops. The size and budget of the entire program should be proportional to its objectives, to the importance of the resources expected to find, and to the planned forms of utilization. The program schedule should be flexible and reassessed as the results come in from the various surveys of each phase; similarly the geological-geothermal model should be progressively updated and improved. These periodic re-assessments of the program should ideally eliminate any operations that are no longer necessary and insert others, according to the results attained at each stage. Clearly any reduction in the number and size of the prospecting will lead to a decrease in costs, and also a corresponding increase in the risk of error or failure. Conversely, by decreasing the risk of error the overall cost is increased. The economic success of a geothermal exploration program hinges on finding the proper balance between the two (WEB_1 2005).

2.3 Utilization of the Geothermal Resources

Geothermal energy developments could be broken down into two distinct categories: electricity production and heating applications. Geothermal heating

applications are called, variously, “direct use” or “low enthalpy”. The term “direct use” serves to distinguish the applications from “indirect” electricity production and the term “low enthalpy” is used to indicate that fluids, which are employed for heating usually, have low heat content (Batik et al 2000).

The range of potential methods for utilizing from any geothermal resource mainly depends on the temperature of resources. The most important commercial thermal applications are:

1. Electricity generation
2. Heating of dwellings, hotels, offices, hospitals, campus areas and other public houses
3. Space cooling applications by using an absorption refrigeration cycle
4. Obtaining of domestic hot and cold water
5. Heat pump applications
6. Agricultural facilities like place heating, combined space and hotbed heating of greenhouses for vegetables, flowers, plants, animal farms; drying of vegetables, fishes, rice, tobacco; mushroom growing or usage in hot irrigation
7. Therapeutic (health) and recreational bathing (heating of thermal and public swimming pools)
8. Heating of aquaculture farms
9. Open field heating (heating of streets, parking areas, and sidewalks)
10. Industrial applications (in sterilization, pasteurization, evaporation, and distillation processes) (Lund 1998)

Direct utilization is the oldest and common method of utilizing the geothermal resources. For instance, space heating, agricultural, balneologic and industrial applications are widely known fields of utilization geothermal energy. On the other hand, generating electricity is required a resource having 150 °C and more temperature capacity. More systematically, Lindal (1973) determines the utilization of the geothermal resource according to its temperature as shown in table below.

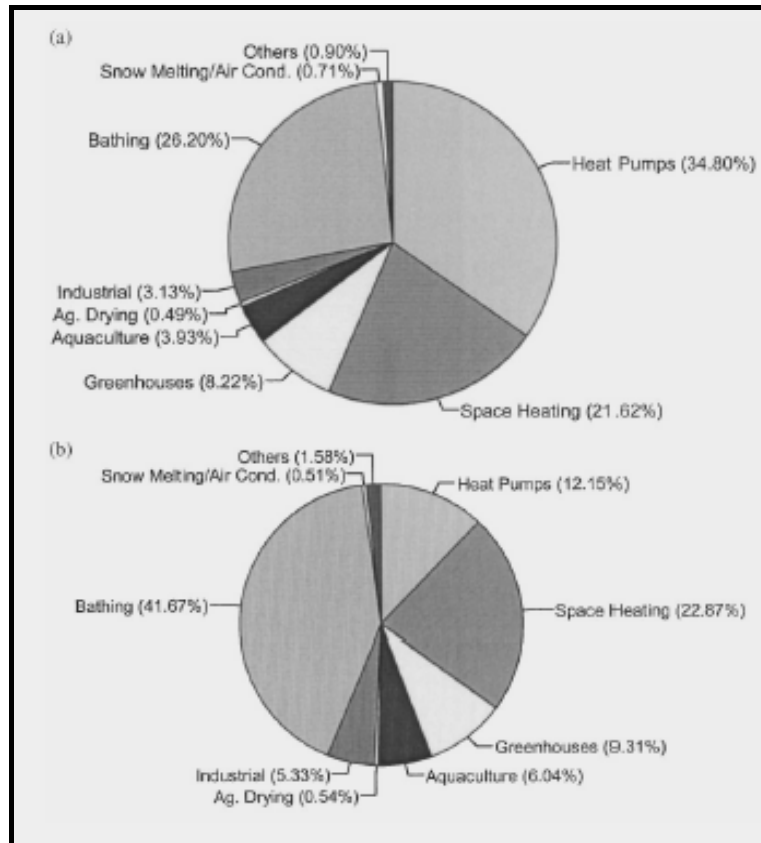
Table 2.Utilization of Geothermal Fluids (Lindal 1973)

^o C	Utilization Fields
180	Evaporation of highly concentrated solutions, Refrigeration by ammonia absorption, Digestion in paper pulp, kraft
170	Heavy water via hydrogen sulphide process Drying of diatomaceous earth
160	Drying of fish meal Drying of timber
150	Alumina via Bayer's process
140	Drying farm product at high rates Canning of food
130	Evaporation in sugar refining Extraction of salts by evaporation and crystallization
120	Fresh water by distillation Most multiple effect evaporations, concentration of saline solution
110	Drying and curing of light aggregate cement slabs
100	Drying of organic materials, seaweeds, grass, vegetables, etc. Washing and drying of wool
90	Drying of stock fish Intense de-icing operations
80	Space heating Greenhouses by space heating
70	Refrigeration (lower temperature limit)
60	Animal husbandry Greenhouses by combined space and hotbed heating
50	Mushroom growing Balneological baths
40	Soil warming
30	Swimming pools, biodegradation, fermentations, Warm water for year round mining in cold climates De-icing
20	Hatching of fish, fish farming

2.3.1 Geothermal Energy Utilization in the World

The levels of geothermal energy capacity and utilization fields differentiate among the countries when the whole world is considered. The most common non-electric use world-wide (in terms of installed capacity) is heat pumps (34.80%), followed by bathing (26.20%), space-heating (21.62%), greenhouses (8.22%), aquaculture (3.93%), and industrial processes (3.13%) (Lund and Freeston 2001). At the graph below, (a) shows the categories of capacity, (b) shows the categories of energy use in % for 2000.

Graph 1. Geothermal Energy Capacity and Utilization Fields in the World



Source: Lund and Freeston 2001

With 41,67 %, bathing is the most widely used field in the world. As a new trend in tourism, thermal foundations have contributed to increasing share of utilization of geothermal resources. Especially in the US, the number of spa locations has doubled in number every four years. According to the International Spa Association (ISPA-2002), health tourism has become more dominant within the all types of tourism. The reasons of this trend can be summarized by the factors: increasing the number of old age individual in especially developed countries, health problems based on old age, increasing concern on personal care and beauty. Thermal tourism have been developing especially in Germany, Japan, America, France, Italy, Austria, Hungary, Czechoslovakia, Switzerland, Spain, Greece, New Zealand and Australia (WEB_2 2002).

The countries that utilize geothermal energy to *generate electricity* are listed in Table 3, which also gives the installed geothermal electric capacity in 1995 (6833 MW_e), in 2000 (7972 MW_e) and the increase between 1995 and the year 2000 (Huttrer, 2001). The same table also reports the total installed capacity at the end of 2003 (8402

MW_e). The geothermal power installed in the developing countries in 1995 and 2000 represents 38 and 47% of the world total, respectively.

The utilization of geothermal energy in developing countries has exhibited an interesting trend over the years. In the five years between 1975 and 1979 the geothermal electric capacity installed in these countries increased from 75 to 462 MW_e; by the end of the next five-year period (1984) this figure had reached 1495 MW_e, showing a rate of increase during these two periods of 500% and 223%, respectively. In the next sixteen years, from 1984 to 2000, there was a further increase of almost 150%. Geothermal power plays a fairly significant role in the energy balance of some areas; for example, in 2001 the electric energy produced from geothermal resources represented 27% of the total electricity generated in the Philippines, 12.4% in Kenya, 11.4% in Costa Rica, and 4.3% in El Salvador (WEB_1 2005).

Table 3. Installed geothermal generating capacities world-wide from 1995 to 2000 and at the end of 2003 (Huttrer 2001)

Country	1995	2000	1995-2000	Increase	2003
Argentina	0.67	-	-	-	-
Australia	0.15	0.15	-	-	0.15
Austria	-	-	-	-	1.25
China	28.78	29.17	0.39	1.35	28.18
Costa Rica	55	142.5	87.5	159	162.5
El Salvador	105	161	56	53.3	161
Ethiopia	-	7	7	-	7
France	4.2	4.2	-	-	15
Germany	-	-	-	-	0.23
Guatemala	-	33.4	33.4	-	29
Iceland	50	170	120	240	200
Indonesia	309.75	589.5	279.75	90.3	807
Italy	631.7	785	153.3	24.3	790.5
Japan	413.7	546.9	133.2	32.2	560.9
Kenya	45	45	-	-	121
Mexico	753	755	2	0.3	953
New Zealand	286	437	151	52.8	421.3
Nicaragua	70	70	-	-	77.5
Papua New	-	-	-	-	6
Philippines	1227	1909	682	55.8	1931
Portugal	5	16	11	220	16
Russia	11	23	12	109	73
Thailand	0.3	0.3	-	-	0.3
Turkey	20.4	20.4	-	-	20.4
USA	2816.7	2228	-	-	2020
Total	6833.35	7972.5	1728.54	16.7	8402.21

As regards *non-electric applications* of geothermal energy, Table 4 gives the installed capacity (15,145 MW_t) and energy use (190,699 TJ/yr) world-wide for the year 2000. During that year 58 countries reported direct uses, compared to 28 in 1995 and 24 in 1985. The number of countries with direct uses has very likely increased since then,

as well as the total installed capacity and energy use.

Table 4. Non-electric uses of geothermal energy in the world (2000): installed thermal power (in MW_t) and energy use (in TJ/yr) (Lund and Freeston 2001)

Country	Power	Energy	Country	Power	Energy
Algeria	100	1586	Israel	63.3	1713
Argentina	25.7	449	Italy	325.8	3774
Armenia	1	15	Japan	1167	26933
Australia	34.4	351	Jordan	153.3	1540
Austria	255.3	1609	Kenya	1.3	10
Belgium	3.9	107	Korea	35.8	753
Bulgaria	107.2	1637	Lithuania	21	599
Canada	377.6	1023	Macedonia	81.2	510
Caribbean	0.1	1	Mexico	164.2	3919
Chile	0.4	7	Nepal	1.1	22
China	2282	37908	Netherlands	10.8	57
Colombia	13.3	266	New Zealand	307.9	7081
Croatia	113.9	555	Norway	6	32
Czech Republic	12.5	128	Peru	2.4	49
Denmark	7.4	75	Philippines	1	25
Egypt	1	15	Poland	68.5	275
Finland	80.5	484	Portugal	5.5	35
France	326	4895	Romania	152.4	2871
Georgia	250	6307	Russia	308.2	6144
Germany	397	1568	Serbia	80	2375
Greece	57.1	385	Slovak	132.3	2118
Guatemala	4.2	117	Slovenia	42	705
Honduras	0.7	17	Sweden	377	4128
Hungary	472.7	4086	Switzerland	547.3	2386
Iceland	1469	20170	Thailand	0.7	15
India	80	2517	Tunisia	23.1	201
Indonesia	2.3	43	Turkey	820	15756
United	2.9	21	Venezuela	0.7	14
USA	3766	20302	Yemen	1	15
Total	15145	190699			

2.3.2 Geothermal Energy Utilization In Turkey

Turkey is one of the first 10 countries in the world in terms of geothermal resource potential. There are nearly 1000 warm and mineral water resources in Turkey. Main resources are presented at the table 5 below. These resources have been used for different fields such as district heating, greenhouse, bathing, refrigeration, fishing and industrial fields.

Table 5. Main Geothermal Resources in Turkey (SPO 2001)

BALIKESİR	İZMİR	GEDİZ	SANDIKLI	REŞADİYE	İNCİRLİOVA
GÖNEN	BALÇOVA	YONCALI	HEYBELİ	SIVAS	NAZİLLİ
SUSURLUK	NARLIDERE	BANAZ	ILGIN	SICAK-ÇERMİK	SALAVATLI
PAMUKÇU	SEFERİHİSAR	SARAYCIK	İSMİL	ŞANLIURFA	SULTANHİSAR
BALYA	ÇEŞME	YALOVA	ZİGA	ÇERMİK	DENİZLİ
HİSARALAN	DİKİLİ	ARMUTLU	NARKÖY	ERZURUM	SARAYKÖY
HAVRAN	ALİAĞA	KEMALPAŞA	ÇİFTEHAN	PASINLER	GÖLEMEZLİ
SINDIRGI	GÜZELBAHÇE	AKYAZI	KIRŞEHİR	ILICA	KARAHAYIT
BİGADİÇ	BAYINDIR	KUZULUK	MAHMUTLU	KÖS	KIZILDERE
EDREMİT	ÇİĞLİ-ULUKENT	BOLU	ÇİÇEKDAĞ	TATVAN	BULDAN
GÜRE	BERGAMA	KARACASU	HAVZA	ERCİŞ	YENİCE
LAPSEKİ	MANİSA	SEBEN	HAMAMÖZÜ	DİYADIN	BUHARKENT
ÇAN	TURGUTLU	KIZILCAHAMAM	SULUSARAY	İKİZDERE	
EZİNE	AHMETLİ	AYAŞ	GÖZLEK	AYDIN	
GÜRPINAR	SALİHLİ	HAYMANA	KOZAKLI	GERMENCİK	
AYVACIK	ALAŞEHİR	ÇAVUNDUR	BOĞAZLIYAN	ALANGÜLLÜ	
TUZLA	KÜTAHYA	AFYON	SORGUN	DAVUTLAR	
KALKIM	EMET	BOLVADİN	SARIKAYA	ORTAKLAR	
	SİMAV	GAZLIGÖL	YERKÖY	SÖKE	

Geothermal district heating applications have started in 1987 in Turkey with the heating of 600 residences in Balıkesir-Gonen. The investigations on geothermal energy in the country gained speed in the 1970s. However, the utilization of geothermal energy could not become widespread sufficiently due to scaling problems up to the early 1980s. Since then, important developments have been recorded in geothermal energy utilization. Recently, geothermal direct use applications have reached up to 52,000 residences equivalence of geothermal heating, and engineering design of nearly 300,000 residences equivalence geothermal district heating has been completed (Mertoğlu 2001a - 2001b; Günerhan et al 2001). Today, Balçova geothermal resource (143,3 MWt) has a capacity heating 9600 residence, and greenhouse including 100.000 m² space. Furthermore this resource has been used for the heating the Dokuz Eylül University campus. In Simav, 3200 dwellings have been heated with 25 MWt capacity. (SPO 2001)

Taking into consideration the current development of geothermal energy in Turkey, it may be concluded that the majority of the geothermal energy utilization occurred in direct use applications (including district heating, thermal facilities and greenhouse heating) with a total installed capacity of 493 MWt. Besides this, geothermal water has been used in 194 spas for balneological purposes with a total capacity of 327 MWt. As a result, the total installed capacity is found to be 820 MWt for direct use and 20.4 MWe for power production obtained from the only geothermal power plant of Turkey in the Denizli–Kizildere geothermal field. An annual average growth of 23% of residence connections to geothermal district heating systems has been

achieved since 1983 in the country, representing a decrease of 5% in the last three years (Mertoğlu 2001a-2001b)

Parallel to the development of geothermal energy utilization in Turkey, it is projected that by the years 2010 and 2020, the total installed capacity will increase to 3500 MWt (500,000 residences equivalent, which is about 30% of the total residences in the country) and 8300 MWt (1,250,000 residences equivalent) for space heating and to 500 MWe and 1000 MWe for power production, respectively (Lund and Freeston 2001; Mertoğlu 2001a-2001b).

In Turkey, 400 geothermal production wells and 300 gradient wells have been drilled until now. Of these, 305 wells were drilled by the MTA with a total well depth of nearly 120,000 m. The regional distribution of the wells drilled by the MTA is as follows (Mertoğlu, 2000; SPO, 2001) 87% in western Turkey, 11% in middle Anatolian, and 2% in eastern Turkey (Batik et al. 2000, Hepbaşlı and Çanakçı 2003).

In Turkey, the investments in geothermal heating systems have been supported by consumers due to the tariff on geothermal heat, which is held constant during the entire year. The investment cost for geothermal district heating systems per residence with a floor area of 100 m² is about 1500–2500 US\$ (excluding heater costs in the residence), while the payback period varies between 5 and 8 years. About 30–50% of the investment costs has been paid by consumers as a connection subscription fee, like a capital investment. The heating fees (2001 heating season) were in the range of 14–29 US\$ (Mertoğlu, 2000)

CHAPTER 3

INTRODUCTION OF BALÇOVA GEOTHERMAL FIELD

3.1 Balçova Geothermal Field

Balçova Geothermal Field that is located in the 10 km west of the İzmir city center. This field covers a total area of about 3.5 km² with an average thickness of the aquifer horizon of 150 m. Assuming that no feeding will occur and 25% of the fluid contained in the reservoir will be utilized, this field has a maximum yield of 810 m³/h at a reservoir temperature of 118°C. Balçova geothermal field or the so-called Agamemnon Spas were attractive places for settlers over the ages. Agamemnon Spas were known in antiquity for the therapeutic qualities of the water. The geothermal resource was used as a spa for hundreds of years till 1995. With the construction of Balçova Geothermal District Heating System (GDHS), the geothermal liquid was started to be exploited to obtain potable water and heating.

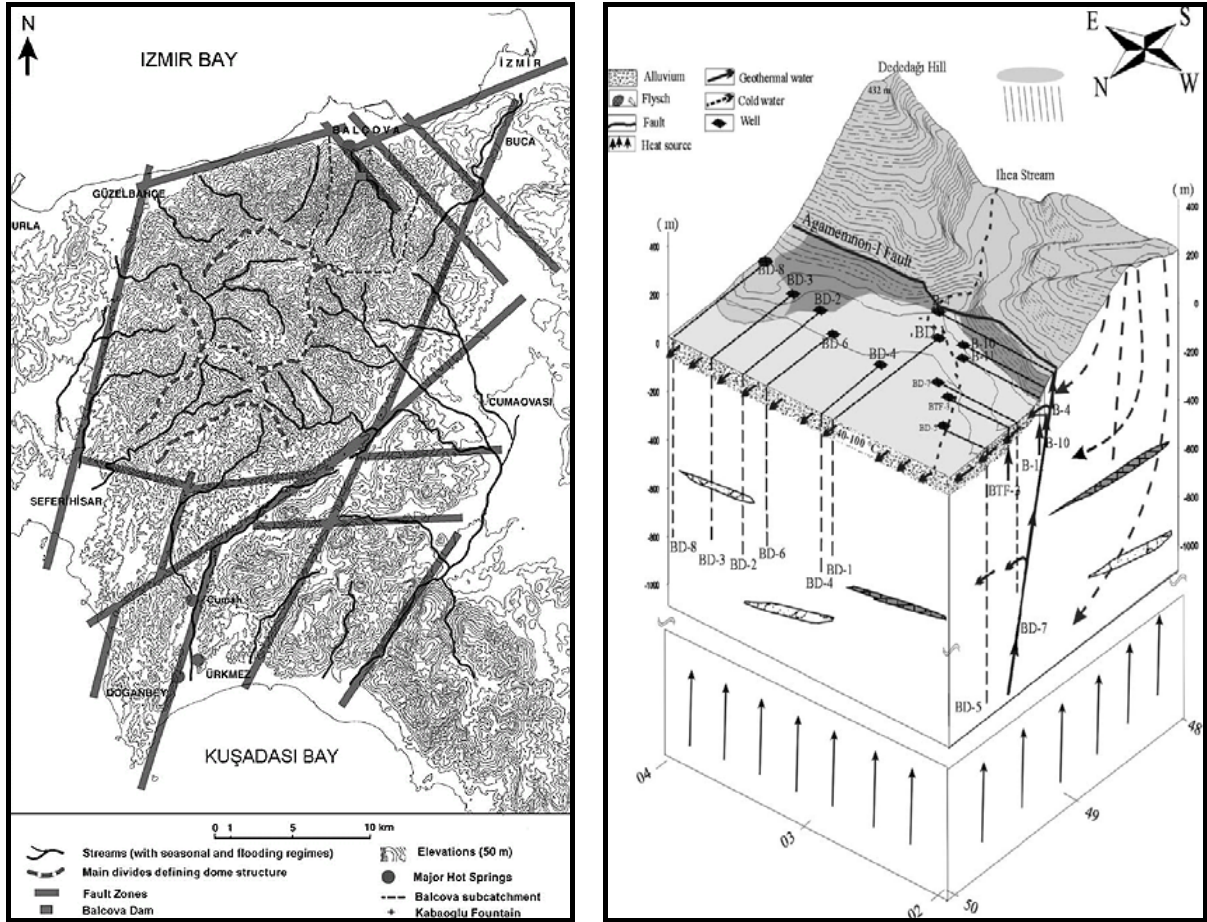
3.1.1 *Geologic and Reservoir Characteristics of the field*

As reported by Özyılmaz (1996), Hepbaşı and Çanakçı (2003), Balçova Geothermal Field has special geology. Agamemnon Geothermal Field is located on Izmir Flysch Sequence which is in a very common zone named as Izmir-Ankara Zone. In and around this field, the outer cretaceous aged Izmir shale–sandstone is seen prevalently. This sandstone consists of stones, such as metasandstone, metamorphic rocks, limestone, serpanthenite diabase etc. The Miyosen aged Yenikoy Formation, which comes upon the Izmir shale–sandstone with discordance, consists of conglomerate, sandstone, claystone and limestone, and is very far from the thermal springs, like the pleosean aged Cumaovasi valconites. Side debris and alluvials are seen in the north of the working area, and they are Kuvantener aged. The general tectonic conduct of the Izmir shale–sandstone is northeast–southwest. The fault and crack systems in the metasandstone and limestone of the Izmir shale–sandstone have the characteristics of the basin. The alluvials and side debris that take place in the working area contain hot and cold water, but after the sounds made in the alluvial, it is seen that there is not enough feeding in the alluvial.

Since 1963, on various dates and in different locations shallow and deep wells have been drilled. Some of the wells drilled in 1995, during the time till the construction

of GDHS, became unavailable because of estrepement and wrong technique applications(Satman et al 2002). A number of these wells have been repaired and reopened for use. 13 shallow and 10 deep wells are available in the field at present. It is possible to see some of these wells in the hydro geologic model below.

Figure 2.Main morpho-tectonic and hydro-geomorphologic features of the mountainous area and surroundings south of Balçova on the left and Hydrogeological model of Balçova geothermal system on the right.



Source: The figure on the left is taken from Kayan 2000; Serpen and Kayan 2001 and Serpen 2003; on the right is taken from Aksoy 2001 and Serpen 2003.

The feeding reservoir of the geothermal field is shown in the figure, too. The feeding field of Balçova Geothermal System is defined on the Seferihisar horst in the south. Although it defines only a field of 35 km², it is possible for the potential of this field to reach 135 km². Izmir Gulf is seen as the main discharge area for the reservoir. Hydrogeological model given in the figure shows the 3D illustration of the reservoir area of Balçova. The locations and the depth of the wells drilled until 2001 and other geological formations of the reservoir are shown in the figure.

3.2 Development of Balçova geothermal field

Balçova Geothermal Field is possibly the geothermal reservoir field which has been studied academically most in Turkey. Particularly, the project named “The Reservoir and Production Performance of Izmir Balçova-Narlıdere Geothermal District”, which was carried out by ITU Petroleum and Natural Gas Department in 2002, could be shown as the most extensive geothermal reserve analysis in Turkey. At the same time, in the literature many publications are available which studies the various aspects of Balçova-Narlıdere Geothermal District Heating system (GDHS).

In Turkey, initial studies on the exploitation and exploration of geothermal energy started in 1962 with the inventory of hot water springs. Dr. Serruya and K. Tezcan realized the reconnaissance and exploration studies. Dr. Serruya accomplished geologic, hydrologic study in 1962. K. Tezcan who was charged by General Directorate of Mineral Research & Exploration (MTA) has done resistivity surveys and applied the self-potential method in Balçova Geothermal Field. Three shallow wells (S1, S2, and S3) were drilled in 1963 by General Directorate of Mineral Research & Exploration after the first evaluation of geological, geophysical, and geochemical data. Depths, temperatures, and flow rates of these three wells were respectively 39 m, 124 °C, 27 l/s; 69 m, 102 °C, 11 l/s and 140 m, 101 °C, 1.25 l/s. Because of high calcite precipitation problem, the field could not be developed until 1983. Up to 1983, approximately 50 gradient, deep, and shallow wells were drilled by MTA. On the other hand, some of household and greenhouse owners drilled their own wells in this region because of the deficiency of geothermal law in those years (OGI 2001, Çanakçı 2003).

In order to utilize geothermal energy in this field for health and tourism purposes, “Termal Turizm ve Özel Eğitim İşletmeleri Ltd. Şti” (Balçova Termal Hotel) was found by the special provincial administration of İzmir. Because of the high calcite problem in Balçova Geothermal Field, “Balçova Termal Turizm ve Özel Eğitim İşletmeleri Ltd. Şti.” used downhole type heat exchangers in 1981. It was the first geothermal heating application in Turkey. The Faculty of Medicine buildings of Dokuz Eylül University and Balçova Princess Hotel were heated by geothermal water respectively in 1983 and 1994. At present, there is a large district heating system in Balçova – Narlıdere regions. (DGI 2002, Çanakçı 2003).

3.3 Balçova and Narlıdere GDHS

In 1962, in order to utilize geothermal energy in this field for health and tourism purposes, “Termal Turizm ve Özel Eğitim İşletmeleri Ltd. Şti” (Balçova Termal Hotel) was found by the special provincial administration of İzmir. Because of the high calcite problem in Balçova Geothermal Field, “Balçova Termal Turizm ve Özel Eğitim İşletmeleri Ltd. Şti.” used downhole type heat exchangers in 1981. It was the first geothermal heating application in Turkey. Following this, in 1983, wells were drilled in the geothermal field to meet the hot water need of DEU Medicine Faculty Hospital. Though there had been no serious development until 1995, the same year, the usage of the field water for district heating was given out in tender by competitive bidding. As the public showed in the process, it was suggested that Narlıdere be included in the heating system. Having the project completed in 1998, Narlıdere was started to be heated by geothermal resource. So far, geothermal resource has been generally used for household heating and the heating of the greenhouses (yet rarely). The project named “The Reservoir and Production Performance Of Izmir Balçova-Narlıdere Geothermal District”, which was carried out by ITU Petroleum and Natural Gas Department in 2002, helped to build strategies about the actions concerning the future of the field. By looking at the estimates about the thermal capacity of the field, it is thought that the system could serve a wider area. At present, projects are prepared to heat the households adjacent to the field (Erdoğan 2003).

The operation concept of Balçova Geothermal District Heating System (GDHS) is based on taking the city water heated by geothermal fluid to the households and meeting household heating and potable water needs. Recently it has been thought to heat the greenhouses by the reinjection of the water obtained. In the beginning of the project, Balçova GDHS was designed according to 7,500 household equivalent, whereas Narlıdere GDHS was designed for 1,500 household equivalent. The feasibility report for the first part of Balçova GDHS which covers the heating of 2,500 and the cooling of 500 households in Balçova region was prepared in October 1995. However, today, an area of 1,050,286 m² is heated and it is planned to increase this figure to 1,445,286 m² by establishing a new thermal centre in the near future (Toksoy et al. 2003). Another alternative (The Turkish Air Force Hospital, several residence areas adjacent to the Balçova and Inciraltı Dormitories) is to increase this figure to 1,900,286 m² (Kutluay et al. 2004).

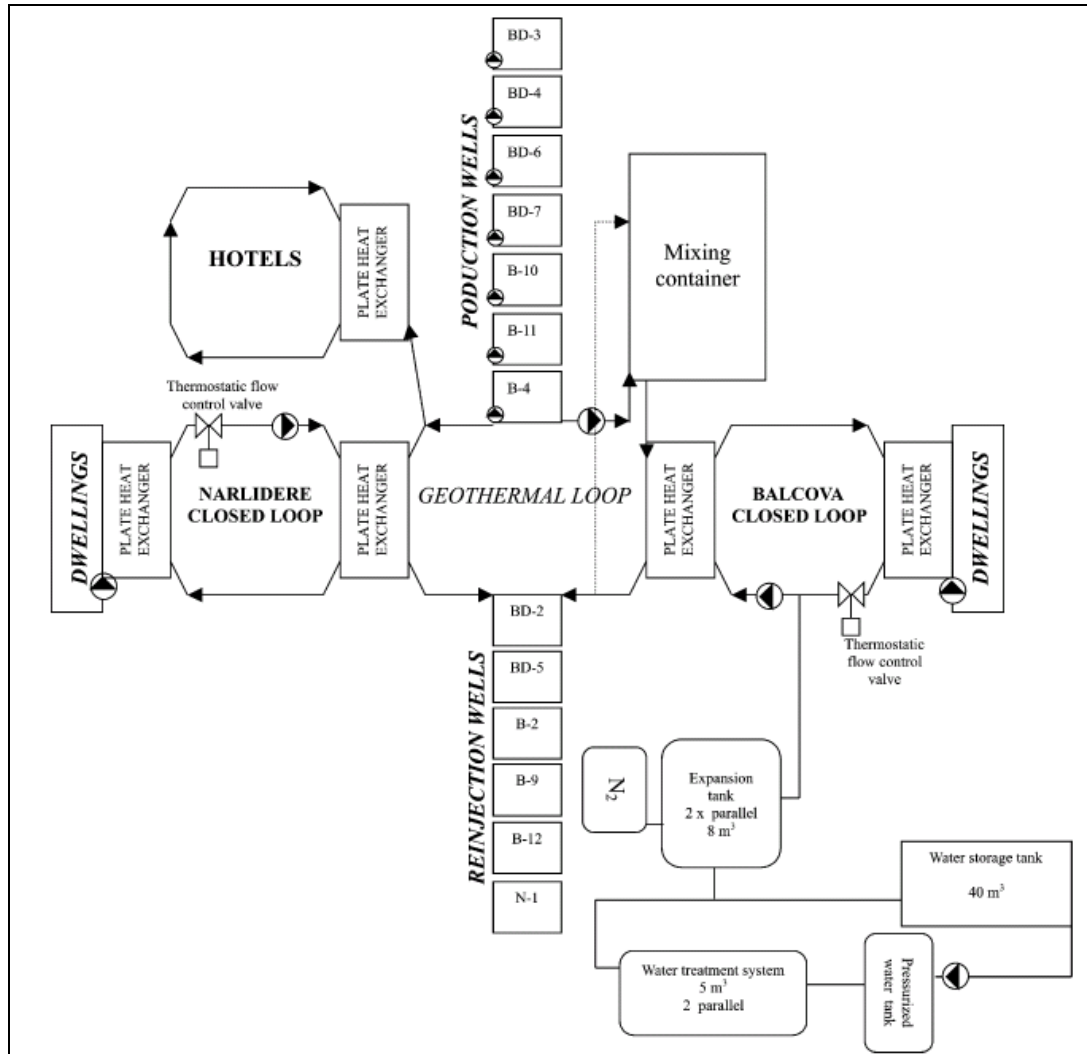
Balçova – Narlıdere GDHS project was drawn up and constructed by a private sector company. The Balçova GDHS is designed according to 7,500 household equivalence, whereas Narlıdere GDHS is designed for 1,500 household equivalence. The feasibility report for the first part of Balçova GDHS which covers the heating of 2,500 and the cooling of 500 households in Balçova region was prepared in October 1995. The feasibility report was accepted and the contract was signed on 20 October 1995 after the competitive bidding. The construction of Balçova GDHS was started out on 25th October 1995 and was over on 20th October 1996. The first part of the system was taken into the operation on 29th October 1996. At this time, it was decided to increase the capacity to the heating of 5,000 and the cooling of 1,000 household equivalents. However, developer called off the cooling of households' contract on 26th November 1996. The heating capacity of Balçova – Narlıdere GDHS was 2,500 dwellings on 30th December 1996, but new connections continued after that time. It was decided to grow the Balçova – Narlıdere GDHS to the system with 7680 household equivalent on 1st July 1997. The contract was signed on 3rd July 1997 and construction of Balçova GDHS investment was completed on 31st December 1999. The construction of Narlıdere GDHS started in April 1997. Narlıdere GDHS has been operated since October 1998. The contractor company and “Balçova Termal Turizm ve Özel Eğitim İşletmeleri Ltd. Şti” had operated Balçova – Narlıdere GDHS until August 2000. In this period, “Balçova Termal Turizm ve Özel Eğitim İşletmeleri Ltd. Şti” was in charge of following the new connection transactions. The contractor was responsible for the operating of the system. At the beginning of August, 2000, “Balçova Jeotermal Enerji San. Tic. Ltd. Şti.”, which is a local government's company, was established and took over distributing hot water and operating of the system (Hepbaşlı and Çanakçı 2001, Satman et al 2002 and Erdoğan 2003).

As of the end of 2001, there are 14 wells ranging in depth from 48 to 1100 m in the IBGF. Of these, seven and six wells are production and reinjection wells, respectively, while one well is out of operation. The well head temperatures of the production wells vary from 95 to 140 °C, with an average value of 118 °C while the volumetric flow rates of the wells range from 30 to 150 m³/h. Geothermal fluid, collected from the seven production wells at an average well head temperature of 118 °C, is pumped to a mixing chamber, where it is mixed with the reinjection fluid at an average temperature of 60–62 °C, cooling the mixture to 98–99 °C. This geothermal fluid is then sent to two primary plate type heat exchangers and is cooled to about 60–62 °C, as its heat is transferred to

the secondary fluid. The geothermal fluid whose heat is taken at the geothermal center is re-injected into the reinjection wells, while the secondary fluid (clean hot water) is transferred to the heating circulation water of the building by the heat exchangers of the substations. The average conversion temperatures obtained during the operation of the IBGDHS are, on average, 80/57 °C for the district heating distribution network and 65/45 °C for the building circuit. By using the control valves for flow rate and temperature at the building substations, the needed amount of water is sent to each housing unit and the heat balance of the system is achieved (Hepbaşlı and Çanakçı 2002).

The schematic mechanism of the Balçova GDHS composed by Çanakçı is given below:

Figure 3. Schematic representation of Balçova–Narlıdere–İzmir geothermal district heating system



Source:Çanakçı C. 2003

From 2004 onwards, the wells which have been given in the table below have been used for production. Half of the reinjection, on the other hand, is made to BD-8 well, which was drilled in 2003. Apart from this, re-injection is made from ND-1 and other shallow wells in the field.

Table 6. Production capacity of the wells in Balçova-Narlıdere geothermal field (Kutluay et al 2004)

Wells	Date of Drilling	2000 Flow (m ³ /h)	2003 Flow (m ³ /h)	Temperature, °C
B-1	1982	0	140	102
B-4	1983	60	140	100
B-5	1983	0	140	102
B-7	1983	0	140	96
B-10	1989	100	250	97
B-11	1989	40	0	100
BD-1	1994	0	50	110
BD-2	1995	0	180	132
BD-3	1996	80	120	120
BD-4	1998	140	180	135
BD-5	1999	0	80	115
BD-6	1999	120	120	135
BD-7	1999	80	80	115
BD-9	2003	0	360	135
Total		620	1980	

Production of the geothermal water that the Geothermal District Heating System needs has been increased parallel to the improvement of the system. By the observation tests made in the field, it has been found that re-injection to the shallow wells is useless and that it cools the field off. As it has been detected that in some shallow wells re-injection caused a cooling that goes down to 20 °C, the re-injection strategy in the field has been changed and after the year 2002, re-injection to the 630 metre deep BD-8 well, which was drilled in the yard of Economy University, has been started. With this process, cooling in the wells has been stopped and the cooled off wells have started to heat again. In addition, in the suggestions part of the study carried out by ITU, cooling in the wells are mentioned and re-injection to the deep wells on the edges of the geothermal field is suggested as a strategy. In Narlıdere-Balçova field, nearly the half of the total production is re-injected to BD-8 well. The aim is 100% re-injection in the field. The drilling works of BD-10 well, which aims to increase the re-injection capacity, have been continuing (Kutluay et al. 2004).

In the table below, the dwelling equivalent heated areas in 1999-2004 heating seasons are given.

Table 7. Growth of Balçova-Narlıdere Geothermal District Heating in terms of dwelling's area (m²) (Toksoy et al 2003)

Type of Load	Heating Seasons					
	1999-2000	2000-01	2001-02	2002-03	2003-04	2004-05 ^e
Dwellings	454500	688449	711370	715132	815132 ^a	815132
Official Buildings	17600	19400	19600	19600	19600	19600
The Princess Hotel	25000	25000	25000	25000	25000	25000
Thermal Treatment Center	13000	13000	13000	13000	13000	13000
Pools of the Hotels ^b	5611	5611	5611	5611	5611	5611
The Thermal Hotel			9543	9543	9543	9543
DEU Hospital ^c			143600	143600	143600	143600
Economy University			18800	18800	18800	18800
The Ozdilek Hotel					27000	27000
Ozdilek Shopping Center					20000	20000
Ozdilek (altitude of -6)					14000	14000
DEU Faculty of Fine Arts					20000	20000
DEU Conservatory					12000	12000
Balçova GDHS-2						302000 ^d
TOTAL	515711	751460	946524	950286	1143286	1445286
Growth (%)	-	45.7	25.9	0.4	20.3	26.4

^a In this season, nearly 100.000square meters of dwellings will be included to the heating load with the projects that started in 2002 and were applied in 2003.

^b Four closed pools with a total volume of 1555 cubic metres and two open pools of a volume of 4050 cubic metres are available in the Thermal and the Princess Hotels.. The value in the table as square metres is the approximate equivalence areas that is calculated according to the average dwelling load

^c Structuring in Dokuz Eylül University continues. It is foreseen that its load will start to increase from the year 2004 onwards.

^d Balçova System –2 project is planned to be applied in 2004 and to be included in the load in 2004-2005 heating season. If the foreseen reservoir studies could be done and the results are positive, it could be taken to a nearer date.

^e Appraisal growth

It could be seen in the table that Balçova GDHS project may grow nearly three times as it was in 1999 up to present. Moreover, another alternative (The Turkish Air Force Hospital, several residential areas adjacent to the Balçova and Inciraltı Dormitories) is to increase this figure to 1,900,286 square metres (Kutluay et al. 2004). This shows that the system could be %66.2 bigger than its size in the years 2003-2004.

3.4 Economic Assessment of Balçova GDHS

In the study named “Economic Assessment of Balçova GDHS”, prepared by Erdoğan (2003), costs and revenues of Balçova GDHS from its construction up to the year 2002 are studied. In this work, the balance between costs and revenues is analyzed, and how the balance will change/be provided is discussed in case the fix charges taken monthly are re-arranged according to different scenarios, provided that the constant connection charge remains the same. Costs and revenues net present value (NPV) is evaluated according to different interest rates, and internal rate of return (IRR) values

are calculated according to different payment scenarios. Because of the up to datedness and the appropriateness of the context, Erdoğan's study is taken as a base in the calculations that are made about costs and revenues of geothermal direct heating system.

Cost items considered in Erdoğan's study:

- Capital investment costs,
- Operating costs,
- Additional investment costs (auxiliary equipment, new connections and drilling costs),
- Future Cost of Renovations,
- Depreciation Expenses.

Revenue items considered in Erdoğan's study:

- Fix charges,
- Connection charges,
- Charges paid according to the contract (DEU Hospital, Economy University, Princess Hotel),
- Other revenues (bank interest and bonds),
- Salvage values.

Given below are the explanations concerning these items.

Items included in capital investment costs for Balçova-Narlıdere GDHS: Construction of heat exchanger and pumping station, transport of materials, electrical equipment, installation of heating equipment used in heat exchanger and pumping station, shared installations (wellhead housing, building, and heat exchanger and pumping station connections), excavation, sanitary installations, automatic control, installation of transformer, thermal line (pipe lines and other fittings, heat exchangers, compensators, steel separator, water softening tank, pumps, actuator butterfly valves, branch valves, stainless steel materials, temperature and flow settling valves, underground valves, butterfly valves, dosage equipment (pumps, piping and other equipment), butterfly valves with gearboxes, aluminum insulation for pipes, flow

meters, other adjustment equipment, strainers), materials without discount (timber, cement, sand).

Items included in operating costs for Balçova-Narlıdere GDHS: Water (tap water costs, cost of city water used in Balçova and Narlıdere heat exchanger and pumping stations), electricity (electricity consumption of wellhead housings, Balçova and Narlıdere heat exchanger and pumping stations), inhibitor (cost of inhibitor which is used in wellhead housings), other chemicals (cost of nitric acid, rock salt, NaOH and nitrogen), miscellaneous costs (cost of equipment and works that needed during the operating of systems like the rents of cranes and other vehicles), marketing (visual advertisements, commissions for credit cards, newspapers, magazines, publications, and television programs on geothermal energy), management (cost of telephone, cargo, posts, rent of vehicles, cost of visitors, stationary costs, facility rent), wages of personnel (operational personnel, management board, advisors)

Future Cost of Renovations: Because of the corrosion and leakage problem in energy distribution network, a renovation will be required in pipelines. It is assumed that 75 % of pipe network installed in Balçova and Narlıdere region will be changed after 5 years while the remaining 25 % of pipes will be changed after 10 years, because most of the piping network had been constructed for 5 years at the end of 2001. It is considered that CTP + PUR + CTP pipes will be installed instead of Steel 37 + PUR + CTP pipes. It is assumed that all pumps will be changed after 10 years. (Erdoğan 2003).

Depreciation Expenses: The declining balance method allocates for depreciation a fixed fraction of initial book balance each year. In other words, it involves applying a depreciation rate against the undepreciated balance, rather than to the original cost (Erdoğan 2003).

Fix charges: These are the use charge that the users pay each month. It consists of an agreement between the customer and the system operator on the monthly sum paid for the provided energy per unit volume. Customers pay charges according to household equivalents of their residence. This charge is 44 YTL (33 USD) for 100 m² dwelling for the year 2005.

Connection charges: These charges are collected at the beginning of the subscription in Balçova – Narlıdere GDHS. Each customer must pay house connection

fees in order to connect their individual heating system to the district heating system. This charge is equal to 1250 USD for 100 m² dwelling for the year 2005

Charges paid according to the contracts: Medicine Faculty and Hospital of Dokuz Eylül University, Izmir Economy University and hotels pay their bills according to their contracts

Salvage value: The estimated value of an asset (approximately %5 of its original value) at the end of its useful life. Equipments and other assets of the Balçova GDHS could be accounted in revenue side.

Table 8. End of 2002 value of all cash flows in US \$ (Erdoğan 2003)

		End of 2002 value (in US \$)
CAPITAL INVESTMENT COSTS		-23,598,820
1.	Balçova GDHS	-18,272,162
2.	Narlıdere GDHS	-1,997,269
3.	Well Drilling Costs	-2,485,024
4.	Additional Investments	-844,366
a.	2001 Investments	-311,970
b.	2002 Investments	-532,396
OPERATING COSTS		-3,462,096
REVENUES		11,039,167
1.	Connection	5,584,181
2.	Fix	5,254,183
3.	Other	200,803
TAXES		-82,547
NET CASH FLOWS AFTER TAX		-16,104,295

In the table above costs, revenues and balance value of Balçova GDHS from 2002 onwards are given. As it could be seen in the table, end of 2002 value is -16,104,295 USD. Assuming that operating cost will continue with end of 2002 value in the following years, it is stated that with the fix charge applied at present and with additional connection charges, 2021 balance of the project (without interest) will be -51,502,098 USD (after depreciation costs are added). It is shown in Table 10. the future value of the derreciation and renovation costs calculated as to different interest rates are given in Tbale 9. These values are calculated by Erdoğan (2003) based on the book values of the investments. The renovation costs of the Balçova GDHS are considerably high because of damage occurred in the insulation material of the pipeline resulting from high water temperature pumped to the pipeline.

Table 9. Future value of depreciation and renovation charges (end of 2021 values as to different interest rates) (Erdoğan 2003)

Year	End of year 2021 value (with different interest rates)		
	3%	5%	7%
2002	421,353	618,996	902,770
2003	6,704,255	9,661,397	13,827,225
2004	3,969,822	5,611,880	7,881,502
2005	2,448,884	3,395,889	4,680,148
2006	2,183,100	2,969,661	4,016,229
2007	1,543,838	2,060,074	2,734,010
2008	1,286,099	1,683,462	2,192,432
2009	1,074,226	1,379,344	1,762,791
2010	899,493	1,132,981	1,420,877
2011	1,196,968	1,478,957	1,820,098
2012	1,223,220	1,482,605	1,790,483
2013	746,322	887,350	1,051,587
2014	617,071	719,700	836,965
2015	511,425	585,122	667,741
2016	521,771	585,589	655,782
2017	392,360	431,961	474,698
2018	325,182	351,184	378,715
2019	270,148	286,193	302,860
2020	224,950	233,771	242,761
2021	1,454,147	1,482,383	1,510,619
Total	28,014,635	37,038,499	49,150,293

Table 10. Net cash flows in case the utilization price is US \$17 (Erdoğan 2003)

r	Year	Net cash flow (A _r) (in US \$)
0	2002	-16,337,588
1	2003	-4,519,775
2	2004	-3,028,285
3	2005	-2,178,048
4	2006	-4,662,139
5	2007	-1,687,364
6	2008	-1,546,696
7	2009	-1,427,928
8	2010	-1,327,319
9	2011	-2,717,197
10	2012	-1,606,623
11	2013	-1,268,426
12	2014	-1,183,554
13	2015	-1,112,268
14	2016	-1,133,408
15	2017	-1,034,885
16	2018	-985,352
17	2019	-943,656
18	2020	-908,469
19	2021	-1,878,115
Total		-51,502,098

Operating cost of the year 2002 is accepted by Erdoğan (2003) as a balance cost which is likely to continue in the following years. Operating cost of 2002 is 1,121,218. The heated area is accepted as 1,150,000 m² (815,132 m² dwellings) in Balçova and Narlıdere regions. It is also important to note that by the end of year 2004, the monthly fix cost increased from \$17 to \$33 for 100 m² dwelling.

End of 2021 net future balance values of the GDHS is given below by employing different interest rates to costs and revenues (in USD) in Balçova and Narlıdere region as seen in Table 11.

Table 11. End of 2021 net future balance value of the GDHS with different interest rates (Modified from Erdoğan 2003)

Year	n	Cost	Revenue	Balance	2%	4%	5%
2002	20	16,337,588		-16,337,588	-24,276,796	-35,797,667	-43,348,485
2003	19	4,944,561	1901472	-3,043,089	-4,433,206	-6,411,329	-7,689,733
2004	18	3,453,070	1901472	-1,551,598	-2,216,064	-3,143,252	-3,734,105
2005	17	2,602,833	3466526	863,693	1,209,378	1,682,387	1,979,600
2006	16	5,086,924	3466526	-1,620,398	-2,224,460	-3,034,976	-3,537,126
2007	15	2,112,149	3466526	1,354,377	1,822,813	2,439,156	2,815,652
2008	14	1,971,481	3466526	1,495,045	1,972,680	2,588,934	2,960,086
2009	13	1,852,714	3466526	1,613,812	2,087,638	2,687,116	3,043,083
2010	12	1,752,104	3466526	1,714,421	2,174,301	2,744,844	3,078,854
2011	11	3,141,982	3466526	324,543	403,529	499,620	555,079
2012	10	2,031,409	3466526	1,435,117	1,749,400	2,124,324	2,337,654
2013	9	1,693,212	3466526	1,773,314	2,119,274	2,523,979	2,750,992
2014	8	1,608,339	3466526	1,858,186	2,177,162	2,543,056	2,745,388
2015	7	1,537,054	3466526	1,929,472	2,216,357	2,539,054	2,714,961
2016	6	1,558,193	3466526	1,908,332	2,149,092	2,414,649	2,557,348
2017	5	1,459,671	3466526	2,006,855	2,215,730	2,441,645	2,561,312
2018	4	1,410,138	3466526	2,056,388	2,225,900	2,405,683	2,499,552
2019	3	1,368,442	3466526	2,098,084	2,226,503	2,360,059	2,428,794
2020	2	1,333,255	3466526	2,133,271	2,219,455	2,307,346	2,351,931
2021	1	2,533,011	3466526	933,514	952,185	970,855	980,190
Total				2,945,752	-3,229,129	-13,114,518	-19,948,972

Despite the augmentation made in fix charge in 2004, end of 2021 balance values with different interest rates still have negative values and they may need another augmentation in the following years. Erdoğan (2003) has analyzed, under different payment scenarios, that fix charge of GDHS should be increased to \$55.5 without changing operating costs and connection charge in order to get zero IRR value.

CHAPTER 4

APPLICATION OF MONTE CARLO SIMULATION TECHNIQUE FOR DETERMINATION OF THE ENERGY RESERVE OF BALCOVA GEOTHERMAL FIELD

4.1 Monte Carlo Simulation Technique and Its Procedure

Simulation means imitating or estimating how events might occur in a real situation. It can involve complex mathematical modeling, role playing without the aid of technology, or combinations. The value lies in the placing you under realistic conditions, that change as a result of behavior of others involved so you cannot anticipate the sequence of events or the final outcome. W. S. Gossett, who published under the pen name “Student,” randomly sampled from height and middle finger measurements of 3,000 criminals to simulate two correlated normal distributions (WEB_3 2005). This is supposed to be the first version of the simulation which is used in statistics as “t distribution”, and being used in determination of the confidence interval of the small samples’ distribution which is assumed to have normal distribution.

By the help of the improvement in computer technology, random number generators are used in modeling real life situations. As the most popular method in the last decade, Monte Carlo Simulation technique has been used widely in the experimental sciences. Credit for inventing the Monte Carlo method often goes to Stanislaw Ulam, a Polish born mathematician who worked for John von Neumann on the United States’ Manhattan Project during World War II. Ulam is primarily known for designing the hydrogen bomb with Edward Teller in 1951. He invented the Monte Carlo method in 1946 while pondering the probabilities of winning a card game of solitaire.

Monte Carlo Simulation technique can be defined as a computerized technique which is the basis for probabilistic risk analysis, and which replicates real life occurrences by mathematically modeling a projected event. Monte Carlo simulation uses pre-defined probability distributions of risk variables to perform random modeling over many "simulations" or computer trials. The results are probabilistic (they form a probability distribution) and therefore yield an expected value (mean) and a standard deviation, as well as cumulative probabilities (zero to 100 percent) which express total likelihood (probability) at any level of variable outcome (WEB_4 2005).

Monte Carlo Simulation process could be defined as follows:

- Determination of the statistical distribution of each uncertain variable. It can be extracted by past experiments or information, or by professional expressions,
- Determination of how many times should the simulation be done depending on the number of variables. This could be determined by using the procedures that are applied for statistically paired samples.
- Obtaining cumulative distribution function concerning each uncertain variable by the help of the computer, and making necessary manipulations according to the desired model.
- Making the sensitivity analysis of the results of the simulation that are obtained. The most popular methods for this are regression analysis and calculation of the correlation coefficient. Although these two methods are related with each other, the former is used to find the elasticity between variables and simulation result while the latter is used to measure the degree of co-variation tendency (the degree of association within variables, and between variables and results of the simulation).

4.2 Use of Monte Carlo Simulation Technique

Monte Carlo Simulation technique could be used to calculate geothermal energy reserve, particularly, in which uncertain variables could play an important role in the calculations made. It is also frequently used in petroleum reservoir modeling studies that are strictly related with the issue of determination of reservoir capacity. This technique is used to determine the cumulative probability distribution curve of the variables such as reservoir thickness, area of the geothermal field, the productivity and the thickness of the reservoir, temperature, density, porosity, specific heat of both the fluid and the hot rock, salinity of the fluid, etc, which offer uncertainty in studies about geothermal reservoir

Before the simulation techniques were used, deterministic methods were preferred in researches, and the reservoir was modeled with the most probable values assigned to unspecified variables. As Satman et al. (2002) has mentioned, these kind of deterministic models do not mention the uncertainty emerging while determining the features of rock and fluid. For example, while porosity, volume, specific heat and the density of the fluid and the hot rock, production factor etc. possibly alter in a wide range, they are taken as a single value in deterministic models. Considering that nearly

all the parameters and data mentioned are about the underground, uncertainties about these could consequently lead to important mistakes (Satman et al. 2002).

While applying the technique, the researcher should make predictions about how the statistical distribution corresponding the nature of each variable will be in the first stage. Methods generally used while making these predictions could be as using personal experiences, using the values in the previous studies, and if there are no previous studies, using the data of regions that has been studied before and that shows similar geological features. For example, if the fluid of desired heat and flow is found in the wells drilled before in a geothermal field between 600 m and 1100 m minimum, these depths could be used as upper and lower limits while making predictions about the possible well depth. The distribution generally used in the models produced about the reservoir is triangular distribution. The reason for using this distribution is that when there are very few data about the variable, it produces better results compared to the other distributions (Newendorp 1975). There are three parameters that has to be determined in triangular distribution - the minimum (below that value occurrence probability of the variable is zero), the maximum (below that value occurrence probability of the variable is zero) and the most probable value of the variable. Furthermore, simulations could be formed by using distributions such as normal distribution (mean value and the standard deviation), Binomial distribution (the number of "successes" (p) in n independent trials), exponential distribution (mean value), lognormal random distribution (mean, standard deviation), Poisson distribution (mean) and uniform distribution (upper and lower limit) etc.

By using cumulative probability distribution curve that belongs to the model produced by simulation data, thresholds concerning the costs of the project could be obtained. Namely, feasibility of the project could be discussed according to the most probable result seen in cumulative probability, or cumulative probability corresponding the minimum benefit that is expected to be obtained from the project is found, and following this, it could be decided whether the project will be done. If it is needed (if the benefit that is expected to be obtained from the project falls into an interval which causes a risk perception), the consequences of the project could be assessed by risk analysis and decisions could be made.

By making sensivity analysis of the data obtained from the simulation (regression or calculation of correlation coefficients) the effects of the variables in the model

(elasticity of the variables) on the result obtained could also be found. Thus variables that cause the maximal change on cumulative probability curve could be determined and simulation parameters could be reformulated. In reservoir models, it is seen that simulation data about volume (the area and the thickness of the reservoir) are generally the variables with the maximum elasticity. The reason for this is that generally the distribution interval of these variables is wide as it is expressed in terms of metres, and this situation may cause serious jumps in the result of the model. In addition, variables such as productivity and recovery factor, in which the shift interval is big, may also affect the results of the model seriously (Satman et al. 2002). It can be seen as a wise attitude for the project appliers to focus on the researches that will limit the shift interval of the variables with the maximum elasticity in their models.

4.3 Balçova Geothermal Field Simulation Model Made by ITU, Petroleum and Natural Gas Department

When the stochastic reservoir model presented in the chapter named “Heat Potential of the Balçova Geothermal Resource” in the project prepared by Satman et al. (2002) is examined, it could be seen that the general equation used is as follows:

$$Reserve\ of\ the\ Field(kW_i) = \frac{Heat\ Energy(kJ) \times Production\ Factor \times Recovery\ Output}{Load\ of\ the\ Station \times Load\ Factor} \dots\dots\dots (4.1)$$

In order to calculate *Heat Energy (kJ)* in the equation above:

$$H_{Total} = H_r + H_f = (1 - \phi) \cdot c_r \cdot \rho_r \cdot V \cdot (T_r - T_a) + \phi \cdot c_f \cdot \rho_f \cdot V \cdot (T_f - T_a) \dots\dots\dots (4.2)$$

could be used, where:

H is heat energy in kJ

ϕ is porosity

c is specific heat in kJ/kg-°C

ρ is density in kg/m³

V is hot rock volume in m³

T is temperature in °C

and subscripts *r*, *f* and *a* stand for rock, fluid and leaving respectively.

In the case of individual structures the independent variables are sampled and the accessible geothermal energy is computed by using the volumetric equation above (Muffler and Cataldi 1979; Serpen 2000):

If the variables given above are examined item by item:

Heat Energy (H; in kJ): It defines the heat energy that the geothermal resource has, and it is the basic value desired to be calculated by simulation model. In order to find the total heat energy, the equation is handled in two parts as heat energy of the hot rock and the fluid, and the total value is calculated by adding these two values.

Production Factor: As noted by Satman et al. (2002), it may be the most critical parameter in the model and represents producible portion/amount of the heat energy. The predictable interval for this parameter, discussed by many researcher, changes between 7% and 25% (White and Williams 1975; Muffler and Cataldi 1978; Sorey et al. 1982, Nathenson and Muffler 1975, Satman et al 2002). Triangular distribution with 18% most probable value is used for this variable.

Recovery Output: This parameter shows the amount of the heat that passes to the distribution system from the main system in which the fluid circulates, and for this parameter triangular distribution is formed. According to the data taken from Balçova Geothermal Ltd. Co., for this variable the minimum value is 70%, the maximum value is 93% and the most probable value is %85 (Satman et al. 2002).

Table 12. Heat produced from Balçova Field and its recovery output to secondary cycle (Satman et al. 2002)

Months	Heat Produced (kCal) x 10 ⁹	Recovery Output (%)
October	2.52	80.0
November	6.19	70.6
December	12.24	92.4
January	17.64	92.6
February	18.33	65.7
March	17.60	43.2
April	15.35	66.8
Total	89.87	-

Load of the Station: It represents the estimated life for the constructed heating station to be used in full capacity. In the model, this value is taken constant and a 25-year load is estimated, which equals 7.88×10^8 secs (Satman et al. 2002).

Load Factor: This value, which enters the model as constant, is determined by an approximation of the number of the days the station is operated. From the data collected it is calculated that the station operates for nearly 150 days in a year, and this is 41% of a year (Satman et al. 2002).

Porosity (ϕ): It is a measure of the water-bearing capacity of subsurface rock. With respect to water movement, it is not just the total magnitude of porosity that is important, but the size of the voids and the extent to which they are interconnected, as the pores in a formation may be open, or interconnected, or closed and isolated. For example, clay may have a very high porosity with respect to potential water content, but it constitutes a poor medium as an aquifer because the pores are usually so small (WEB_5 2005). Values of the porosity distribution are obtained from well log data and the karots. Based on these values, it is assumed that the values concerning the field display triangular distribution, and the minimum value is taken as 0.275, maximum value as 0.7 and the most probable value as 0.05.

Specific Heat (c ; in kJ/kg-°C): This value is a descriptive coefficient that varies from material to material. Specific heat value for hot rock is 0.9 kJ/kg-°C, and for fluid it is 4.18 kJ/kg-°C. These values are used as constants in the model.

Density (ρ ; in kg/m³): This is a value which varies from material to material. Densities of the hot rock and the fluid change according to the heat of the material. In

the model, it is estimated that the density of the fluid will show triangular distribution. The minimum, maximum and the most probable values of the fluid density are respectively estimated as 921.7, 986.7 and 930.6. It is stated that density of the hot rock shows uniform distribution and it will take values as 2600, 2700 and 2650 (Satman et al. 2002).

Volume (V ; in m^3): this defines the volume of the hot rock in the geothermal field. In the model, this value is obtained by multiplying the field area by thickness. In the triangular distribution formed for the field area and thickness, the minimum-the maximum and the most probably values are accepted respectively as 5×10^5 , 2×10^6 and 9×10^5 , and 250, 1000 and 350 (Satman et al. 2002).

Temperature (T ; °C): This value includes three different values as rock, fluid and leaving. Among these, only leaving temperature -not the atmospheric temperature- is taken as 80 °C, which is the leaving temperature of the secondary cycle of the GDHS fluid. In the triangular distribution formed for the temperature of the fluid, the minimum, maximum and the most probable values are stated respectively as 100, 145 and 135. These values are the temperatures of the fluid brought out in Balçova geothermal field (Satman et al. 2002).

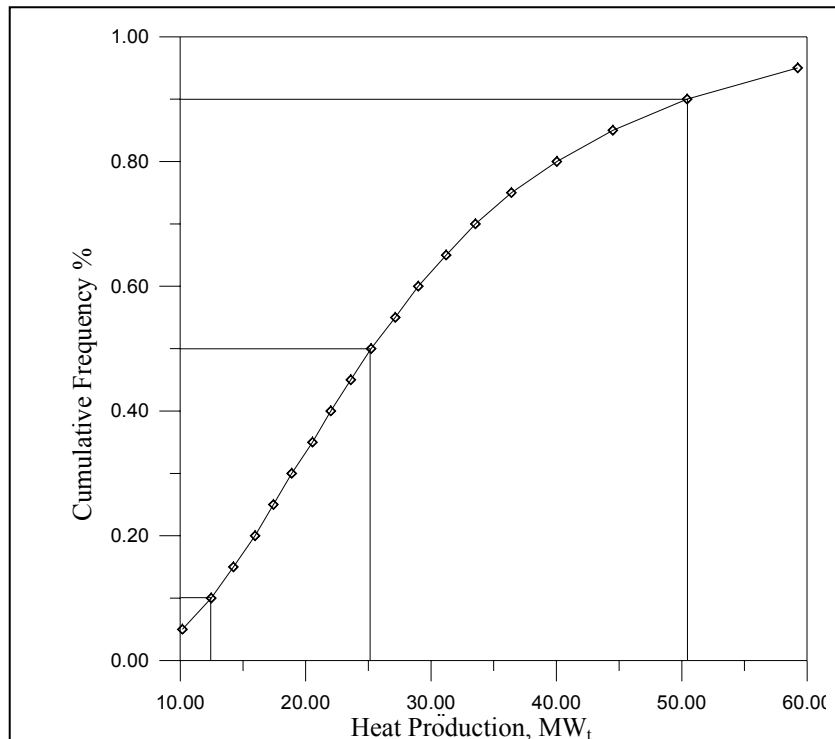
The parameters stated above are given collectively in Table 13.

Table 13. Entries for Monte Carlo Simulation applied in Balçova Reservoir Model (Satman et al. 2002)

Parameters	The Most Probable Value	Probability Distributions		
		(Model)	Type	Minimum
Leaving Temperature, °C	80	Constant	-	-
Spe.Heat of Hot Rock, kJ/kg °C	0.9	Constant	-	-
Spe.Heat of Fluid, kJ/kg °C	4.18	Constant	-	-
Porosity, %	0.05	Triangular	0.0275	0.7
Temperature, °C	135	Triangular	100	145
Production Factor, %	0.18	Triangular	0.07	0.24
Recovery Output, %	0.85	Triangular	0.70	0.93
Load Factor, %	0.41	Constant	-	-
Load of the Station, sn	7.88E8	Constant	-	-
Field Area, m ²	0.9x10 ⁶	Triangular	0.5x10 ⁶	2x10 ⁶
Thickness, m	350	Triangular	250	1000
Density of Hot Rock, kg/m ³	2650	Uniform	2600	2700
Density of Fluid, kg/m ³	930.6	Triangular	921.7	986.7

After having 10,000 simulations done, cumulative probability distribution curve seen in the figure below is obtained.

Graph 2. Cumulative probability distribution curve for heat production



Source: Satman et al. 2002

As it can be observed in the figure, the potential of the field is 12.5 MW_t with 90% probability, 50.5 MW_t with 10% probability, and most important of all, the expected

value is 25.5 MW_t. The most probable obtained value of 25.5 MW_t should be taken as the potential of the known part of the field in which the reserve spreads with isotherms till the depth of 1000 m. According to this model, heat production is made for 150 days with a constant flow of nearly 21.5x10⁶ kCal/h. However, as it can be seen in the figure above, production actually occurs in a normal distribution. Therefore, the total production of 77.4x10⁹ kCal at the end of 150th day with a flow of 21.5x10⁶ kCal/h remains a little below the sum used for heating in the system (89.87x10⁹, Satman et al. 2002).

According to the sensitivity analysis the parameters that affect the results the most are respectively thickness and field, in other words volume. This is natural as the method is volumetric. The other following input variables that the simulation is sensitive to are producibility and temperature. These inputs and variables are either measured or determined parameters except producibility (Satman et al. 2002).

A simulation showing the probable potential of the field is done by using TOUGH2 3D geothermal simulator in ITU Petroleum and Natural Gas Engineering department. With this simulation a number of values are found, and these values are compared to the simulation values above. The aim of the modeling study is to answer two of the important questions that are desired to be answered. That is, the aim is to determine the sustainable and renewable production potential of the field and to determine the life of the field in case of a specific annual production-injection difference

Based on the stored heat in 3D heat distribution model, the producible, observable power is 66 MW_t. It is estimated that the genuine producible heat potential is a value between 25.5 MW_t (which comes from Monte Carlo simulation above) and 66 MW_t (Satman et al. 2002).

If deeper wells are drilled and it is determined that Balçova geothermal field extends to deeper layers, and if geophysical studies are done and it is determined that the geothermal field extends to a wider area, the 3D model and the model applied in this chapter could be updated, new estimations could be done and they could be used for economic risk analysis (Satman et al. 2002).

4.4 Application of Monte Carlo Simulation to calculate Balçova Geothermal Field potential

Within the context of this study, the simulation done by ITU Petroleum and Natural Gas Department, given in the previous chapter, is applied again with the same functional form and parameters. This chapter aims to compare the obtained results with the results obtained in the previous chapter.

The function concerning the calculation of the geothermal reserve is given below so as to make a reminder.

$$Reserve\ of\ the\ Field(kW_1) = \frac{Heat\ Energy(kJ) \times Production\ Factor \times Recovery\ Output}{Load\ of\ the\ Station \times Load\ Factor} \dots\dots\dots (4.1)$$

In order to calculate *Heat Energy (kJ)* in the equation above:

$$H_{Total} = H_r + H_f = (1 - \phi) \cdot c_r \cdot \rho_r \cdot V \cdot (T_r - T_a) + \phi \cdot c_f \cdot \rho_f \cdot V \cdot (T_f - T_a) \dots\dots\dots (4.2)$$

could be used, where:

H is heat energy in kJ

ϕ is porosity

c is specific heat in kJ/kg-°C

ρ is density in kg/m³

V is hot rock volume in m³

T is temperature in °C

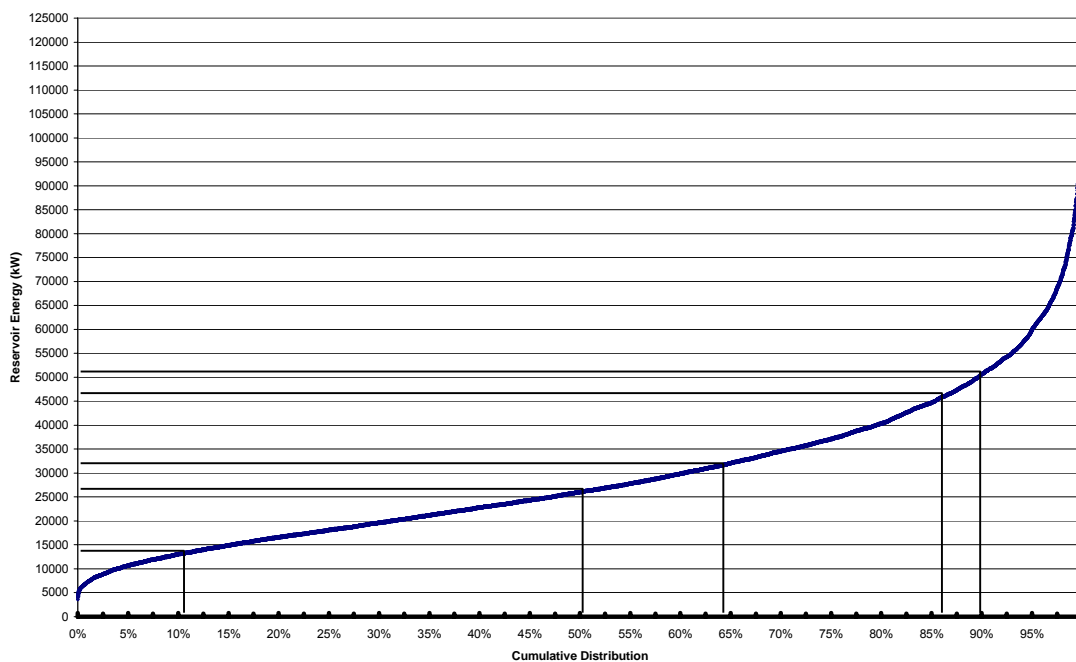
and subscripts *r, f* and *a* stand for rock, fluid and leaving respectively.

The distribution table mentioned under the previous heading could be used for the distribution of the parameters in the function and the estimated limits.

MS Excel 2003 spreadsheets are used to make Monte Carlo Simulation. Although special programs written for simulation are available, there are also simulation tools as “add-in” in the widely used MS Excel program. In this study, Simtools add-in, prepared by Roger Myerson, is used. Simtools adds statistical functions and procedures for doing Monte Carlo simulation and risk analysis in spreadsheets. Formlist, another add-in coming with Simtools, is a simple auditing tool that adds procedures for displaying the formulas of any selected range (WEB_6 2005).

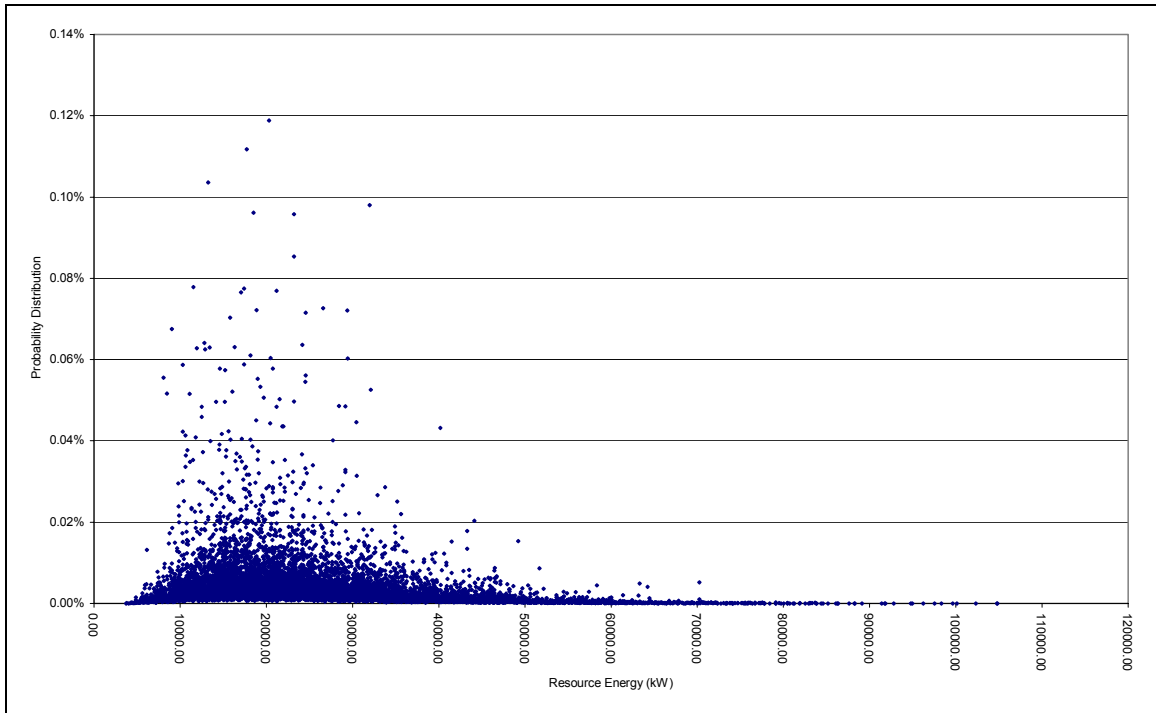
In the first step, parameters and its distributional forms are introduced into the cells in Excel spreadsheet. Then the functions used for the statistical distributions of parameters are written into corresponding cells in the spreadsheet. Following this, these statistical functions are copied into the columns as many as the number of the simulations to be done (in this study 10,000 cells are seen as enough). In the next stage, the necessary calculations are done according to the function above, and the simulation results concerning the geothermal reserve are obtained. The data generated by the model could be find in Appendix B.

Graph 3. Cumulative distirbution curve of the simulation



As expected the results of the two of the models are similar. When cumulative probabilities are studied, it is expected for the resource to be 50.6 MWt with 10%, 13 MWt with 90% and most probably 26.02 MWt as seen in Graph 3.

Graph 4. Distribution of the output of model



In Graph 4, the mean value of the simulation is 26.2 MWt and the standard deviation is 13.8, distribution of the simulation could be named left skewed normal distribution.

It is calculated by the authorities that, in February 2001, 24.1×10^6 kkal/st ($\cong 28$ MW_t) heat was given to the system from Balçova Heating Centre. The heat mentioned above is used to heat the dwellings and to meet the hot water needs of the dwellings (Satman et al. 2002).

It is also reported by Satman et al. (2002) that all through February 2001, 18.33×10^9 kcal heat was given to the system. It is equal to 31.7 MWt.

Two values (28 MWt and 31.7 MWt) are greater than probable heat energy value acquired from the results of the simulations (25.5 MWt and 26.02 MWt by Satman et al. (2002) and this study, respectively).

According to this it is possible to obtain more energy than modeled from geothermal resource. It could be suggested that the functional form of the model be reconsidered, and maybe the simulation be retried with another functional form including effect of the reinjection .

CHAPTER 5

**EVALUATION OF THE GEOTHERMAL RESOURCE
EXPLOITATION SCHEMAS OF BALÇOVA GEOTHERMAL
FIELD BY USING MULTICRITERIA DECISION AID
TECHNIQUE**

5.1 Multicriteria Decision-Aid Technique

One can say that, the ethical and logical accuracy of the decisions made in an organization is always a controversial issue. It can be asserted that behind the decisions that the decision-makers make lies related issues such as individual, corporate and social needs, their priorities and measuring the efficiency of the results after making the decision. These issues are related to the quality of the organization that they take place in. One of the methods which is created to evaluate these decisions from logical and ethical points of view is Multicriteria Decision-Aid.

Multicriteria Decision-Aid (MCDA) or Multiple Criteria Decision Making methods are mainly evaluated in the areas of operations research and decision theory but one cannot ignore the links which exist between other fields of research such as the theory of social choice, voting procedures, decision in a context of uncertainty, the theory of fuzzy sets, negotiation and expert systems.

The book titled “Multicriteria Decision-Aid”, which is formed by Vincke (1992) by collecting the important publications about the subject, can be shown as an important reference. In this book, definitions about the subject and classifications can be found within a general frame.

As its name indicates, MCDA aims to give the decision-maker some tools in order to enable him to advance in solving a decision problem where several –often contradictory- points of view must be taken into account. The first fact which should be noted when dealing with this type of problem is that there does not exist, in general, any decision (solution, action) which is the best simultaneously from all points of view. Therefore, the word “optimization” doesn’t make any sense in such a context; in contrast to the classical techniques of operations research, multicriteria methods do not yield “objectively best” solutions (such solutions do not exist). This is why the word “aid” seems essential to define this methodology. The evolution of multicriteria

methods illustrates this point of view perfectly: aggregation into a unique criterion (in order to bring the multicriterion problem back to an optimization problem) was contested and progressively replaced by more flexible, less mathematicized (some will say less rigorous) methods; similarly, interactivity has played an ever-increasing part in the proposed procedures.

Specialists in MCDA have a tendency of dividing the methods into three great families, even if the boundaries between these families are rather fuzzy:

1. multiple attribute utility theory,
2. outranking methods,
3. interactive methods.

The first family, of American inspiration, consists in aggregating the different points of view into a unique function which must subsequently be optimized. It is also directly connected to the utility theory in economics, in particular, school of theorists which allege the utility could be stated as a quantity. The work related to this family studies the mathematical conditions of aggregation, the particular forms of the aggregating function and the construction methods.

The second family, of French inspiration, aims first to build a relation, called an outranking relation, which represents the decision-maker's strongly established preferences, given the information at hand. The latter relation is therefore, in general, neither complete nor transitive. The second step will consist in exploiting the outranking relation in order to help the decision-maker solve his problem.

The third and the most recent family propose methods which alternate calculation steps (yielding successive compromise solutions) and dialogue steps (sources of extra information on the decision-maker's preferences). Though they are mostly developed in the frame of multiple objective mathematical programming, some of these methods can be applied to more general cases.

The methods that MCDA families mentioned above include are stated below with their definitions.

5.1.1 Multiple Attribute Utility Theory

Multiple attribute utility theory (MAUT) is based on a relatively simple idea. The fundamental axiom is that any decision maker is unconsciously or implicitly trying to maximize some function

$$U = U(g_1, g_2, \dots, g_n) \dots \dots \dots (5.1)$$

where g_i is the measure of attribute a_i that aggregates all the different points of view taken into account. If the decision maker is asked about his/her preferences, the answers will be coherent and consistent with that certain unknown function U . The key here is that more than one criterion affects the decision maker's utility. In a sense, the utility function is based on the criteria as a whole rather than on individual utilities. Having said that, convenient additive utility functions occur under certain assumptions, the analysts' role with these techniques is to try to discover the nature of that function, U , by asking the decision maker some well-chosen questions.

Two types of problem are studied in the frame of this theory:

- Decision maker's preferences must fulfill, so the properties can be reasonably represented by a function U with an analytical form, such as the additive, multiplicative, mixed and other forms
- The other is to build such a function, identify its analytical form and estimate its parameters.

5.1.2 The Additive Model

The most simple and the most common analytical form is additive form

$$U(a) = \sum_{j=1}^n U_j(g_j(a)) \dots \dots \dots (5.2)$$

where $g_j(a)$ means the value of the action a corresponding to criterion j and the U_j 's are strictly increasing real (utility) functions and their only purpose is to transform the criteria in order for them to follow the same scale: This avoids problems of units and ensures that summation makes sense.

It is important to note that in order to evaluate utility function reasonably and to get comparable results from the differences of them (eg. $U(a)-U(b)$) utility independence between criteria should be provided.

Two type of method constituting the additive model mentioned in the work of Vincke (1992) could be summarized as below:

First, direct method consists of several different methods. Some of these methods suggest that utility function could be formed by dialogue with the decision maker on determining mid points of the best and the worst values of the criteria and going further by taking midpoint of the best-mid, mid-the worst so on. The others, on the other hand, suggest assigning probabilities to the best and the worst state of the criteria to find probabilistic mid points of the function while there are methods that suggest finding the common points according to the points of view of the decision-makers and comparing these with the answers of the others.

Second, indirect methods could be used for building the additive model. These methods of building the function U consist in estimating it on the basis of the global judgments made by the decision-maker on set A , set of all possible actions or plans. In essence, these methods are the generalization of the U function by discriminant analysis. The indirect method, which is also called UTA (Utilité Additive), consists in first determining and optimizing utility function through linear programming and then performing a sensitivity analysis. It assumes the criteria are expressed in numerical form. Then, the interval of the best and the worst states in the set of all possible states divided into r_j equidistant intervals. The utility of each action can be determined by interpolation. Linear programming is applied to minimize the errors that will be found hypothetically in the assumptions about the best values of each action. This step yields a function U which is the sum of partial piecewise linear utility function. If the sum of the error associated with the estimation is greater than 0 (this shows that the utility function will be changed according to the criterion that the decision-maker has chosen), the smallest number obtained in the previous step being greater than the sum of errors is added to the constraints set, and thus a set of utility functions which are suitable for the representation of the decision-maker's preferences is obtained. PREFCALC software can be used to solve UTA problems (Vincke 1992).

5.1.3 The Multiplicative Form

The additive model can be made into multiplicative one which is also related to the functional form of the utility equation (e.g. logarithmic relationships between criteria). By letting,

$$U'(a) = e^{U(a)} \dots\dots\dots(5.3)$$

$$U'_j(g_j(a)) = e^{U_j(g_j(a))} \dots\dots\dots(5.4)$$

and we get

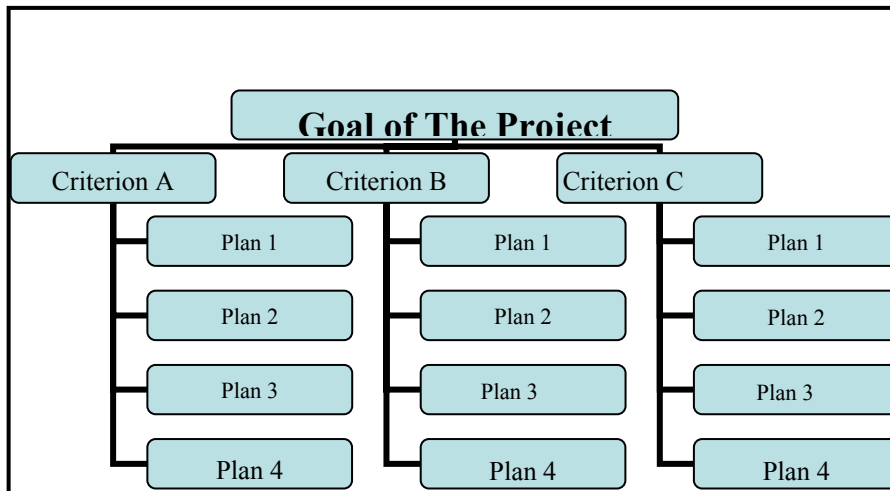
$$U'(a) = \prod_{j=1}^n U'_j(g_j(a)) \dots\dots\dots(5.)$$

The converse is also true that by using logarithm multiplicative model could be converted to additive one. Multiplicative form which is convertible into the additive form utility functions could be solved by using the appropriate additive method.

5.1.4 The Analytical Hierarchy Process (AHP)

Another MAUT method suggested by Saaty (1980) is AHP. It is possible to explain this method in three steps. In the first step, the decision problem is represented as a hierarchy in which the top vertex is the main goal of the problem, the bottom vertices are the actions or plans and the intermediate vertices represent the criteria. The figure below shows hierarchic representation of the AHP problem.

Graph 5. Hierarchic representation of the AHP problem



Source: Yoe 2002

At the second step, at each level of the hierarchy, a pairwise comparison of the vertices is performed from the point of view of their contribution to each of the higher-level vertices to which they are linked. These comparisons are made in terms of “preference ratios” (if they are actions) or “importance ratios” (if they are criteria) evaluated on a numerical scale. The computation of the eigenvalues of this matrix of pairwise comparisons, allows the calculation of the value to be given to each comparisons. At the last step the global contribution of each action to the main goal is calculated by an aggregation of the weighted average type (Saaty 1980).

5.2 Outranking Methods

Methods based upon MAUT lead to a function allowing the ranking of all actions from best to worst. The large amount of information contained in the result is due to the theory’s strong assumptions (existence of function U , additivity etc.). However, it is necessary to go that far in the frame of decision aid, for example, if it is known that some action a is better than b and c , it becomes irrelevant to analyze preferences between b and c . The underlying idea of the outranking methods is thus that it is better to accept a result less rich than the one yielded by MAUT, if one can avoid introducing mathematical hypotheses which are too strong and asking the decision-maker questions which are too intricate. The outranking methods can be sorted as follows:

5.2.1 The ELECTRE I Method

This method’s aim is to obtain a subset N of actions such that any action which is not in N is outranked by at least one action of N . According to the weight assigned to

each criterion, a concordance index that shows the preference of each plan over the other plans, and discordance indexes that show the incomparability or tie state are formed (to form the discordance indexes, discordance conditions are defined, for example, if the difference between two actions, say cost difference, exceeds x units, an outranking relation between them cannot be found). Then, the outranking relation is defined according to the weight value that is chosen between them. An outranking relation might not be formed between some actions (because of discordance conditions or tie state) (Vincke 1992).

5.2.2 The ELECTRE II Method

Different from ELECTRE I, ELECTRE II aims to rank the actions from the best to the worst (ranking problem). In this method new constraints are brought concordance and discordance indexes that take place in the previous method. These constraints are as defining concordance thresholds and grouping the outranking relations as “strong” and “weak” relations. By selecting the weak actions from the strong ones a set is formed, and another set is formed by selecting the strong ones from the weak actions. Then, they are compared to see whether they are the same or not. If the sets that are formed are not the same, for example, if a certain action doesn’t outrank any other and is itself outranked by no other action, or the data too divergent is able to build an acceptable ranking, robustness analysis is necessary (Vincke 1992).

5.2.3 The ELECTRE III Method

The valued outranking relation of the ELECTRE III method is characterized by the definition of an outranking degree $S(a,b)$ associated with each ordered pair (a,b) of actions, representing the more or less great outranking credibility of a over b . Here concordance index pseudo-criteria is formed according to the weights assigned. The mentioned pseudo-criteria could take the value representing indifference till a threshold value that will be determined, and could take a certain preference value (which is generally 0 or 1) after reaching the threshold value, or it could be linear between indifference and preference thresholds. Discordance index is formed by introduction veto threshold. This index, as explained in pseudo-criteria above, is formed by veto values that are assigned according to the threshold values. Then, the degree of the outranking of the actions is defined by pairwise comparison:

$$S(a,b) = \begin{cases} c(a,b) & \text{if } D_j(a,b) \leq c(a,b), \forall j, \\ c(a,b), \prod_{j \in J(a,b)} \frac{1 - D_j(a,b)}{1 - c(a,b)}, & \dots\dots\dots (5.6) \end{cases}$$

where $c(a,b)$ is the concordance index, $D_j(a,b)$ is the discordance or veto index, $J(a,b)$ is the set of criteria for which $D_j(a,b) > c(a,b)$ and j is the number of criteria (1,2,3,....., j) (Vincke 1992).

5.2.4 The ELECTRE IV Method

The ELECTRE IV method is based upon the consideration of a family of pseudo-criteria, it aims to rank the actions, but without introducing any weighing of the criteria. Instead of the weighing the criteria, two relations are built (strong and weak) on the basis of “common sense” considerations compatible with the lack of information on the relative importance of the criteria. The exploitation is performed as in ELECTRE III but is made simple by the fact that there are only two outranking levels. One determines the subset of actions which have the largest qualification in all actions for strong relation. If the number of the element in this set is only one, qualifications start again in the remaining actions in the largest qualification subset. When there are more than one element in the former qualified set, same procedure is applied inside this set but on the basis of weak relation. Second direction is built by and ascending procedure as mentioned above (Vincke 1992).

The subsequent outranking methods involve (in) an importance relation on the criteria.

5.2.5 The MELCHIOR Method

This method involve (in) an importance relation on the criteria. A family of n pseudo-criteria is at hand, provided with a relation T such that iTj means: criterion i is at least as important as criterion j . The basic idea is to say that a outranks b is the criteria which are unfavorable to the latter assertion are “hidden” by those which are in its favor and if no criterion j exists such that $g_j(b) > g_j(a) + v_j$ (means state of action b according to criterion j is greater than state of action a according to criterion j plus a veto threshold).

It remains to define (1) criteria which are in favor of the outranking of b by a , (2) criteria which are unfavorable to the outranking of b by a , (3) to hide (Vincke 1992).

5.2.6 *Trichotomic Segmentation*

The procedure description of this method was built in order to help a decision-maker who must, during the process of discovering the actions, decide to which category he will assign them among several defined in respect of the treatment they will receive later; this kind of situation occurs, for example, in loan allocation problems, when launching new products or research projects, and so on. This procedure is limited to the case where there are three categories considered: K^+ , K^- , and $K^?$ (in the example of loan allocation, they correspond to “accepting”, “refusing” and “awaiting extra information”).

First of all, the “high profile” (values that the decision-maker will accept without any hesitation) and “low profile” (values that the decision-maker will refuse without any hesitation) of each criterion are defined as vectors. If an action has a state over the high profile of a criterion, it is assigned to K^+ , if it has a state below, it is assigned to K^- and finally if it has a state between the high and the low profile, it is assigned to $K^?$. After this, outranking indexes are formed by pairing high and low profiles and the state of actions (it is calculated as in ELECTRE III) (Vincke 1992).

5.2.7 *The PROMETHEE Method*

Just as ELECTRE III, this method consists in building a valued outranking relation, but this time trying to involve concepts and parameters which do have physical interpretation easily understandable by the decision-maker. Procedure of this method is summarized as: having assigned to each criterion a weight p_j , increasing with the importance of the criterion, the outranking degree of each ordered pair of actions (a,b) is computed by introducing six types of criterion form which are offered the decision-maker to make a choice (detailed information about the types of criterion will be given in this chapter).

Outranking degree of the PROMETHEE method is quite similar to the concordance index in the ELECTRE III method; they are even identical if all functions F_j (preference intensity of the criterion which is represented in a graphical form) are of linear pseudo-criterion form mentioned above. On the other hand, there is no discordance concept is introduced to PROMETHEE. According to the outranking degree, each action is compared first as (a,b) , and then as (b,a) , and their “outgoing flow” and “ingoing flow” are found respectively. Their intersection yields the partial preorder of the

PROMETHEE I method. The PROMETHEE II method consists in ranking the actions following the decreasing order of numbers which is sum of outgoing flow and ingoing flow. The software called PROMCALC, DECISION LAB and GAIA is used to operate the PROMETHEE method with analytical and graphical tools (Vincke 1992).

5.3 Interactive Methods

An interactive method consists of alternating computation steps and dialogue with the decision-maker. The first computation step provides a first solution which is presented to the decision-maker, who reacts giving extra information about his preferences. Injecting the latter information into the model allows a new solution to be built (Vincke 1992).

Any decision aid method includes some kind of dialogue with the decision-maker, if only to define sets of actions and criteria. However, in order for it to be classified as an interactive method, that dialogue must be one of the principle investigation tools, meaning that the decision-maker brings a direct contribution towards the elaboration of a solution by intervening in the procedure and not only in the definition of the problem.

For generalization, those methods firstly act from Multiple Attribute Utility Theory, and multiobjective linear programming methods are used. The extreme points of the utility function are modified according to the weights that the decision-maker puts. The optimized “ideal point” is presented to the decision-maker. If the decision-maker is satisfied with the result, he can end the process. If not, according to the method that will be chosen, questions – such as whether the decision-maker wants to improve any criterion, whether concession will be given to any criterion, or whether there are criteria that he wants to relax or restrict – are asked to the decision-maker. Information about the possible consequences of the changes that will be made is given, and the process is carried to the end and it is checked whether the changes that the decision-maker has made converge an action (Vincke 1992).

The purpose of an interactive method is essentially to find a “satisfactory compromise solution”. Supporting to decision-maker is one of the most important aspects of an interactive method. The role of a method is not to decide for decision-maker, but to enlighten him on his problem (learning-oriented conception): what is possible, what are the consequences of a certain choice, how can an aspect be improved, and so on (Vincke 1992).

5.4 Selecting PROMETHEE

In the work of Goumas et al. (1999), which has been mentioned before as the inspiration for this study, the reasons for the election of PROMETHEE as multicriteria decision aid methods are given. These are shortly listed as the simplicity of the method and the limited amount of input data that is required. By simplicity of the method the intent is to say that it is easy to follow even for persons with no expert training in the multicriteria analysis. The users can better estimate the parameters required to express their own preferences and evaluate the results. Limited amount of input data can be put forward as a general reason of preference of outranking methods, mentioned above, by the users.

The following steps are required for the implementation of the method.

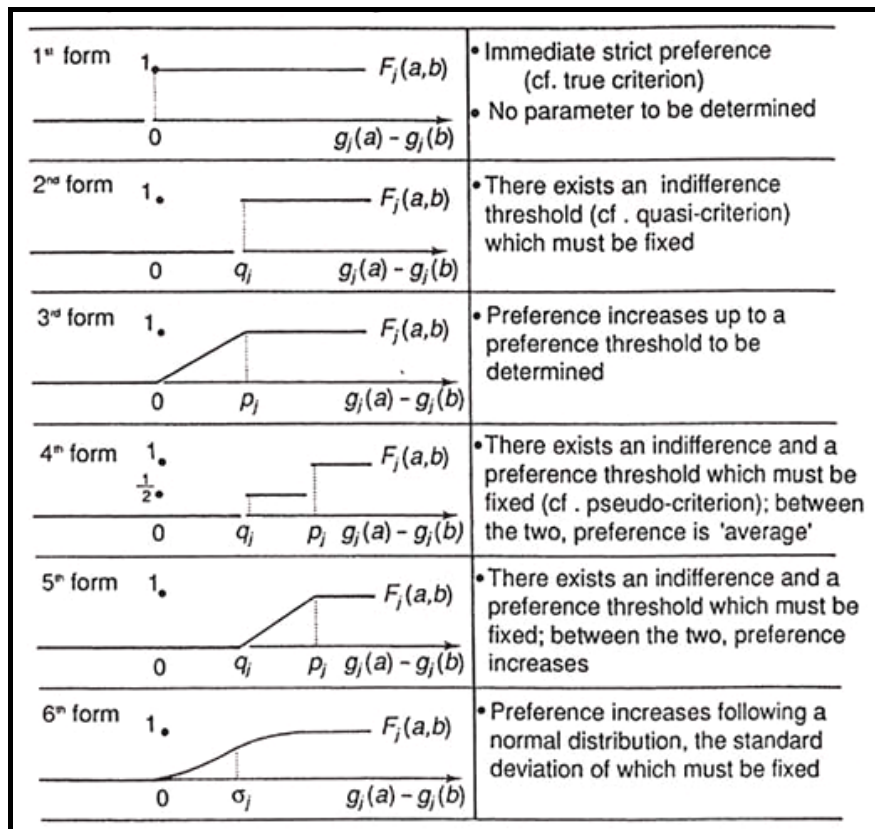
1. Having assigned to each criterion a weight p_j , increasing with the importance of the criterion, the outranking degree $\pi(a,b)$ of each ordered pairs of actions (a,b) is computed. The computation is made as follows:

$$\pi(a,b) = \frac{1}{P} \sum_{j=1}^n p_j F_j(a,b) \text{ where } P = \sum_{j=1}^n p_j \dots\dots\dots(5.7)$$

and where $F_j(a,b)$ is a number between 0 and 1 which increases if $g_j(a)-g_j(b)$ is large and equals zero if $g_j(a) \leq g_j(b)$ (where $g_j(a)$ is the state of the action a evaluated by criterion j)

2. In order to estimate $F_j(a,b)$'s, the decision-maker is offered a choice, for each criterion, between the six forms of curves presented below. According to the way his preference increases with the difference $g_j(a)-g_j(b)$, the decision-maker sets, for each criterion, the form of F_j and the associated parameters.

Figure 4. Six form of the preference intensity in the PROMETHEE



Source: Vincke 1992

a and b actions has states according to criterion j . In the figure above, when the 5th form is chosen for criterion j , difference between the states of the actions a and b according to criterion j is tie till threshold -indifference- value (q_j); over that threshold, action a is preferred linearly to action b , and at the preference threshold, a is preferred to b . Index takes a value in $[0, 1]$ interval between these two threshold values. For example, if the criterion is determined as the total profit, it is asked to the decision-maker to what extend he wants the actions that he has to be the indifferent, and from what point on it will result in definite preference of one of these actions to the other one. if we suppose these thresholds as, for example, 200 and 1000, this means that if the difference between action a and b is 200 and less, actions are indifferent; if the difference is more than 1000, then the action which causes the difference is preferred to the other one. however, if, for example, the difference is 600, preference intensity index value will be 0.5, if it is 400, this value will be 0.25, and if the difference is 900, then it will be 0.875.

3. For each ordered pairs of actions, $\pi(a,i)$ value given above (where i is the all actions except a) is found. By using the sum of these values ϕ^+ (outgoing flow) value can be found. When the same procedure is calculated for $\pi(i,a)$ and these values are added up, ϕ^- (ingoing flow) value is found.

$$\phi^+(a) = \sum_{i \in A} \pi(a,i) \text{ and } \phi^-(a) = \sum_{i \in A} \pi(i,a) \dots\dots\dots(5.8)$$

where A is the set of all actions. $\phi^+(a)$ value shows the general superiority of action a to the other actions.

4. When evaluating the results conditions given below should be satisfied:

a outranks b if:

$$\phi^+(a) \geq \phi^+(b) \text{ and } \phi^-(a) \leq \phi^-(b) \dots\dots\dots(5.9)$$

a and b are incomparable if:

$$\phi^+(a) > \phi^+(b) \text{ and } \phi^-(a) > \phi^-(b) \text{ or vice versa} \dots\dots\dots(5.10)$$

PROMETHEE I may not give the complete order of actions because it only emphasize outranking relations as a outranks b , or a is tie with b , or a is incomparable with b . It does not compare conflicting actions.

While the process to be followed for PROMETHEE I method is as stated above, in PROMETHEE II, the ordering of the actions can be made by adding up $\phi^+(a)$ $\phi^-(a)$ values.

$$\phi(a) = \phi^+(a) + \phi^-(a) \dots\dots\dots(5.11)$$

It gives complete order of the actions.

When the decision-maker is not able or does not want to allocate precise weights to criteria, it is possible to specify intervals of possible values rather than one fixed value for each weight. In this case, the PROMETHEE VI procedure can be used to indicate whether the problem is *soft* or *hard*. It is *soft* when the decision axis π always remains in the same general direction for the weight distributions that are compatible with the intervals. It is *hard* when opposite directions are possible depending on the actual

values of the weights. In the case of a *hard* problem, the decision-maker should concentrate on more precise values of the weights (WEB_7 2005).

It is often the case that several alternatives have to be selected and that additional constraints must hold. In this case a (0-1) linear program can be associated to the problem, the solution of which gives the best selection of r actions among n . The PROMETHEE V procedure allows investigating such problems (WEB_7 2005).

5.5 Exploitation Possibilities of Geothermal Resource in Balçova

At present district heating (main system) is generally utilized as a resource for greenhouse heating and thermal spa uses. In addition to these utilizations, small scale fruit and vegetable drying facility is presented in this study. The evaluation of the mentioned utilizations in terms of economy, return on investment (ROI) and employment are studied as follows.

It could be said that the model prepared by Monte Carlo Simulation technique underestimates the resource. The value of 25.5 MWt obtained from the model is a little below February 2001 value of 31.7 MWt. The simulation done by TOUGH2 shows that the resource of the field might have a capacity of 66 MWt. In this study, the average of these two values is taken, and it is assumed that the resource of the field could have a power of 45.75 MWt. This value equals to 14% cumulative probability value of the geothermal resource modeled by Monte Carlo Simulation technique as seen in Graph 3.

The difference between the value of 45.75 MWt taken as probable value and February 2001 value of 31.7 MWt is nearly 14 MWt. This difference value is assumed as the resource value to be exploited in the subsequent calculations. ROI, tons of oil equivalent (TOE) value and annual working days are chosen as criteria.

ROI is used to evaluate the efficiency of economic investments, and it is equal to the ratio of net benefit and investment. For example, if a project has an ROI of 300%, the net benefits derived from that project are three times those of the expected total costs to implement the project. As such, the ROI calculation represents the relative value of the project's cumulative net benefits (benefits minus costs) over the analysis period, divided by the project's cumulative total costs, and expressed as a percentage.

Another criterion is TOE (tons of oil equivalent). TOE defines the oil equivalent quantity of the energy obtained from an energy resource other than oil, and it equals to 10^7 kcal (41.860 GJ). The use of oil increases parallel to the economic growth. It is

categorized as export product. The need for oil as energy raw material increases oil import dependency and causes environmental problems.

Annual working days calculates the annual working days that the jobs possible to be created by proposed alternatives would create.

While calculating ROI, the existing GDHS cost-benefit and the cost-benefit of alternatives, in which assumed additional capacity of 14 MWT will be evaluated, are calculated together. Here the basic attitude is to analyze the cost-benefit to the local economy and to calculate its ROI. For the alternatives, cost items are evaluated as investment, operating and depreciation. Revenue is handled as production benefits.

TOE is calculated by using the degree day procedure. The general relation for fuel calculations using the degree day procedure is as follows [26]:

$$F = \frac{24(DD)C_D\dot{q}}{\eta_h(T_i - T_o)H} \dots\dots\dots(5.12)$$

where F is the quantity of fuel required for the period desired (the units depend on H), DD is the degree days for the period desired in °C day, C_D is the interim correction factor for degree days based on 18 °C (Mc Ouiston and Parker, 1994) or based on various outdoor design temperatures (Lund and Lineau 1997), \dot{q} is the total calculated heat load based on design conditions in W, η_h is the average heating system efficiency in percent, H is the heating value of the fuel in kWh per unit volume or mass and T_i and T_o are the indoor and outdoor design temperatures in °C, respectively (Üner and İleri 2000).

Annual working days are calculated taking into consideration full-time – seasonal and with shift – without shift types of employment.

There are other criteria of interest in problems concerning renewable energy exploitation projects, such as the environmental impact, the risk of the enterprise and the acceptance by the local community. Their evaluation is not straight forward; however, a comparative index e.g. a grade in a scale 0-10 can be applied. In this example these three additional criteria were not included in the evaluation because the five options that were ranked exhibit approximately equal performance for the criteria of environmental impact and risk. The criterion of acceptance by the local community was not considered independent as it mostly depends on the creation of new jobs and

the environmental impact. Thus, its effect can be taken into consideration by properly adapting the weighting factors of other criteria. Although theoretically there is no limit to the number of independent criteria that can be considered, it is a good practice to avoid extending the analysis by including criteria that are not expected to influence the ranking. The omission or elimination of criteria, when justified, reduces the required decision parameters keeping the decision process simple and unambiguous (Goumas et al. 1999).

The criteria values of all alternatives are calculated for the period till the end of the year 2021. An annual interest rate of 5% is used for calculation of net end of year 2021 value.

5.6 Exploitation scenarios proposed for Balçova geothermal field

5.6.1 District Heating

Following electricity production, geothermal energy is exploited most for district heating systems. District heating is heating residential areas by using geothermal fluid that transfers heat directly to the heating system of the dwelling or that is used for secondary fluid.

The main reasons for geothermal being more convenient than other energy sources are discussed below.

1. As the selling price of geothermal heat is held constant for the whole year, geothermal heating projects are more attractive to consumers. The cost of geothermal heating, including hot sanitary water, varies from 14 to 33 US\$/month for a 100 m² residence, relative to existing geothermal district heating systems. As this cost remains the same throughout the year in Turkish lira and is not affected by currency variations, it is more economically attractive to the consumer than fossil fuel-driven schemes.
2. Existing heating systems can be connected directly to geothermal district heating systems.
3. Previous radiator models, designed for the 90/70°C temperature intervals of conventional heating systems, have not caused any problems when used with temperature intervals of 80/40°C, 80/45°C or 70/50°C, which are typical of geothermal systems. This suggests that the radiator heating surface was originally of a larger design than necessary.

4. The investment costs per residence of geothermal district heating systems varied between 1250 and 1800 US \$ (excluding installation of radiators). These investment costs are currently being paid back commercially in 5–8 years. The GDHS have relatively low initial and operational costs and the sales price of the heat is also low compared to conventional fuels (coal, oil, etc.).
5. About 40–50% of the investment costs were paid by the consumers in the form of a connecting fee, like cash in capital. As a result, the economy of GDHS investments is improving. (Mertoglu et al. 2003)

Table 14. City based geothermal district heating systems installed in Turkey (Batık et al. 2000, Mertoğlu 2001a, Hepbaşlı and Çanakçı 2003)

Location	Province	Capacity (MW _t)	Geothermal fluid temperature (°C)	Year commissioned	District heating distribution network supply/return temperatures (°C) ^a	Installed Capacity (residence)/Number of dwellings heated
Gönen	Balıkesir	32	80	06.1987	-	4500/3400
Simav	Kütahya	25	120	10.1991	65/50	6500/3200
Kırşehir	Kırşehir	18	54-57	03.1994	48/42	1800/1800
Kızılcahamam	Ankara	25	80	11.1995	-	2500/2500
Izmir-Balçova (Narlidere)	Izmir	72	115	10.1996	85/60	20000/6849
Kozaklı	Nevşehir	11.2	90	1996	-	1250/1000
Afyon	Afyon	40	95	10.1996	60/45	10000/4000
Sandıklı	Afyon	45	70	03.1998	70/40	5000/1700
Diyadin	Ağrı	42	78	09.1998	78/45	2000/1037
Salihli	Manisa	142	94		-	20000 ^b

^a Average values are given

^b Target capacity

In Table 14, city based geothermal district heating system installed could be seen. As seen in the table, İzmir-Balçova GDHS is the biggest geothermal district heating system in Turkey. Afyon, Salihli, Simav have important geothermal energy reserve that is utilized or planned to utilized by the SPO and the local authorities.

The biggest district heating system in Turkey is Balçova GDHS. One of the main considerations in this study is how economic balance would change when estimated potential geothermal capacity is exploited in district heating system. The items listed below are main evaluation criteria that are used to make decision on proposed exploitation schemas.

- Increase in investment cost

- Increase in operating cost
- Change in depreciation cost
- Benefits to be obtained
- Potential of the system to create employment
- TOE value of the system

The calculation of these parameters is based on the values in the study of Erdoğan (2003). Besides this, calculations of customer benefit and heat load based on the design condition made by Toksoy and Çanakçı (2001) are used in the calculation of TOE value of the district heating system. It is assumed that 1 m² area will create an employment of 0.02607 days/yr. From the year 2004 on, a fix charge of 33 \$ have been collected.

5.6.2 Thermal Tourism

Recently the interest in thermal tourism has increased as, particularly, the aged population has increased and as it has lower costs to treat orthopedic and blood circulation diseases by thermal therapy.

One of the alternatives that the Ministry of Culture and Tourism suggests to widen the scale of tourism service is thermal tourism. Given table below are the places determined by the Ministry that have this kind of tourism potential.

**Table 15. Alternative Tourism Investment Areas and Thermal Tourism Centers
(WEB_8 2005, Ministry of Culture and Tourism)**

Thermal Tourism Center	Area	Beds Available	Beds Planned	Total Beds	Thermal Capacity (Lt/ Sec)	Thermal Fluid Prod. (Lt/ Sec)	Thermal Fluid Consump (Lt/ Sec)	Temp. of the Fluid (°C)
Afyon-Gazlıgöl	73,0	287	1950	2.237	15,5	30,0	12,0	50-75
Afyon-Bolvadin Heybeli	262,0	500	12300	12.800	89,2	55,0	29,0	57
Afyon-Ömer Gecek	1.300,0	1000	9000	10.000	69,5	100,0	80,0	50-95
Afyon-Sandıklı Hüdai	126,5	1500	5000	6.500	45,1	175,0	52,0	45-70
Ağrı-Diyadin	280,0	-	-	-	-	6,0	6,0	45-75
Amasya-Terziköy	-	-	-	-	-	-	-	-
Ankara-Seyhamamı	78,5	502	2000	2.502	17,4	21,0	21,0	43
Balıkesir-Gönen	72,5	520	1120	1.640	11,4	100,0	28,0	40-45
Balıkesir-Edremit Güre	98,7	82	2766	2.848	11,4	45,0	2,0	50-60
Bolu-Karacasu	30,0	500	1500	2.000	13,7	33,7	17,6	40-45
Bursa-Kükürtlü	18,0	133	967	1.100	7,8	14,8	6,6	90-110
Çanakkale-Ezine Kestanbol	312,5	600	6000	6.600	46,0	65,0	15,0	60-75
Diyarbakır-Çermik	73,0	1634	1160	2.794	19,5	10,0	5,0	45-50
Erzurum-Pasinler	18,7	66	704	770	5,4	220,0	15,0	47
Eskişehir-Sarıcakaya	13,4	500	1000	1.500	10,4	9,0	9,0	50
İzmir-Balçova	64,2	1004	-	1.004	-	100,0	12,0	45-140
İzmir-Seferihisar Doğanbey	470,0	500	12000	12.500	86,9	90,0	-	78
Kütahya-Emet	25,2	200	900	1.100	7,4	17,0	5,9	40-45
Kütahya-Gediz Ilcası	17,7	770	2500	3.270	22,7	225,0	15,8	65-75
Kütahya-Gediz Muratdağı	36,0	84	3500	3.584	24,3	45,2	5,4	42
Kütahya-Ilıca Harlek	15,0	302	1750	2.052	15,0	36,0	27,0	43
Kütahya-Simav Eynal	51,0	411	1500	1.911	13,3	200,0	15,2	97
Kütahya-Yoncalı	123,4	450	1400	1.850	12,9	65,0	63,5	41
Niğde-Çiftelhan	31,6	1765	2000	3.765	26,1	21,0	14,0	53
Niğde-Narlıgöl	245,2	-	7615	7.615	53,0	110,0	-	65
Osmaniye-Haruniye	27,0	-	-	-	-	15,0	15,0	33
Rize-Çamlıhemşin Ayder	-	665	-	665	-	17,0	14,0	55
Samsun-Havza & 25 Mayıs	313,0	814	1760	2.574	18,0	70,0	21,0	52
Sivas-Kangal Balıklıçermik	24,2	240	360	600	5,0	50,0	-	36
Sivas-Sıcak Çermik	63,8	356	1600	1.956	0,5	200,0	39,0	45-50
Yalova	90,0	704	780	1.484	0,3	18,0	18,0	66
Yozgat-Bahariye Cavlak	87,0	-	2600	2.600	18,1	511,0	35,0	35-40
Yozgat-Sarıkaya	10,5	233	1590	1.823	11,3	28,0	15,0	45-50
TOTAL	4.451,6	16.322	87.322	103.644	677,1	2.702,7	614,0	-

Ministry of Culture and Tourism plans to direct alternative tourism investment to these districts given in the table below. As seen in the table, İzmir-Balçova district has 1004 bed available and there is no bed accrual planned.

The Balçova Thermal Hotel located in Balçova is one of the pioneer facilities in thermal tourism. The numbers of the visitors till the year 2003 are given in the table below. In particular, Scandinavian visitors prefer the Thermal Hotel, because health insurance firms at these countries have contract with the hotel.

Table 16. Visitors of the Balçova Thermal Hotel by nations (WEB_9 2005)

Nationality	1999	2000	2001	2002	2003
Turkish	2386	2200	2125	2457	3148
Norwegian	1175	1235	1403	1482	1321
Denmark	575	520	475	450	275
Other Nations	450	600	615	520	410
TOTAL	4586	4555	4618	4909	5154

The therapy alternatives that this facility offers are balneotherapy, hydrotherapy, electrotherapy, kinesytherapy, paraffin wax and mud, massage, dental treatment. The number of the personnel related with thermal therapy is 64 (WEB_9 2005).

In Balçova, other than Balçova thermal hotel, thermal therapy service is given in two more five-star hotels – the Crowne Plaza and the Princess Hotel. The information about the hotels located in Balçova, nearby the geothermal resource is given in the table below.

Table 17. Hotels in Balcova

	Area	Rooms	Beds
Princess Hotel	25,000	278	556
Crowne (Özdilek) Plaza	27,000	219	333
Balçova Thermal Cure Center	13,000	215	435
Izmir University of Economics (former Grand Plaza)	18,800	200	380
Pools of the Hotels	5,611	0	0
AVERAGE	20,950	228	426

When the average of the areas of these hotels is taken, a value of nearly 21,000 m² is obtained. All of the hotels have 200 or more beds. The number of the personnel working in this kind of five-star hotels could change between 290 and 320 (WEB_10 2005).

In this study, while economic assessment of this kind of hotels is made, 2001 statistics collected by DIE are used. According to this, the statistics between the values of bed number and input, output and value added are as follows.

Table 18. Number of establishments, input, output and value added by number of beds (DIE 2001)

Number of bed's groups	Number of establishments	Input	Output	Value added
		in million TL		
-10	6	2,261,376	4,843,748	2,582,372
11-25	1437	14,332,561	33,665,933	19,333,372
26-50	3767	121,939,080	243,970,625	122,031,545
51-75	2119	300,205,908	582,622,628	282,416,720
76-100	1133	109,162,997	245,307,035	136,144,038
101-150	902	168,571,102	407,577,000	239,005,898
151-200	330	97,453,759	217,983,056	120,529,297
201+	807	1,631,211,173	3,759,110,383	2,127,899,210
Total	10501	2,445,137,956	5,495,080,408	3,049,942,452

The hotels in Balçova are in 201+ bed number group, and the biggest portion per facility as added value belongs to this group.

While calculating the construction costs of the hotels and the therapy centers, the table of minimum construction costs determined annually by the Ministry of Public Works and Settlements is used (The Official Newspaper 2004). It is estimated that, in Balçova, the cost of a facility with a total area of 21,000 m² hotel and thermal therapy center could be 17.3 million YTL. The decision of an investment of this magnitude could be seen as rather risky when it is examined in terms of the opportunity cost of the money, risk of the tourism market and risk of the investment.

Moreover, the tourism parcels which will enable investments in this scale in Balçova zoning ordinance are not currently available.

It is assumed that, value added of a five-star hotel which will be heated by geothermal energy and give therapy service will be 8% more than that of the other hotels. These values are obtained directly from DIE statistics. It is assumed that the investment will be completed in two years, and in the first year 33% and in the second year 66% of the total construction cost will be spent.

Working days calculation is made by assuming that 320 personnel will be working full-time with shifts and its value is equal to 107200 days/yr.

TOE is taken as 1800 tons/yr approximately by applying degree day procedure. The maximum thermal requirement for this facility is calculated as 1,586 MW_t.

5.6.3 Agricultural greenhouse production

Agricultural greenhouse production could be summarized as providing the agricultural crops that the market needs in seasons when the climatic conditions are not suitable through artificial environments.

A number of commercial crops can be raised in greenhouses, making geothermal resources in cold climates particularly attractive; however, growth can even be optimized in warmer climates. These include vegetables, flowers (potted and cut), house plants, and tree seedlings. The use of geothermal energy for heating can reduce operating costs (which can amount for up to 35 percent of the product cost) and allows operation in colder climates where commercial greenhouses would not normally be economical. In addition, greenhouses are suited to large quantities of relatively low-grade heat. Furthermore, better humidity control can be derived to prevent condensation (mildew), botritis, and other problems related to disease control. (Schmitt 1981).

Some of the advantages of using geothermal energy are (WEB_11 2002):

- Good correlation between the sites of greenhouse production area and low-enthalpy geothermal resources,
- Low-enthalpy geothermal resources are common in many countries,
- Geothermal energy requires relatively simple heating installations, but advanced computerized installations can later be added for total conditioning of the inside climate in the greenhouses,
- The economic competitiveness of geothermal energy for greenhouse heating, especially in colder climates,
- Strategic importance of energy sources that are locally available for food production, and
- Using a geothermal resource in combination with an existing fossil fuel system for peak heating.

In recent years, it can be observed that, especially in the Balkan states, studies about making greenhouse production by using geothermal energy have increased. The issue of using low-enthalpy geothermal resources in greenhouse production is especially considered.

Based on papers for the WGC2000 and more recent communications, the following estimates are made for the top countries using geothermal energy for greenhouse and soil heating:

Table 19. Top countries using geothermal energy for greenhouse and soil heating (Rafferty 2000)

Countries	Greenhouse using geothermal energy
Tunisia	102 ha
Hungary	90 ha
China	69 ha
Italy	50 ha
USA	50 ha
Romania	43 ha
Japan	40 ha
Russia	32 ha
Iceland	29 ha
Bulgaria	22 ha

The amount of energy use varies from 15 to 23 TJ/yr/ha, and thus, using an average of 19 TJ/yr/ha, this would estimate that there are around 940 ha presently using geothermal energy for heating. Of course, the energy use is a function of location, number of heating days, solar radiation, type of construction, wind, etc. (WEB_11 2002).

The equations suggested by Bakos et al. (1999) to calculate the heat loss when constructing greenhouse heating system are given below.

Heat loss during the night takes place through the cover material, the soil and as a result of the entry of cold air into the greenhouse.

The heat loss resulting from the thermal conductivity of the cover material is given as follows:

$$Q_l = K_{cov}A_{cov}\Delta t \dots\dots\dots(5.13)$$

where Δt is the temperature difference inside and outside the greenhouse; A_{cov} is the total surface area of the cover material, including the sides and roof.

The total surface area of the cover material is increased by 18.8% because of corrugations in the material (Lienau 1978). In the event of strong winds, K_{cov} could increase by up to 40%, with a relative increase of heat loss (Kiritsis 1982; Lund 1996).

The heat loss due to soil thermal conductivity is expressed as follows (Kiritsis, 1982):

$$Q_2 = K_{soil}A_{soil}\Delta t' \dots\dots\dots(5.14)$$

where $K_{soil} = 1.86 \text{ W}/(\text{m}^2\text{°C})$ and, for a well-heated greenhouse during the night (when soil temperature is greater than the air inside the greenhouse), is $\Delta t \cong \Delta t'$. The calculation of $\Delta t'$ is very complicated and depends on the soil water concentration, greenhouse width and the heating system selected.

The following equation describes the heat loss caused by entry of cold air into the greenhouse:

$$Q_3 = CVn \Delta t \dots\dots\dots(5.15)$$

where C is air specific heat [$0.2 \text{ kcal}/(\text{m}^3\text{°C})$]; V is greenhouse volume; n is air changes per h (mean value $n = 2$).

In the presence of strong wind, the above loss is increased by approximately 34.5%.

According to Kiritsis (1982), the cover material heat loss through radiation was estimated at approximately 20-25% of the total loss. (Bakos et al. 1999)

The maximum thermal requirement per 1000 m^2 was estimated as approximately 170,000 kcal/h.

Greenhouse heating can be accomplished by (1) circulation of air over finned-coil heat exchangers carrying hot water, often with the use of perforated plastic tubes running the length of the greenhouse in order to maintain uniform heat distribution, (2) hot-water circulating pipes or ducts located in (or on) the floor, (3) finned units located along the walls and under benches, or (4) a combination of these methods. A fifth approach is using hot water for surface heating.

The most efficient and economical greenhouse development consists of large structures covering 0.2 - 0.4 ha. A typical size would be 36 by 110 m constructed of fiberglass with furrow-connected gables. Heating would be from a combination of fan coils connected in series with a network of horizontal pipes installed on outside walls and under benches. A storage tank would be required to meet peak demand and for recirculation of the geothermal water to obtain the maximum temperature drop. Approximately 6.3 L/s of 60°C - 82°C water will be required for peak heating. The average is much less. Fortunately, most crops require lower nighttime than daytime temperatures. Greenhouse construction and outfitting will run from \$54 to \$108 per m² (WEB_11 2002).

In the study of Bakos (1999), various heating systems are tried. The first one of these alternatives is heating the geothermal fluid by auxiliary oil-burning installation on cold windy days, and heating the greenhouse by the help of fan units. This alternative is marked as a method that increases the costs considerably. In order to adjust this, the fluid could be heated at the outlet, but more pipes would be needed. The pipes should be of heavy duty steel in order to minimize any corrosion caused by water flow. Yet, the heavy duty steel pipes used in this method have not been able to pull the costs down to a reasonable level.

The second method offers a choice between two different options: (a) greenhouse heating using water of high temperature (95°C) and (b) greenhouse heating using water of low temperature and, in the case of maximum thermal demands, direct use of the geothermal fluid

The first heating option consists of 521 m of heavy-duty steel pipes (5 cm diameter) for a 25°C temperature reduction from 95 to 75°C, and four auxiliary air fan-coils to reduce the water outlet temperature from 75°C to approximately 50°C (Bakos 1999).

The second heating option involves the use of low-temperature water together with the direct use of geothermal fluid during periods of maximum thermal requirements. For a water temperature of 50°C, the on-the-soil pipe installation was the most economic and most efficient heating system since the plastic pipes run close to the cultivated plants. Plastic pipes of 20 mm and 25 mm diameter and efficiency of 30-40 kcal/(h m), placed one pipeline per m, can be used. In this case, the heavy-duty steel pipes cost more without improving the heating system performance. The air fan-coils, furthermore, cost four times more than plastic pipes of similar efficiency.

Furthermore, the direct use of geothermal fluid can provide fast space-heating, especially where there is a maximum thermal requirement. As far as installation and operation costs are concerned, the proposed method is cheaper than using heavy-duty steel pipes. Heating by means of plastic pipes positioned near the cultivated plants is also a more efficient method. One of the disadvantages of this method, however, is that a large part of the soil is covered by the plastic pipes (approximately 15%), which are sometimes destroyed or damaged by inexperienced cultivators. As a result the pipes have to be removed and replaced annually, leading to increased labor and pipe costs (Bakos 1999).

Because of lower cost, (b) option of the second method could be used for greenhouse heating system in Balçova assuming an efficiency of 30 kcal/h m. It was calculated that 6500 m of plastic pipes (25 mm diameter) would be needed.

The greenhouse production in İzmir is considerably high compared to the overall agricultural production of Turkey. Distribution of the agricultural lands according to their allocation in İzmir by districts is shown in Table 20.

Table 20. Distribution of the Agricultural Lands According to Their Allocation in İzmir, 2004, (in hectare) (WEB_12 2004)

Districts	Agr. Field	Vegetables	Floriculture	Vineyard	Fruits	Citrus Fruits	Olive	Popler Grove	Fallowing Land	Vacant Land Allocable to Agriculture	Total Agr. Land
BALÇOVA	5	99	67.6	10	5	160	130	-	-	68	543
BORNOVA	95	97	0.4	265	160	-	650	-	125	1,145	2,537
BUCA	909	73	-	125	132	-	555	-	560	556	2,910
ÇİĞLİ	970	37	-	6	6	-	1	-	7	712	1,739
GAZİEMİR	32	9	-	-	-	-	115	-	63	26	245
GÜZELBAHÇE	42	99	23.9	118	13	127	572	-	494	637	2,125
KARŞIYAKA	29	19	-	-	12	5	100	-	-	266	431
KONAK	4	32	-	365	30	-	60	-	-	77	568
NARLIDERE	29	31	7.6	2	11	200	90	-	-	28	399
TOTAL	2,115	496	99.4	891	368	492	2,273	-	1,249	3,514	11,497

The agricultural structure of the districts of İzmir, according to 2004 statistics of Provincial Agriculture Administration (PAA) is summarized in the table above.

Table 21. Greenhouse production in Izmir (WEB_12 2004)

	Type of Greenhouse	Area in hectare or Number	Balçova	Province Central	Province General
			Total	Total	Total
Vacant	Glass	7	27	44	58
	Made from Plastic	20			
	High Tunnel	-			
	Low Tunnel	-			
	Number of Families Working	-			
Fruit and Vegetable	Glass	10	56	121.3	7586.9
	Made of Plastic	43			
	High Tunnel	3			
	Low Tunnel	-			
	Number of Families Working	20 families			
Floriculture	Glass	98	634.5	952.2	3541.6
	Made of Plastic	536.5			
	High Tunnel	-			
	Low Tunnel	-			
	Number of Families Working	175 families			
Grand Total	Glass	115	717.5	1117.5	11186.5
	Made of Plastic	599.5			
	High Tunnel	3			
	Low Tunnel	-			

In Table 21, the greenhouse production in İzmir is shown and fruit and vegetable production takes the greatest stake (68%). 67% of the floriculture production in İzmir is made in Balçova.

Table 22. Cultivation, production, output and production value of the floriculture agriculture in Izmir (WEB_12 2004)

Species	GREENHOUSE+FIELD				PRICE (TL/ unit)	OUTPUT (YTL/1000 m ²)
	CULTIVATE D (x1000 m ²)	PRODUCTIO N (unit)	OUTPUT (unit/1000 m ²)	PRODUCTIO N VALUE (YTL)		
LILY	54.0	2,060,000	38,148	2,884,000	1,400,000	53,407
GERBERA	207.0	29,450,000	142,271	7,215,250	245,000	34,856
STARLICYA	35.0	970,000	27,714	1,212,500	1,250,000	34,643
ÇITIR	30.0	15,000,000	500,000	750,000	50,000	25,000
CARNATION	1,692.4	286,419,000	169,238	38,666,565	135,000	22,847
ROSE	767.5	113,700,000	148,143	17,055,000	150,000	22,221
TULIP	2.0	40,000	20,000	40,000	1,000,000	20,000
PANJUR	12.0	2,880,000	240,000	201,600	70,000	16,800
LISIANTHUS	5.0	450,000	90,000	83,250	185,000	16,650
GYPHOPHILLA	21.5	1,779,000	82,744	355,800	200,000	16,549
FREZIA	67.0	6,940,000	103,582	763,400	110,000	11,394
CHRYSANTHEMUM	330.7	26,278,000	79,462	3,678,920	140,000	11,125
WALLFLOWER	6.0	180,000	30,000	40,500	225,000	6,750
LIMONIUM	3.0	270,000	90,000	18,900	70,000	6,300
CYCLAMEN	2.0	75,000	37,500	11,250	150,000	5,625
HYACINTH	3.4	61,000	17,941	18,300	300,000	5,382
GLADIOLUS L	83.0	2,180,000	26,265	327,000	150,000	3,940
SOLIDAGO	1.0	30,000	30,000	3,000	100,000	3,000
HYACINTH	146.0	3,297,500	22,586	263,800	80,000	1,807
DAFFODYL	1,375.0	25,010,500	18,189	2,125,893	85,000	1,546
CUPRESSUS	1.0	1,500	1,500	210	140,000	210
TOTAL	4,844.5	-	-	75,715,138	-	

As production conditions in Balçova are compatible with the climate and as it is close to Izmir flower market, floriculture takes the greatest place in greenhouse agriculture.

As it is noted by Coşkun (2000), greenhouses are not able to work with the desired efficiency and profitability because of the structural deficiencies. It is possible to improve the greenhouses to the desired condition by solving these kinds of problems,

and by using geothermal energy for heating. In this way, it will be possible to raise crops that are sensitive to heat and light, and expensive.

In this study, it is analyzed what the costs, benefits, ROI and job creation will be in case of heating a 1000 m² greenhouse by geothermal energy. Costs are grouped into three categories: investment (cover and structure, irrigation system, heating pipes, shadow curtain, lights, measurement equipments, planting and control equipments, heat exchanger, water depot and pumps), operating (seeds, fertilizers, sand, turf, perlite, agri. chemicals, disinfection chemicals, seedbed, seedling viol, regulatory chemicals, electricity, water, transportation, manpower, geothermal energy) and depreciation costs.

When production value is calculated, it is assumed that the most profitable four species of flowers will be grown with an efficiency exceeding 1/3 of regular output because of proper temperature and humidity conditions of the greenhouses heated by geothermal energy.

In greenhouse production, cost of manpower is tried to be minimized by generally employing members of a household. Still, seasonal manpower could be employed in high seasons or as the greenhouse gets bigger. In this study, it is also assumed that a 1000 m² greenhouse will create 546 working days annually.

TOE is taken as approximately 258.1 by applying degree day procedure. The maximum thermal requirement per 1000 m² of greenhouse is ($T_i=19^{\circ}C$ and $T_o=0^{\circ}C$) estimated as approximately 186 kW.

5.6.4 Dehydration of Fruit and Vegetables

Dehydration (or drying) of fruit or vegetables is one of the oldest forms of food preservation methods known to man. The process involves the slow removal of the majority of water contained in the fruit or vegetable so that the moisture contents of the dried product is below 20%. In the Mediterranean countries the traditional technique of vegetable and fruit drying (including tomatoes) is by using the sun, a technique that has remained largely unchanged from ancient times. However, on an industrial scale, most fruit is dried using sun (or sometimes solar drying), while most vegetables are dried using continuous forced-air processes. Dried fruits and vegetables can be produced by a variety of processes. These processes differ primarily by the type of drying method

used, which depends on the type of food and the type of characteristics of the final product (Mujundar 1988; Nijhuis et al. 1998, Andritros et al 2002):

1. Sun drying. It is limited to climates with hot sun and dry atmosphere with strong winds. Typical areas with such climates are most of the Mediterranean regions, and most of the Aegean islands. Solar drying can be also used.
2. Atmospheric dehydration by passing heated air over the food to be dried.
3. Sub-atmospheric dehydration
4. Freeze-drying, for added value products, such as coffee.
5. Electromagnetic drying (e.g. microwave drying).
6. Drying using the osmotic phenomenon.

Drying of agricultural products is probably the most important industrial application of low or medium-temperature geothermal energy (40-150°C). Fresh or recycled air is forced to pass through an air-water converter and to be heated to temperatures in the range 40-100°C. The hot air passes through or above trays or belts with the raw products, resulting in the reduction on their moisture content. In geothermal drying, electric power is used to drive fans and pumps. Agricultural products that are dried using geothermal energy include (Lienau 1998; Lund 2000): onions, garlic, various fruits (apple, mango, pear, bananas, pineapple), alfalfa, grain, coconut meat, seaweed, timber, etc (Andritsos et al. 2002).

Recently, researches about small scale vegetable and fruit drying have increased. Studies concerning the improvement of the methods about making productions with high surplus value and increasing agricultural variety play an important role in this. Information about a small scale tomato drying facility which is tried in Greece could be used in the context of this study.

Andritsos et al (2002) introduces the technical details of this facility as follows:

In any tomato drying technique the required time for drying the product depends on many parameters such as tomato variety, the soluble solids content (brix) of the fresh product, the air humidity, the size of the tomato segments, the air temperature and velocity and the efficiency of the drying system. The rate of drying affects the end quality of the dried product.

In general, dried tomatoes undergo the following process steps: predrying treatments, (such as size selection, washing and tray placing), drying or dehydration, and postdehydration treatments, such as inspection, screening and packaging.

Traditional sun-drying has the advantages of simplicity and the small capital investments, but it requires long drying times that may have adverse consequences to the product quality: the final product may be contaminated from dust and insects or suffer from enzyme and microbial activity. On the other hand, industrial drying under high temperatures ($\sim 90^{\circ}\text{C}$) suffers from quality losses regarding color and aroma and may lead to case hardening (the formation of a hard outer shell), impeding the drying of the interior part of the product. It is obvious that the ideal conditions for drying tomatoes are mild temperatures between 45 and 55°C , which enable the dried product to retain its nutrients (including vitamins and lycopene, the nutrient responsible for the deep-red color of tomatoes) and flavors (Andritsos et al. 2002).

The complete tomato dehydration process can be divided into three stages: a pre-drying preparation step (pretreatment), the drying step, and the postdrying treatment. The predrying treatment prepares the raw tomatoes for the dehydration process. This step involves initially the selection of the tomatoes, regarding their maturity and soundness. About 40-70% of the tomatoes are selected to proceed for drying depending mainly upon the climatic condition during tomato growth and harvesting. The sorting of the tomatoes into two sizes is followed: tomatoes above 90 g and tomatoes of lower weight. The raw tomatoes are then placed in crates, washed to remove dust, dirt, plant parts etc, cut into two halves and placed into stainless steel trays (mesh type, $100 \times 50 \text{ cm}^2$). It is noted that blanching of the raw tomatoes is not required because of the richness of tomatoes in antioxidants substances. The drying step is carried out in a tunnel drier (Andritsos et al. 2002).

Drying system equipments could be summarized as finned-tube coil air-water heat exchanger (having a capacity of 300,000 kcal), two fan units totaling a rated power of 7 kW, 14 m long rectangular drying tunnel (width 1 m and height 2 m, constructed of polyurethane aluminum panels), measuring instruments (thermocouples) (Andritsos et al. 2002).

The 'cold' air enters the heat exchanger at atmospheric conditions ($20\text{-}35^{\circ}\text{C}$) and leaves the exchanger at an almost constant temperature of 55°C . The incoming geothermal water a temperature is 59°C , while the temperature of the water at the outlet

is 51-53°C. The mean water flow rate used during the first two drying periods was about 25 m³/h. The air flow rate in the tunnel was 10,000-12,000 m³/h and the superficial air velocity in the tunnel (without the trays loaded with product) was 1.7 m/s.

The postdehydration step involves inspection and screening (the removal of dehydrated pieces of unwanted size, of foreign materials etc.) and packaging in glass jars with olive or sunflower oil, wine vinegar, salt, garlic and various herbs (Andritsos et al. 2002).

The solids contents of the tomatoes range between 8 to 10% w/w and the moisture content of the final product is estimated to be about 10%. Accordingly, the weight of the processed product reduced about 10-12 times after drying. The removal of the moisture content appears to be faster at the first half part of the tunnel (Andritsos et al. 2002).

In this study, probable costs and revenues of the facility mentioned above are estimated by using corresponding local prices. It is assumed that this facility will work five months in a year because of high prices of the products cultivated in the greenhouse in the market that makes the facility unprofitable. Cool rooms into the facility could provide reasonable costs, because vegetables could be purchased with the lower price in the summer season and be stored for production till the season when the prices of the greenhouse products begin getting higher. This situation is also included into the cost calculations of the facility. The months of June, July, August, September, and October are selected as production season of the facility. The important point that must be emphasized is that these months do not match the heating season of the GDHS and this facility could be operated in the low-load season of the heating station. As an opportunity, three facilities are suggested in this work to analyze the help of these facilities to overall balance of the heating system.

Calculation of the costs are made as a base of investment (tomato paste machine, office room, heat exchanger, fan units, drying tunnel, trays, thermocouples, packaging machine, tables and panels, other equipments, construction, cooling rooms), operating (vegetables, electricity, water, geothermal energy, auxiliary materials, transportation, manpower) and depreciation costs.

In this study, selected raw material (vegetable) is tomato. By the help of the production methods explained above, value of the production is tried to be determined an accordance with the local market prices.

Working day calculation is made by assuming that seasonal manpower will be used. According to this, it is possible for such a facility to create 1050 working days annually.

TOE is taken as 28.8 approximately by applying degree day procedure. The maximum thermal requirement for this facility is calculated as 116.2 kW_t.

5.6.5 Application of the PROMETHEE Method for Different Scenarios

As emphasized previous section, one of the Multicriteria Decision Aid Technique, PROMETHEE, will be used to evaluate different scenarios by different point of views of the decision-makers. First, alternative exploitation scenarios will be defined as to corresponding criterion values. Common point of all scenarios is that three vegetable drying facilities will be constructed to utilize potential energy of the low heating season. These scenarios are given below:

Scenario #1: In this scenario all of the available geothermal resource will be allocated to district heating system that will heat 219,290 m² dwelling equivalent area. Three dehydration units will be attached to the system.

Scenario#2: Available resource will be allocated to a hotel, 10 hectares of greenhouse and the rest will be used for district heating system (approximately 165,314 m² dwelling equivalent area).

Scenario#3: Geothermal resource will be distributed equally to tourism, district heating and greenhouse uses. It means that three hotel, 72,525 m² dwelling and 2.48 hectares greenhouse will be heated.

Scenario#4: As being tourism weighted scenario, resource will be used for heating of hotel and rehabilitation center as much as possible, and the rest will be allocated to district heating system. Eight hotel and 20,550 m² dwelling could be heated in this scenario.

Scenario#5: Resource will be apportioned to greenhouse and district heating system which is equal to 3.76 hectares greenhouse, and 109,645 m² dwelling.

Scenario#6: After allocation of the resource to two hotels, the rest of the energy will be utilized for district heating purpose. Total dwelling area heated by this schema is equal to 169,606 m².

In order to present alternative exploitation schemas clearly, the table given below is prepared:

Table 23. Allocation of the resources according to the scenarios proposed

Scenarios	District Heating	Greenhouse	Tourism Establishment	Drying Facility
1	219,290 m ²	-	-	3
2	165,314 m ²	10 ha	1	3
3	72,525 m ²	2.48 ha	3	3
4	20,550 m ²	-	8	3
5	109,645 m ²	3.76 ha	-	3
6	169,606 m ²	-	2	3

Three evaluation criteria, employment created, TOE and ROI will be employed in this study. According to these criteria, corresponding performance values are given in the table below:

Table 24 Performance of six alternative options for the exploitation of a geothermal resource for three criteria

Scenarios	Performance criteria		
	Employment created	TOE	ROI
1	8,867	5,275	1.11
2	120,120	6,016	0.40
3	340,260	7,814	0.27
4	861,286	14,973	0.25
5	26,560	3,501	0.36
6	221,972	7,699	0.36

First step of the PROMETHEE method is that having assigned to each criterion a weight p_j , increasing with the importance of the criterion, the outranking degree $\pi(a,b)$ of each ordered pairs of actions (a,b) is computed. In order to make apparent the steps of the method, the difference tables for each criterion could be examined.

Table 25. Analysis of differences of the scenarios according to employment created criterion

	1	2	3	4	5	6
1	-	n/a	n/a	n/a	n/a	n/a
2	111,133	-	n/a	n/a	93,560	n/a
3	331,393	220,140	-	n/a	313,700	118,288
4	852,419	741,166	521,026	-	834,726	639,314
5	17,693	n/a	n/a	n/a	-	n/a
6	213,105	101,852	n/a	n/a	195,412	-

Table 26. Analysis of differences of the scenarios according to TOE criterion

	1	2	3	4	5	6
1	-	n/a	n/a	n/a	1,774	n/a
2	735	1	n/a	n/a	2,515	n/a
3	2,539	1,798	-	n/a	4,313	115
4	9,698	8,957	7,159	-	11,472	7,271
5	n/a	n/a	n/a	n/a	-	n/a
6	2,424	1,683	n/a	n/a	4,198	-

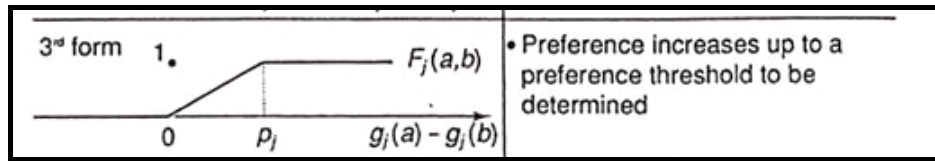
Table 27. Analysis of differences of the scenarios according to ROI criterion

	1	2	3	4	5	6
1	-	0.71	0.84	0.86	0.75	0.75
2	n/a	-	0.13	0.15	0.04	0.04
3	n/a	n/a	-	0.02	n/a	n/a
4	n/a	n/a	n/a	-	n/a	n/a
5	n/a	n/a	0.90	0.11	-	0.00
6	n/a	n/a	0.90	0.11	0.00	-

These tables are prepared by taking differences of the each scenario corresponding performance values with the other performance values. When the difference is smaller than zero, not available abbreviation (n/a) is noted to table cells.

In this study the *third form of preference intensity* in the PROMETHEE method will be used. This form has only one threshold value which is upper limit (lower limit is equal to zero) of the differences between different scenarios under the same criterion. Hypothetical decision makers are asked for determination of these upper limits. This upper limits are: 120,000days/yr for employment created, 2000 tons/yr for TOE, and 0.2 for ROI value.

Figure 5. The third form of preference intensity in the PROMETHEE method



Source: Vincke, 1992

After determination of the upper limits for difference values of the performance values, differences tables given above are converted according to selected form of preference intensity. Converted tables are given below:

Table 28. Converted form of differences of the scenarios according to employment created criterion

	1	2	3	4	5	6
1	-	0.00	0.00	0.00	0.00	0.00
2	0.92	-	0.00	0.00	0.78	0.00
3	1.00	1.00	-	0.00	1.00	0.98
4	1.00	1.00	1.00	-	1.00	1.00
5	0.15	0.00	0.00	0.00	-	0.00
6	1.00	0.85	0.00	0.00	1.00	-

Table 29. Converted form of differences of the scenarios according to TOE criterion

	1	2	3	4	5	6
1	-	0.00	0.00	0.00	0.89	0.00
2	0.37	1.00	0.00	0.00	1.00	0.00
3	1.00	0.90	-	0.00	1.00	0.06
4	1.00	1.00	1.00	-	1.00	1.00
5	0.00	0.00	0.00	0.00	-	0.00
6	1.00	0.84	0.00	0.00	1.00	-

Table 30. Converted form of differences of the scenarios according to ROI criterion

	1	2	3	4	5	6
1	-	1.00	1.00	1.00	1.00	1.00
2	0.00	-	0.65	0.75	0.20	0.20
3	0.00	0.00	-	0.02	0.00	0.00
4	0.00	0.00	0.00	-	0.00	0.00
5	0.00	0.00	0.45	0.55	-	0.00
6	0.00	0.00	0.45	0.55	0.00	-

In order to find $\pi(a, b)$ values, hypothetical decision makers are asked again to determination of the weight assigned to each criterion. The criterion weights given by these three decision makers are listed below:

Table 31. Criterion weights given to each criterion by hypothetical decision makers

	Employment created	TOE	ROI
Decision Maker #1	30%	20%	50%
Decision Maker #2	33%	33%	34%
Decision Maker #3	50%	30%	20%

By the help of these information, $\pi(a, b)$ values could be determined. The computation is made as follows:

$$\pi(a, b) = \frac{1}{P} \sum_{j=1}^n p_j F_j(a, b) \text{ where } P = \sum_{j=1}^n p_j \dots\dots\dots(5.7)$$

and where $F_j(a, b)$ is a number between 0 and 1 which increases if $g_j(a) - g_j(b)$ is large and equals zero if $g_j(a) \leq g_j(b)$ (where $g_j(a)$ is the state of the action a evaluated by criterion j). Calculated $\pi(a, b)$ values according to the weight distribution of the first decision maker are listed below:

$$\begin{aligned} \pi(1, 2) &= 0.3 * (0) + 0.2 * (0) + 0.5 * (1) = 0.500 \\ \pi(1, 3) &= 0.3 * (0) + 0.2 * (0) + 0.5 * (1) = 0.500 \\ \pi(1, 4) &= 0.3 * (0) + 0.2 * (0) + 0.5 * (1) = 0.500 \\ \pi(1, 5) &= 0.3 * (0) + 0.2 * (0.9) + 0.5 * (1) = 0.678 \\ \pi(1, 6) &= 0.3 * (0) + 0.2 * (0) + 0.5 * (1) = 0.500 \end{aligned}$$

$$\begin{aligned} \pi(2, 1) &= 0.3 * (0.92) + 0.2 * (0.4) + 0.5 * (0) = 0.350 \\ \pi(2, 3) &= 0.3 * (0) + 0.2 * (0) + 0.5 * (0.65) = 0.325 \\ \pi(2, 4) &= 0.3 * (0) + 0.2 * (0) + 0.5 * (0.75) = 0.375 \\ \pi(2, 5) &= 0.3 * (0.78) + 0.2 * (1) + 0.5 * (0.2) = 0.534 \\ \pi(2, 6) &= 0.3 * (0) + 0.2 * (0) + 0.5 * (0.2) = 0.100 \end{aligned}$$

$$\begin{aligned} \pi(3, 1) &= 0.3 * (1) + 0.2 * (1) + 0.5 * (0) = 0.500 \\ \pi(3, 2) &= 0.3 * (1) + 0.2 * (0.9) + 0.5 * (0) = 0.480 \\ \pi(3, 4) &= 0.3 * (0) + 0.2 * (0) + 0.5 * (0.1) = 0.050 \\ \pi(3, 5) &= 0.3 * (1) + 0.2 * (1) + 0.5 * (0) = 0.500 \\ \pi(3, 6) &= 0.3 * (0.98) + 0.2 * (0.06) + 0.5 * (0) = 0.306 \end{aligned}$$

$$\begin{aligned} \pi(4, 1) &= 0.3 * (1) + 0.2 * (1) + 0.5 * (0) = 0.500 \\ \pi(4, 2) &= 0.3 * (1) + 0.2 * (1) + 0.5 * (0) = 0.500 \\ \pi(4, 3) &= 0.3 * (1) + 0.2 * (1) + 0.5 * (0) = 0.500 \\ \pi(4, 5) &= 0.3 * (1) + 0.2 * (1) + 0.5 * (0) = 0.500 \\ \pi(4, 6) &= 0.3 * (1) + 0.2 * (1) + 0.5 * (0) = 0.500 \end{aligned}$$

$$\begin{aligned} \pi(5, 1) &= 0.3 * (0.15) + 0.2 * (0) + 0.5 * (0) = 0.045 \\ \pi(5, 2) &= 0.3 * (0) + 0.2 * (0) + 0.5 * (0) = 0.000 \\ \pi(5, 3) &= 0.3 * (0) + 0.2 * (0) + 0.5 * (0.45) = 0.225 \\ \pi(5, 4) &= 0.3 * (0) + 0.2 * (0) + 0.5 * (0.55) = 0.275 \\ \pi(5, 6) &= 0.3 * (0) + 0.2 * (0) + 0.5 * (0) = 0.000 \end{aligned}$$

$$\begin{aligned} \pi(6, 1) &= 0.3 * (1) + 0.2 * (1) + 0.5 * (0) = 0.500 \\ \pi(6, 2) &= 0.3 * (0.85) + 0.2 * (0.84) + 0.5 * (0) = 0.423 \\ \pi(6, 3) &= 0.3 * (0) + 0.2 * (0) + 0.5 * (0.45) = 0.225 \\ \pi(6, 4) &= 0.3 * (0) + 0.2 * (0) + 0.5 * (0.55) = 0.275 \\ \pi(6, 5) &= 0.3 * (1) + 0.2 * (1) + 0.5 * (0) = 0.500 \end{aligned}$$

By using the sum of these values ϕ^+ (outgoing flow) value can be found. When the same procedure is calculated for $\pi(i,a)$ and these values are added up, ϕ^- (ingoing flow) value is found.

$$\phi^+(a) = \sum_{i \in A} \pi(a,i) \text{ and } \phi^-(a) = \sum_{i \in A} \pi(i,a) \dots\dots\dots(5.8)$$

where A is the set of all actions. $\phi^+(a)$ value shows the general superiority of action a to the other actions.

By using PROMETHEE II, the ordering of the actions can be made by adding up $\phi^+(a)$ $\phi^-(a)$ values.

$$\phi(a) = \phi^+(a) + \phi^-(a) \dots\dots\dots(5.11)$$

It gives complete order of the actions.

The procedure explained above is repeated for the weights assigned to each criterion by the second and the third decision makers. Outgoing and ingoing flow of the method, and the sum of them as to assigned weights to criteria by decision makers are given below:

Table 32. Outgoing and ingoing flow and the sum of these flows according to the first decision maker

Scenarios	$\phi^+(a)$	$\phi^-(a)$	$\phi(a)$
1	2.678	1.895	0.783
2	1.684	1.903	-0.219
3	1.836	1.775	0.061
4	2.5	1.475	1.025
5	0.545	2.712	-2.167
6	1.923	1.406	0.517

Table 33. Outgoing and ingoing flow and the sum of these flows according to the second decision maker

Scenarios	$\phi^+(a)$	$\phi^-(a)$	$\phi(a)$
1	1.9937	2.4552	-0.4615
2	1.6251	2.1847	-0.5596
3	2.3242	1.5015	0.8227
4	3.3	1.309	1.991
5	0.3895	3.2691	-2.8796
6	2.2177	1.4112	0.8065

Table 34. Outgoing and ingoing flow and the sum of these flows according to the third decision maker

Scenarios	$\phi^+(a)$	$\phi^-(a)$	$\phi(a)$
1	1.267	2.046	-0.779
2	1.621	2.447	-0.826
3	2.898	1.31	1.588
4	5	0.77	4.23
5	0.275	3.597	-3.322
6	2.477	1.548	0.929

By using these tables complete order of the scenarios could be obtained

Table 35. Complete order of the scenarios

Decision Makers	Order of the scenarios
The first decision maker	4>1>6>3>2>5
The second decision maker	4>3>6>1>2>5
The third decision maker	4>3>6>1>2>5

When the order of the scenarios examined, one could say that scenario#4 dominates all other scenarios. Scenario#2 and Scenario#5 may be evaluated as the scenarios with the least performance based on the criteria selected and the weights assigned to them by the decision makers.

CHAPTER 6

RESULTS AND DISCUSSION

The considerations of this study could be listed as the following:

- Modeling of geothermal resource by simulation, and determination of its heat energy on the basis of probability distribution,
- Forming exploitation alternatives by this heating energy, and calculating their performances according to the criteria that the decision maker will select,
- Evaluating the scenarios that will be formed from the obtained alternatives by employing PROMETHEE method and determining which scenario could be the best.

The first consideration is that, having done studies about the simulation, it is concluded that the reservoir will most probably have energy of 25.5 MWt. However, as the energy given to the system in February 2001 is 37.1 MWt, and as it is asserted in the study done by ITU that 66 MWt energy could be produced, it is assumed that the simulation underestimates the real energy potential of the reservoir. Due to this, the average of the values 25.5-66 MWt is taken, and 45.75 MWt is assumed as the heating capacity of the reservoir. Additionally, 14 MWt the difference between the average value (45.75 MWt) and 37.1 MWt, is assumed as the reserve quantity that could be added to the system.

Two assessments could be done about the simulation. The first one is that the model is accurate and the real value of the sustainable heating capacity is 25.5 MWt. The second one is that the result could be misleading because of the equation selected. In the functional form selected, there exists no parameter related to the sustainability of the reserve. In addition there are no parameters concerning the suggested reinjection to increase the sustainability of the geothermal field. Yet, estimation could be done by introducing the model the data about the reinjection in TOUGH2 model done by ITU. In this case, it could be asserted the result, that is the real heating value of the reservoir could be 25.5 MWt, becomes insignificant. If so, the reservoir could be re-simulated by another functional form.

The second consideration in the study is the determination of the utilization alternatives of the estimated 14 MWt energy. These alternatives are specified as dwelling heating, thermal tourism, greenhouse production and dehydration of fruit and

vegetable, by evaluating the conditions specific to Balçova. Apart from this, alternatives such as electricity generation, fishing or industrial raw material production are considered. However, as the resource falls into the low enthalpy resources category, it is thought that the cost of electricity generation could be high. Fishing is not preferred because of the sea pollution it will create and its closeness to the recreation areas within the city. The chemical materials in the fluid do not have the concentration to make raw material production.

Efforts is given to find the heat demand for the alternatives mentioned above from the lowest temperature value to the comfort (or production) temperature value. According to the data gathered from the various resources, these values are taken as 54.93 kcal/h m² for dwellings, 160 kcal/h m² for greenhouses, 65 kcal/h m² for tourism establishment, and 116.2 kWt for dehydration of vegetables. At the same time, these values are used in degree day procedure. By this way, TOE values of the alternatives are obtained. These values are found as 0.0237 ton/yr m², 0.0857 ton/yr m² and 0.0218 ton/yr m² for dwellings, hotels and greenhouses respectively.

The construction and operating costs of the heating station that will be constructed to utilize 14 MWt additional capacity are calculated by using the data from Erdoğan (2003). (Data about this could be found in Appendix A). Here, three assumptions are made. First, the amount of the investment per square meter could be found by dividing the end of 2002 investment costs of Balçova GDHS by the dwelling equivalent heated that year (1,150,000 m²). In addition, it is assumed that the operating costs of the year 2002 will continue in the following years without changing, and operating cost per square meter is calculated. Finally, it is assumed that depreciation costs of the Balçova GDHS could be used for new heating system on the basis of same future periods.

It is found that, 219,290 m² dwelling area could be heated with such a heating system, and it is calculated that it will cost 4.5 million USD to construct a suitable heating station. Net future value of overall costs of 2021 is equal to 11.3 million USD. This value is calculated separately for the six scenarios formed, and ROI calculations are also used. ROI values for 1 m² dwelling, 1,000 m² greenhouse, 21,000 m² hotel and drying facility are 0.16, 0.18, 0.25 and 0.08, respectively.

Employment created value of each alternative is calculated by various data sources, such as DIE statistics, agriculture and tourism related web sites. Employment created

value of 1 m² dwelling, 1,000 m² greenhouse, 21,000 m² hotel and a drying facility equal respectively to 0.026 days/yr, 546 days/yr, 107,200 days/yr and 1,050 days/yr.

For the third consideration, that is finding the outranking relations of the scenarios formed by using PROMETHEE method, hypothetical decision makers are designed. It is assumed that, they select the third form as the preference intensity of the criteria and structural form of this preference.

Upper limits of the preference intensity according to criteria TOE, ROI and employment created are also assumed as 2,000 tons/yr, 0.2 and 120,000 days/yr, respectively. The weights, hypothetically, assigned to these criteria are given in the table below:

Table 31. Criterion weights given to each criterion by hypothetical decision makers

	TOE	ROI	Employment created
Decision Maker #1	20%	50%	30%
Decision Maker #2	33%	34%	33%
Decision Maker #3	30%	20%	50%

Economic and social aspects of the exploitation scenarios could have special weight for the decision makers. Difference in the weights of, in particular, ROI and employment created criteria is formed in order to take these political aspects into consideration.

When the PROMETHEE method is employed, the outranking order of the scenarios is formed as follow:

Table 35. Complete order of the scenarios

Decision Makers	Order of the scenarios
The first decision maker	4>1>6>3>2>5
The second decision maker	4>3>6>1>2>5
The third decision maker	4>3>6>1>2>5

When the order of the scenarios is examined, one could say that Scenario#4 dominates all other scenarios. Scenario#2 and Scenario#5 may be evaluated as the scenarios with the least performance based on the criteria selected and the weights assigned to them by the decision makers. For the first decision maker, first and third scenarios become second and fourth and this is the only difference between the outranking order of the second and the third decision makers.

The reason for the situation is that TOE and employment created of the eight hotels suggested for the fourth scenario are very high. Insomuch as that, the superiority of the fourth scenario which has the lowest ROI value, according to weights that the decision makers assign, continuous. It could be said that the difference between orders of the first and the second-third decision makers results from the performance values of the first and the third scenarios according to ROI and employment created criteria. Particularly, ROI value of the first scenario is the greatest value compared to the values of other scenarios, but it has the smallest value of employment created (ROI: 1.11 and employment created: 8,867 days/yr).

CHAPTER 7

CONCLUSION

The results that will be concluded from the study could be listed as follows:

- There exists a serious difference between the values obtained from the simulation and the values of the modeling done by employing TOUGH2 by ITU. The possible reason for this is that, the functional form assigned for Monte Carlo Simulation might have underestimated energy capacity of the reservoir.
- PROMETHEE results show that tourism investment, in particular, stands out because of high TOE and employment created values. Yet, it could be asserted that, this might not be a correct preference because of high investment costs and market risks.
- The decision makers, scenarios and selected criteria are hypothetical, and this brings out the results that PROMETHEE method is not tried with the real life problems. As the criteria of the decision makers and especially weights assigned to these criteria could change the results considerably.
- The alternative concerning to dehydration of the fruit and the vegetable is formed by a number of assumptions. With the improvement of the sector related to this, clearer cost and revenue values could be obtained. Small scale facilities could be especially suggested for rural areas because of their low operating costs.
- The indirect effects caused by the exploitation alternatives are ignored. These indirect effects are dwelling price and the increase in the rents, the increase in the commercial activities related to thermal therapy facilities (beauty salons, physical rehabilitation offices, and offices of the doctors), the increase in the tourism revenues, expansion in the product range of the greenhouses, noise pollution that may occur during the operations of the drying facilities and the increase in the real estate taxes etc. Taking these effects into consideration could change the performances of the alternatives.
- Land use data obtained from scenarios could be used in physical development plans. By this way, relation between development plan and the local economic development could be established.

- Investment and depreciation costs of the geothermal heating systems could be decrease gradually by the help of advance in the geothermal technology created locally.

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APPENDIX A

Table 36. Cost items for the tomato drying facility

Investment Items	Cost (YTL)
Tomato Paste Machine	60000
Office	11000
Heat Exchanger	11970
Fan Units	3000
Drying Tunnel	3000
Trays	8800
Thermocouples	2000
Packeting Machine	34000
Tables and Panels	2000
Other Equipments	8000
Construction (240 m2)	46710
Cool Rooms (120 m2)	33960
TOTAL	224440

Depreciation	n	Cost (YTL)
Maintenance	Annual	1330
Thermocouple	3 yrs	1900
Fan units	4 yrs	2850
Trays	7 yrs	8360

Operating Costs	YTL
Raw Material (tomato)	78240
Jar	20779
Water Cons.	1750
Electricity	2500
Olive Oil	87273
Garlic	831
Transportation	3600
Geothermal Energy	1500
Labor	21000

NOTE: This costs are calculated based on seasonal operations of the facility for five-month

Table 37. Cost items for the 1,000 m² greenhouse

Investment Costs	YTL
Cover and structure	33000
Irrigation system	4500
Heating pipes	3300
Shadow curtain	5500
Measurement Equipments	20000
Planting and control equipment	18500
Heat exchanger	12000
Water depot and pumps	4500
Total	101300

Depreciation and Salvage	n	YTL
Cover Material	3 yrs	10345.5
Irrigation system	5 yrs	4275
Shadow curtain	3 yrs	5225
Maintenance	annual	1500
Heating pipes	2 yrs	3135

Operating Costs	YTL
Seeds	2100
Fertilizer (natu. and chem.)	2900
Sand	300
Torf	1800
Perlit	800
Agri. Chemicals	1500
Disinfection chemicals	1000
Seedbed	1700
Seedling viol	1000
Regulatory chemicals	500
Electricity	960
Water	1500
Transportation works	1000
Manpower	11200
Geothermal	720
Total	28980

Table 38. Input, output and value added data for one thermal tourism establishment

Number of bed's groups	Number of establishments	Input	Output	Value added
		in million TL		
-10	6	2,261,376	4,843,748	2,582,372
11-25	1437	14,332,561	33,665,933	19,333,372
26-50	3767	121,939,080	243,970,625	122,031,545
51-75	2119	300,205,908	582,622,628	282,416,720
76-100	1133	109,162,997	245,307,035	136,144,038
101-150	902	168,571,102	407,577,000	239,005,898
151-200	330	97,453,759	217,983,056	120,529,297
201+	807	1,631,211,173	3,759,110,383	2,127,899,210
Total	10501	2,445,137,956	5,495,080,408	3,049,942,452

Table 39. Economic analysis of 1 m² of dwelling

Year	Total Cost	Revenues acured by the firm	Balance	n	Net Future Value of year 2021 in USD (i=5%)	Net Future Value of Costs of year 2021 in USD (i=5%)
2005	20.521		0.000	17	0.000	46.267
2006	1.395	16.470	16.470	16	35.952	17.127
2007	1.395	3.960	3.960	15	8.233	16.056
2008	1.395	3.960	3.960	14	7.841	14.986
2009	1.395	3.960	3.960	13	7.467	13.915
2010	1.395	3.960	3.960	12	7.112	12.845
2011	3.152	3.960	3.960	11	6.773	12.829
2012	2.186	3.960	3.960	10	6.450	11.126
2013	1.892	3.960	3.960	9	6.143	9.870
2014	1.818	3.960	3.960	8	5.851	8.742
2015	1.756	3.960	3.960	7	5.572	7.626
2016	4.040	3.960	3.960	6	5.307	7.307
2017	1.689	3.960	3.960	5	5.054	5.430
2018	1.646	3.960	3.960	4	4.813	4.334
2019	1.610	3.960	3.960	3	4.584	3.245
2020	1.579	3.960	3.960	2	4.366	2.160
2021	2.622	3.960	3.960	1	4.158	1.136

125.676 195.003

employment	0.026	days/yr
TOE	0.024	tons/yr
ROI	0.16	

Table 40. Economic analysis of the small scale drying facility

Year	Total Cost	Revenues	Balance	n	Net Future Value of year 2021 (i=5%)	Net Future Value of year 2021 in USD (i=5%)	Net Future Value of Costs of year 2021 in USD (i=5%)
2005	442,363	259,740	-182,623	17	-418,575	-314,718	762,334
2006	219,253	259,740	40,487	16	88,378	66,450	359,851
2007	219,253	259,740	40,487	15	84,170	63,286	342,715
2008	221,153	259,740	38,587	14	76,400	57,444	329,224
2009	222,103	259,740	37,637	13	70,970	53,361	314,894
2010	219,253	259,740	40,487	12	72,709	54,668	296,050
2011	221,153	259,740	38,587	11	65,997	49,622	284,396
2012	227,613	259,740	32,127	10	52,332	39,347	278,765
2013	222,103	259,740	37,637	9	58,388	43,900	259,064
2014	221,153	259,740	38,587	8	57,011	42,865	245,672
2015	219,253	259,740	40,487	7	56,969	42,834	231,963
2016	219,253	259,740	40,487	6	54,257	40,794	220,917
2017	224,003	259,740	35,737	5	45,611	34,294	214,956
2018	219,253	259,740	40,487	4	49,212	37,002	200,379
2019	227,613	259,740	32,127	3	37,191	27,963	198,113
2020	221,153	259,740	38,587	2	42,542	31,987	183,324
2021	222,103	259,740	37,637	1	39,519	29,714	175,345
			427,551		533,082	400,813	4,897,963

employment	1,050	days/yr
TOE	28.80	tons/yr
ROI	0.08	

Table 41. Economic analysis of 1000 m² of greenhouse

Year	Total Cost	Revenues	Balance	n	Net Future Value of year 2021 (i=5%)	Net Future Value of year 2021 in USD (i=5%)	Net Future Value of Costs of year 2021 in USD (i=5%)
2005	130280	53,577.90	-76,702.10	17	-175,803	-132,182	224,514
2006	30480	53,577.90	23,097.90	16	50,420	37,910	50,026
2007	33615	53,577.90	19,962.90	15	41,501	31,204	52,544
2008	46050.5	53,577.90	7,527.40	14	14,904	11,206	68,554
2009	33615	53,577.90	19,962.90	13	37,643	28,303	47,659
2010	34755	53,577.90	18,822.90	12	33,803	25,416	46,929
2011	49185.5	53,577.90	4,392.40	11	7,512	5,648	63,251
2012	30480	53,577.90	23,097.90	10	37,624	28,289	37,330
2013	33615	53,577.90	19,962.90	9	30,969	23,285	39,209
2014	46050.5	53,577.90	7,527.40	8	11,121	8,362	51,156
2015	37890	53,577.90	15,687.90	7	22,074	16,597	40,086
2016	30480	53,577.90	23,097.90	6	30,953	23,273	30,711
2017	49185.5	53,577.90	4,392.40	5	5,606	4,215	47,199
2018	30480	53,577.90	23,097.90	4	28,076	21,110	27,856
2019	33615	53,577.90	19,962.90	3	23,110	17,376	29,258
2020	50325.5	53,577.90	3,252.40	2	3,586	2,696	41,717
2021	33615	53,577.90	19,962.90	1	20,961	15,760	26,538
			177,106.74		224,061.27	168,467	924,537

employment	546	days/yr
TOE	21.80	tons/yr
ROI	0.18	

Table 42. Economic analysis of the thermal tourism establishment that would be constructed in Balçova

Year	Investment	Input	Output	Balance	n	Net Future Value of year 2021 (i=5%)	Net Future Value of year 2021 in USD (i=5%)	Net Future Value of Costs of year 2021 in USD (i=5%)
2005	5,193,000			-5,193,000	17	-11,902,451	-8,949,211	8,949,211
2006	12,117,000			-12,117,000	16	-26,449,891	-19,887,136	19,887,136
2007		2,021,327	4,658,129	2,636,802	15	5,481,722	4,121,595	3,159,545
2008		2,021,327	4,658,129	2,636,802	14	5,220,688	3,925,329	3,009,090
2009		2,021,327	4,658,129	2,636,802	13	4,972,083	3,738,409	2,865,800
2010		2,021,327	4,658,129	2,636,802	12	4,735,318	3,560,389	2,729,333
2011		2,021,327	4,658,129	2,636,802	11	4,509,826	3,390,847	2,599,365
2012		2,021,327	4,658,129	2,636,802	10	4,295,073	3,229,378	2,475,586
2013		2,021,327	4,658,129	2,636,802	9	4,090,545	3,075,598	2,357,701
2014		2,021,327	4,658,129	2,636,802	8	3,895,757	2,929,141	2,245,429
2015		2,021,327	4,658,129	2,636,802	7	3,710,245	2,789,658	2,138,504
2016		2,021,327	4,658,129	2,636,802	6	3,533,567	2,656,817	2,036,671
2017		2,021,327	4,658,129	2,636,802	5	3,365,302	2,530,302	1,939,686
2018		2,021,327	4,658,129	2,636,802	4	3,205,049	2,409,812	1,847,320
2019		2,021,327	4,658,129	2,636,802	3	3,052,428	2,295,059	1,759,353
2020		2,021,327	4,658,129	2,636,802	2	2,907,074	2,185,770	1,675,574
2021		2,021,327	4,658,129	2,636,802	1	2,768,642	2,081,686	1,595,785
						21,390,977	16,083,441	63,271,090

employment	107,200	days/yr
TOE	1,800	tons/yr
ROI	0.25	

Table 43. Overall performance of the Scenario#1 according to criteria selected

ASPECTS OF THE SCENARIOS		
EMPLOYMENT	TOE	ROI
8,867	5,275	1.11

0 X 1000 m² of greenhouse
 3 drying facilities
 0 tourism establishment
 219290 m² dwelling

Table 44. Overall performance of the Scenario#2 according to criteria selected

ASPECTS OF THE SCENARIOS		
EMPLOYMENT	TOE	ROI
120,120	6,016	0.40

10 X 1000 m² of greenhouse
 3 drying facilities
 1 tourism establishment
 165314.4 m² dwelling

Table 45. Overall performance of the Scenario#3 according to criteria selected

ASPECTS OF THE SCENARIOS		
EMPLOYMENT	TOE	ROI
340,260	7,814	0.27

24.8 X 1000 m² of greenhouse
 3 drying facilities
 3 tourism establishment
 75525 m² dwelling

Table 46. Overall performance of the Scenario#4 according to criteria selected

ASPECTS OF THE SCENARIOS		
EMPLOYMENT	TOE	ROI
861,286	14,973	0.25

0 X 1000 m² of greenhouse
 3 drying facilities
 8 tourism establishment
 20550.6 m² dwelling

Table 47. Overall performance of the Scenario#5 according to criteria selected

ASPECTS OF THE SCENARIOS		
EMPLOYMENT	TOE	ROI
26,560	3,501	0.36

37.64 X 1000 m² of greenhouse
 3 drying facilities
 0 tourism establishment
 109645 m² dwelling

Table 48. Overall performance of the Scenario#6 according to criteria selected

ASPECTS OF THE SCENARIOS		
EMPLOYMENT	TOE	ROI
221,972	7,699	0.36

0 X 1000 m² of greenhouse
 3 drying facilities
 2 tourism establishment
 169606.2 m² dwelling

APPENDIX B

Table 49. First and last five pages of the print-out of the Monte Carlo Simulation model used in this study

gözetkenlik	sıcaklık	üretim faktörü	dönüştürme	yüzey alanı	kalınlık	kayac d	su d (yoğ)	derinlik	kayac sıcaklık	terketme sıcaklığı	kayac öz ıs	su öz ıs	yük faktörü													
														min	max	mode	min	max	mode	min	max	mode	min	max	mode	min
0.04898873	139.2343837	0.186187435	0.719938255	173834.795	623.0165894	2618.33381	958.0441313	775.7285445	462.3410068																	
1	0.15161038	138.853666	0.214353666	0.830047631	717518.6468	450.5383433	747.587951	427.5882931	447.5485993	166.911.098.076.358.00	30.998.973.136.293.90	197.910.071.212.652.00	35.229.871.628.720.10	18.320.96	3.271.70	0.0%										
3	0.192781083	118.9630964	0.202597382	0.741422351	1200963.672	531.8293093	2650.558366	963.8054432	487.2778533	492.264.765.926.956.00	19.336.607.792.682.30	511.601.373.719.638.00	76.847.720.647.452.70	39.963.93	3.738.10	0.0%										
4	0.329237599	119.1740951	0.224278615	0.815685979	1236613.87	451.2872296	2607.322789	929.2310517	0.567.6672091	392.0086429	274.068.929.445.877.00	27.957.313.862.497.00	302.026.242.908.374.00	55.252.959.332.294.30	28.733.78	3.829.95	0.0%									
5	0.503962476	118.8842876	0.155385966	0.781542196	899781.8754	567.3498561	2665.489736	931.2950097	0.843.0758436	481.9937546	369.017.276.320.547.00	58.848.121.423.141.20	427.885.891.655.688.00	51.980.328.882.168.60	27.021.48	4.027.44	0.0%									
6	0.071952354	136.181172	0.189872666	0.773129162	1090736.284	570.948739	2665.854914	935.8870238	0.863.5294962	487.806329	561.266.680.321.00	9.846.885.684.374.95	571.133.571.004.696.00	83.840.177.963.556.40	43.600.30	4.274.25	0.0%									
7	0.177298649	134.0844706	0.128714503	0.751012807	1398227.177	721.9517975	2680.648916	947.2406176	0.612.1853661	410.7235073	637.329.180.315.977.00	36.729.704.519.131.90	674.058.884.835.109.00	66.081.971.700.303.10	33.645.27	4.306.34	0.1%									
8	0.634200016	131.5827464	0.132268711	0.762408764	863262.3947	501.0145827	2687.325913	968.0245523	0.857.3030665	485.9684686	155.342.365.105.828.00	57.251.459.472.890.60	212.583.824.578.718.00	11.438.667.566.871.70	11.448.98	4.379.13	0.1%									
9	0.452848968	133.4525295	0.159314907	0.744622148	1298850.687	596.7121486	2610.176714	936.741075	0.968.033568	516.7464465	435.055.600.402.995.00	73.426.697.499.549.40	508.482.305.902.544.00	60.320.955.047.711.80	31.369.34	4.430.25	0.1%									
10	0.576116187	136.1839741	0.12275322	0.870186672	820148.0948	548.8131061	2616.152847	934.5842561	0.647.730707	420.8454272	153.118.153.135.466.00	56.915.955.290.697.60	210.034.108.426.164.00	20.520.435.027.192.60	10.671.46	4.498.25	0.1%									
11	0.186177941	116.9343533	0.135931527	0.756684118	870338.6248	581.1662666	2674.039597	936.4646863	0.698.0564227	438.5852015	355.239.147.307.024.00	13.883.883.859.103.20	369.123.031.166.127.00	37.965.967.988.490.30	19.743.84	4.612.62	0.1%									
12	0.329623638	122.1795544	0.157381727	0.765896749	1061813.362	546.141833	2693.039081	931.493994	0.755.6132328	456.3077716	355.097.836.228.157.00	31.297.579.561.864.60	396.395.415.790.021.00	46.575.399.905.218.60	24.221.09	4.730.76	0.1%									
13	0.247770253	121.7960936	0.174337326	0.74383773	925257.2181	581.4285598	2695.240343	955.4971188	0.739.3743971	451.3779033	352.583.039.721.304.00	21.477.513.829.068.50	374.060.550.549.371.00	49.040.590.959.289.30	25.503.08	4.736.97	0.1%									
14	0.477890336	136.46401	0.144074194	0.771190645	1084566.195	609.1375592	2611.12387	938.9683436	0.732.27419	449.1010389	298.169.277.980.994.00	72.735.688.018.668.00	370.804.985.999.699.00	41.210.754.878.318.50	21.431.27	4.802.79	0.1%									
15	0.259350389	139.3090793	0.131613261	0.913631083	1604247.764	860.8086777	2646.408196	967.8077895	0.678.6355843	492.0527677	98.795.851.695.023.00	90.795.851.695.023.00	1.072.111.496.964.140.00	129.917.181.178.625.00	67.042.17	4.858.00	0.1%									
16	0.09493777	118.2329938	0.183038984	0.769788279	1189915.698	415.8802935	2688.993878	959.8452726	0.936.2438992	507.9285076	462.013.720.348.570.00	7.476.988.381.088.28	469.490.709.329.658.00	66.150.115.731.246.20	34.400.75	4.889.46	0.2%									
17	0.101096537	122.1524046	0.138622071	0.794868832	657721.5323	398.5647221	2673.469672	944.8197239	0.713.4981164	443.4090183	4.412.021.980.176.33	202.376.031.869.816.30	4.412.021.980.176.33	22.850.010.833.648.60	11.882.93	4.892.79	0.2%									
18	0.061773974	122.3466147	0.181492862	0.724556471	1016787.945	651.0844178	2652.749607	963.4116756	0.777.8740648	462.9805966	567.899.417.064.079.00	6.973.662.067.407.46	574.873.079.131.486.00	75.596.677.877.543.70	39.313.34	4.927.95	0.2%									
19	0.099238242	133.3958444	0.16777241	0.791117148	1029454.606	717.2054398	2667.802029	943.2162299	0.758.4716875	457.1209459	707.639.609.535.290.00	18.124.451.817.870.40	725.755.061.353.161.00	96.334.324.747.509.00	90.097.76	4.941.80	0.2%									
20	0.245675135	132.3045278	0.151739612	0.862651246	1556949.694	443.8845102	2666.2881	939.1888062	0.713.9558851	443.5512188	454.808.363.829.782.00	34.861.233.060.876.00	489.689.596.890.659.00	64.094.415.097.476.60	33.317.0	4.967.65	0.2%									
21	0.404898215	133.5154811	0.22041033	0.754208181	701852.2058	369.020564	2623.541105	938.8048683	0.883.2376042	433.9041146	22.036.102.600.846.70	150.826.221.808.291.00	25.072.638.262.784.40	13.038.79	5.091.22	0.2%										
22	0.31946821	131.4874705	0.182751782	0.844388413	617520.2964	310.2612447	2608.327432	936.0985519	0.792.2087807	467.2268608	128.898.214.026.662.00	13.404.297.406.082.60	142.302.511.432.745.00	21.958.678.080.268.60	11.419.40	5.128.03	0.2%									
23	0.306364698	114.8894684	0.190680559	0.883198703	653308.9765	631.8835947	2683.433663	965.8810766	0.728.4162985	448.0205299	128.256.051.472.258.00	8.617.031.268.761.24	137.169.082.741.019.00	23.100.423.076.944.10	12.013.16	5.154.18	0.2%									
24	0.07831383	136.0935247	0.196363557	0.834789434	1746494.024	738.5898778	2679.564164	924.7946673	0.970.7983253	517.2167796	644.303.969.574.038.00	10.872.313.366.972.60	655.176.283.121.011.00	107.394.935.025.511.00	55.849.29	5.192.92	0.2%									
25	0.27592922	135.203267	0.212362972	0.83844724	1612452.604	619.2811859	2621.255385	967.6663281	0.856.6298706	426.3714875	31.072.387.423.555.10	328.631.272.603.390.00	50.314.314.307.137.60	30.429.82	5.237.32	0.2%										
26	0.132501272	127.2904862	0.140620762	0.791578093	1675995.6	317.787456	2601.393442	939.3114875	0.981.2242118	487.1538521	404.439.414.469.717.00	13.103.572.227.128.20	453.542.986.896.899.00	50.484.919.573.916.90	26.254.21	5.254.78	0.2%									
27	0.261122424	132.0078653	0.17900032	0.767957714	1090917.933	446.8856537	2685.023532	940.4120722	0.741.1197909	451.9103527	323.720.892.368.373.00	26.024.178.137.668.00	349.744.840.526.039.00	46.054.679.812.252.30	24.890.38	5.274.59	0.3%									
28	0.335292946	108.6689346	0.178878486	0.827638539	6287639.986	540.4685174	2696.724835	938.1984747	0.838.062064	449.1030604	20.240.275.386.853.10	338.020.631.740.027.00	53.038.904.188.025.70	27.582.59	5.294.30	0.3%										
29	0.034721529	142.5387411	0.173157614	0.821341129	730333.0712	693.2089478	2654.403033	926.7296471	0.763.2774725	458.6161143	443.709.161.950.286.00	4.259.555.077.067.96	447.962.717.027.323.00	53.716.897.841.073.90	37.532.25	5.320.35	0.3%									
30	0.063740716	123.633985	0.12803649	0.818918907	820786.3605	402.162634	2688.619924	977.837524	0.973.3290882	397.4752364	238.021.040.734.524.00	3.804.443.506.587.29	24.825.484.241.091.00	12.980.04	5.328.18	0.3%										
31	0.334191651	126.0223404	0.110377116	0.819396388	1211394.03	376.7418744	2609.856347	954.8441641	0.823.0934089	434.5497696	302.871.048.838.127.00	28.015.759.457.135.60	330.886.890.295.263.00	29.926.265.786.811.50	15.622.87	5.353.82	0.3%									
32	0.05245574	143.033764	0.161840464	0.757305614	1490342.439	498.9352071	2614.967092	936.3662178	0.834.1980873	479.4490932	673.670.450.880.713.00	9.605.070.856.907.50	683.583.521.737.620.00	83.781.966.930.82	43.596.96	5.396.53	0.3%									
33	0.15842809	114.1384735	0.138327529	0.877394589	695800.8775	312.7034394	2650.532951	937.6189509	0.735.392116	490.1567455	159.572.841.378.725.00	4.483.436.007.540.09	164.055.917.386.275.00	19.111.099.957.792.10	10.354.59	5.468.18	0.3%									
34	0.43806106	109.3870824	0.148007398	0.809240778	1445712.303	901.012545	2621.931301	979.0985574	0.868.4490319	489.1930245	706.611.875.073.779.00	68.651.541.823.135.00	775.463.396.896.915.00	92.880.059.856.934.70	48.301.40	5.475.76	0.3%									
35	0.518317133	132.3723262	0.214388024	0.811616487	754876.4788	296.5621624	2651.153829	965.9853801	0.809.6512385	472.3425614	100.947.368.475.253.00	24.313.941.372.890.50	125.261.327.848.143.00	21.795.679.788.964.60	11.334.64	5.507.90	0.3%									
36	0.424521643	134.1818473	0.147648808	0.731291891	1268687.106	477.2316334	2626.639121	966.7848612	0.772.5850813	461.4003816	313.702.414.836.388.00	56.196.942.012.558.00	369.898.956.848.946.00	39.939.609.196.383.60	20.770.22	5.507.97	0.3%									
37	0.435954975	118.8499833	0.185368111	0.897101227	1004662.757	641.7380884	2663.559682	970.5028223	0.837.0886887	418.9936642																

Table 49. (continued)

gözetlenebilirlik	ısıcaklık	üretim faktörü	dönüşüm	yüzey alanı	kalınlık	kayac d uniform	su d (yöğ)	derinlik	kayac sıcaklık	terketme sıcaklığı	kayac öz ıs		su öz ıs		yük faktörü		
											sabit	Hs	sabit	Hs			
min	0.0275	min	100	0.07	min	500000	min	2600	min	921.7	500	-	80	0.9	4.18	0.41	
max	0.7	max	145	0.24	max	2000000	max	2700	max	986.7	1100	-	-	-	-	-	
mode	0.05	mode	135	0.19	mode	900000	mode	2650	mode	930.6	650	-	166	Hk	Hs	13835.17	
							350	expect								26196.98	
66	0.20080908	141.9239438	0.20398494	0.764631192	1125870.533	374.2743769	2676.682472	938.8776343	0.715.0610107	443.8943704	295.219.013.301.278.00	20.565.606.666.593.20	315.764.619.967.871.00	49.224.953.653.879.30	25.598.97	5.949.71	0.6%
67	0.12789338	115.3354097	0.136720324	0.752144436	1186559.11	839.7083257	2617.734913	960.2503695	0.746.8954261	453.967634	603.892.504.824.275.00	45.183.311.068.842.00	648.075.895.811.118.00	86.746.790.200.875.10	34.711.04	5.958.11	0.7%
68	0.32758298	134.7399573	0.154088748	0.861991439	1289535.455	702.9580242	2682.820351	947.044214	0.874.6212333	490.9283319	609.810.295.150.834.00	64.346.295.850.278.60	869.158.991.000.914.00	88.871.367.844.339.80	46.216.72	5.983.91	0.7%
69	0.148373248	134.9645589	0.184074374	0.814803182	1622401.369	537.2843766	2686.265531	942.4753256	0.609.3261896	409.7632546	596.719.894.273.201.00	27.880.463.863.212.60	614.600.127.336.414.00	92.146.482.863.562.20	47.919.91	5.989.39	0.7%
70	0.23468394	130.2138501	0.098251232	0.804575057	823337.5147	541.0379164	2680.210031	938.8895607	0.724.1937534	446.7200812	520.592.885.896.421.00	35.447.469.781.393.10	556.040.155.677.814.00	44.402.623.075.962.70	23.091.17	6.029.51	0.7%
71	0.178276994	125.6113634	0.224350904	0.827732896	928119.2384	760.5675064	2688.777834	938.4137332	0.634.8689575	418.2441362	472.140.560.464.494.00	22.919.524.077.285.00	494.460.084.541.779.00	91.822.534.726.980.80	47.751.45	6.041.42	0.7%
72	0.201978033	119.3810082	0.155362646	0.809115598	1294125.117	369.3814656	2679.482465	953.3060324	0.670.4813561	429.8346888	321.827.814.396.132.00	15.151.187.385.462.80	336.979.001.781.595.00	42.357.670.593.168.90	22.027.71	6.071.77	0.7%
73	0.147977765	130.1841068	0.1846899	0.795888875	1441768.916	720.627516	2629.657149	933.71665875	0.817.9820056	474.7663862	827.058.750.899.064.00	30.113.221.418.921.60	857.171.972.317.985.00	125.994.188.144.272.00	65.522.09	6.075.19	0.7%
74	0.182394506	131.7887339	0.190917587	0.913405844	1201801.504	768.7201799	2684.206972	978.9018535	0.865.6167718	488.9486471	733.785.288.828.244.00	35.707.833.697.305.60	769.493.122.525.550.00	134.188.242.575.537.00	69.783.33	6.083.86	0.7%
75	0.19386907	121.7477704	0.155997842	0.796619494	1166023.012	397.8857251	2684.238316	924.4964657	0.924.4964657	504.7318556	383.754.993.455.233.00	15.102.232.224.970.90	398.857.225.880.204.00	49.566.355.031.863.20	25.756.52	6.088.39	0.7%
76	0.073904136	114.4993464	0.109632315	0.832754985	971557.1082	826.2011262	2674.664271	952.2118259	0.777.5679335	462.889425	765.264.864.752.904.00	9.820.350.391.177.95	775.065.215.144.082.00	70.762.843.885.760.50	36.799.55	6.089.71	0.7%
77	0.049273083	129.6889323	0.171862705	0.738815705	1338423.411	326.3596551	2651.459794	955.2513044	0.697.6142476	438.4456432	355.219.371.534.777.00	4.268.531.268.524.02	359.487.902.823.301.00	45.645.928.227.604.10	23.737.74	6.115.88	0.7%
78	0.304267596	121.8117973	0.169553631	0.863382402	887644.4618	310.98664	2619.248239	951.2532327	0.941.1744726	509.264212	194.341.886.251.663.00	13.963.732.319.511.60	208.305.418.571.175.00	30.493.751.285.784.80	15.857.99	6.119.10	0.8%
79	0.148473431	127.0604362	0.227404712	0.751050562	1189994.708	919.1737620	2674.908617	957.8384335	0.837.046319	480.562101	897.875.343.229.850.00	30.589.323.158.352.50	928.464.666.386.003.00	158.670.894.881.079.00	82.515.31	6.138.97	0.8%
80	0.383799838	122.6024394	0.106888518	0.825963559	1452133.723	775.8265446	2649.044757	959.9948101	0.588.0283574	402.5383199	533.834.774.181.801.00	73.887.948.592.177.30	607.722.722.773.978.00	54.655.659.135.380.50	28.423.16	6.139.77	0.8%
81	0.467257882	133.0003523	0.143009885	0.780739291	1229777.688	603.4105484	2661.139049	908.7686598	0.900.4201154	500.4201154	398.061.578.708.317.00	71.134.383.580.045.70	469.195.962.288.983.00	51.046.329.765.241.30	26.546.16	6.177.99	0.8%
82	0.308419181	108.9345553	0.204139955	0.786733443	1191360.794	396.3939986	2623.327209	954.5433279	0.828.201974	416.0616963	242.220.727.030.448.00	15.135.199.356.139.00	257.355.971.388.597.00	41.333.374.396.621.00	21.495.03	6.226.74	0.8%
83	0.183493248	126.2942275	0.204407246	0.828629428	1009077.154	444.0418062	2603.881017	935.1245164	0.510.1241179	375.0636208	252.867.859.186.844.00	14.877.284.855.413.40	267.864.923.842.257.00	45.370.332.683.955.30	23.594.41	6.242.40	0.8%
84	0.177846197	135.8440029	0.143073554	0.758873542	900764.336	447.079588	2600.949072	946.6724025	0.646.7294169	422.1525295	285.446.209.207.962.00	15.828.053.703.011.90	30.523.619.698.879.60	15.873.52	6.264.50	0.8%	
85	0.200107914	127.0519136	0.214223966	0.837226783	1889157.11	532.4892117	2677.38986	927.0425331	0.786.052717	465.420684	680.727.180.166.872.00	32.428.033.542.496.90	692.700.793.709.369.00	124.237.239.295.050.00	64.808.66	6.271.23	0.8%
86	0.051210874	126.3440729	0.156639094	0.710284327	586259.9555	332.1039127	2656.807957	954.7247455	0.880.7519003	492.645811	179.130.090.485.766.00	1.794.119.568.822.72	179.130.090.485.766.00	19.929.795.481.252.10	10.364.30	6.307.71	0.8%
87	0.235744655	140.8398585	0.181516341	0.777862777	1483911.024	340.7169221	2661.988215	956.8013471	0.607.5839077	409.1702707	304.702.071.867.781.00	29.000.377.796.699.60	333.702.449.654.840.00	47.104.937.001.440.60	24.496.48	6.319.29	0.9%
88	0.138770167	127.8699442	0.138777026	0.875191661	654689.0602	626.3799777	2669.824889	925.0054545	0.875.1983562	491.0902759	295.535.001.016.285.00	20.525.466.777.395.60	316.050.527.793.890.00	38.212.156.303.404.80	19.871.87	6.346.79	0.9%
89	0.272644154	130.8184279	0.103979704	0.772423436	1600495.19	629.7740286	2668.098335	956.4108351	0.595.6125528	405.1259002	573.172.673.780.341.00	56.686.734.335.801.10	629.659.408.116.142.00	50.589.253.070.045.60	26.308.47	6.349.08	0.9%
90	0.266390714	120.9631225	0.190429489	0.870782098	805301.115	327.6911621	2636.767956	960.0428966	0.487.030102	212.5961002	212.5961002.000.000.00	13.138.147.122.706.40	225.734.687.986.829.00	37.440.082.846.433.00	19.470.36	6.358.69	0.9%
91	0.188501253	105.9693195	0.182682827	0.878637008	1445166.884	757.344368	2622.998353	927.0063556	0.1036.93303	534.4048452	953.249.255.966.081.00	20.771.551.973.322.40	974.020.807.939.044.00	156.341.922.863.866.50	81.304.15	6.362.60	0.9%
92	0.3471964	137.654959	0.146799883	0.80379189	816558.2163	711.648267	2623.584844	975.88587	0.585.4488453	401.654364	265.845.049.158.844.00	54.314.248.868.558.40	320.259.298.147.403.00	37.789.488.922.545.00	19.652.07	6.378.36	0.9%
93	0.310894922	122.1830576	0.157119848	0.797584348	1254298.873	337.3201687	2687.456372	977.9006444	0.642.046038	420.6212147	238.418.948.982.640.00	22.681.241.167.949.40	261.100.173.160.589.00	32.720.111.933.663.00	17.015.79	6.400.57	0.9%
94	0.528944614	140.4983099	0.222908769	0.739840511	1312048.495	570.4861136	2669.26301	971.7083514	0.774.0176431	461.8330463	327.007.894.782.131.00	97.270.138.649.855.50	424.278.033.431.989.00	72.736.120.506.805.00	37.325.74	6.435.05	0.9%
95	0.229758827	123.8041113	0.209697344	0.815591682	1166682.782	436.2617812	2631.780234	951.8454231	0.568.1261829	395.9678016	406.177.1016.827.00	28.113.378.155.764.90	434.290.488.834.392.00	73.212.966.194.115.00	38.073.71	6.401.42	0.9%
96	0.615715222	114.0606006	0.175938319	0.83032025	1164338.723	424.6993213	2625.181853	974.932198	0.586.1890305	404.9819306	145.906.472.010.008.00	42.261.328.979.561.80	188.167.800.989.570.00	27.488.208.610.535.20	14.294.98	6.423.39	0.9%
97	0.187148743	115.7570214	0.171853121	0.726432798	694107.3209	525.3624511	2633.36297	925.8708264	0.773.473599	461.9897173	455.299.183.041.024.00	15.916.019.327.345.50	471.215.202.388.370.00	58.757.921.119.257.00	30.556.50	6.434.37	1.0%
98	0.27693993	134.1859433	0.115735039	0.839838441	1139180.22	530.8611727	2668.784613	931.718936	0.868.521684	521.9165353	469.580.892.844.258.00	34.140.039.853.981.70	504.090.701.486.239.00	48.996.978.438.233.40	25.480	6.437.84	1.0%
99	0.452526296	128.492603	0.145891447	0.843759512	1271771.588	646.8447598	2632.110099	948.331629	0.818.4761048	474.909755	419.800.423.728.557.00	70.534.894.440.375.40	490.335.118.186.833.00	80.147.927.519.731.30	31.279.86	6.479.86	1.0%
100	0.172639794	127.4839976	0.125489139	0.871971085	1843745.414	317.3951832	2694.724053	933.7859914	0.658.099702	425.8473387							

Table 49. (continued)

gözetlilik üçgen	sıcaklık üçgen	Üretim faktörü üçgen	dönüşüm üçgen	yüzey alanı		kalınlık üçgen	kayaç d uniform	su d (yog) üçgen	denizlik üçgen	kayaç sıcaklık	terleme sıcaklığı sabit	kayaç öz ısı	su öz ısı	yük faktörü sabit			
				min	max												
min	0.0275	100	0.07	0.7	500000	min	250	2600	821.7	min	500	0.9					
max	0.7	145	0.24	0.93	2000000	max	1000	2700	896.7	max	1100		4.18				
mode	0.05	135	mode	0.6	900000	mode	350	2650	850	mode	650			0.41			
131	0.166285298	131.5430083	0.105218727	0.791767132	1350895.746	526.4597178	2685.330524	940.6862906	0.863.1916744	487.7100551	584.244.333.297.796.00	23.967.992.132.392.10	608.212.325.430.188.00	50.669.396.036.883.80	26.350.14	6.848.38	1.3%
132	0.043189453	136.2042812	0.200683072	0.85750238	944400.8184	565.9236982	2600.034642	950.6549736	0.691.4749681	436.521329	426.615.025.541.517.00	5.155.437.136.450.55	431.770.462.677.967.00	74.301.743.210.586.20	38.639.92	6.852.00	1.3%
133	0.235469851	136.8920752	0.189460254	0.787128785	919896.7961	427.9745294	2607.994272	943.3332736	0.1029.903094	532.728147	319.844.795.350.784.00	20.796.235.546.906.30	340.641.030.897.691.00	50.799.667.413.612.50	26.417.89	6.884.48	1.3%
134	0.352022562	129.6951137	0.182263409	0.796368026	1432072.382	662.1551084	2675.323842	955.3947176	0.552.7396199	390.2728913	459.036.573.974.508.00	66.247.273.525.349.80	525.263.847.499.858.00	76.244.294.537.991.60	39.650.13	6.891.83	1.3%
135	0.44211327	119.9253463	0.141820883	0.850922836	1400468.282	691.0881125	2664.368119	969.8182128	0.810.4634702	472.579426	508.296.365.733.667.00	69.255.705.801.828.10	577.552.071.535.495.00	69.696.191.675.839.00	36.245.94	6.904.94	1.3%
136	0.440424063	134.3537358	0.160847779	0.846890067	1314931.551	675.8528923	2634.566307	942.5286870	0.535.3330028	384.0796544	713.768.875.554.778.00	34.631.872.393.711.60	748.400.547.948.490.00	101.947.418.940.020.00	53.016.49	6.927.50	1.3%
137	0.140491803	140.2117763	0.175023116	0.843888208	901651.333	669.5248937	2655.875824	958.8253908	0.614.6981543	491.566564	270.758.888.121.20.00	63.240.572.777.100.50	333.999.460.898.302.00	49.331.701.421.894.00	25.654.89	6.950.16	1.4%
138	0.153799936	122.2196277	0.124064427	0.841474856	878664.8246	466.8687073	2605.775437	930.2940071	0.777.887275	462.895182	311.007.387.006.270.00	10.334.669.566.983.50	321.341.856.573.253.00	33.547.156.490.988.90	17.445.88	6.956.34	1.4%
139	0.163916252	121.2023566	0.169830421	0.874255495	1540942.098	647.8621708	2697.81625	954.8784471	0.715.752914	444.1089777	737.571.007.290.190.00	26.899.060.390.123.50	764.470.009.643.113.00	113.504.820.041.585.00	59.027.11	6.988.21	1.4%
140	0.548465013	122.7206993	0.127428819	0.743526214	901982.5741	318.5904403	2656.429586	936.5092233	0.711.4334383	442.7669796	112.535.798.810.489.00	26.080.000	136.615.799.047.945.00	13.133.385.004.292.80	6.829.89	6.999.21	1.4%
141	0.125857369	123.5629652	0.164400397	0.753239561	1396583.652	694.2355129	2659.114112	970.0056211	0.684.8924607	428.039445	690.927.776.892.198.00	21.057.071.824.750.20	711.984.949.716.949.00	86.166.859.310.303.30	45.850.34	7.009.37	1.4%
142	0.046115743	108.4919089	0.135218147	0.787657739	1439208.747	374.8598959	2665.907833	946.2232976	0.983.0310112	520.465201	305.606.034.387.376.00	29.224.462.673.524.10	333.830.498.960.900.00	35.554.923.921.296.20	19.469.85	7.009.27	1.4%
143	0.485366185	130.7801705	0.080811684	0.851148971	1009597.452	440.8584732	2688.05002	938.4175492	0.595.831978	405.204568	198.932.845.985.527.00	44.983.380.460.398.10	231.966.206.345.923.00	15.955.276.939.258.90	8.297.39	7.021.78	1.4%
144	0.367165479	134.5851158	0.170234658	0.759216704	819027.121	352.8586745	2661.298316	976.9011983	0.633.281119	417.732896	147.716.261.895.989.00	23.677.878.113.932.50	171.394.139.809.920.00	22.151.834.863.511.70	11.519.85	7.034.08	1.4%
145	0.121321981	136.8097996	0.148624881	0.842812019	1150833.128	418.5812658	2668.069322	958.7331196	0.733.4783106	449.5745581	377.989.293.937.937.00	13.211.785.823.394.30	396.201.079.807.321.00	48.376.642.661.048.40	25.187.82	7.037.35	1.4%
146	0.516771975	129.2045652	0.207887021	0.831291665	1403542.331	805.287479	2638.351525	966.0680998	0.501.807.639.934.00	97.447.742.420.993.60	599.255.680.060.938.00	103.650.127.327.617.00	103.650.127.327.617.00	53.855.52	7.043.39	1.4%	
147	0.282002439	119.1737229	0.168582366	0.865142044	761306.5513	350.0930175	2622.349275	927.4450992	0.671.8491664	430.2725566	158.199.517.337.626.00	11.537.532.093.724.40	169.737.049.401.350.00	24.755.757.082.887.00	12.874.00	7.079.19	1.5%
148	0.184208886	115.7871287	0.188820111	0.715035162	1635047.51	418.7048294	2667.590831	925.5715775	0.808.8518715	472.4010814	545.223.715.654.131.00	14.678.333.352.012.50	559.902.049.006.144.00	75.594.113.525.882.20	39.312.01	7.100.22	1.5%
149	0.354071963	108.1827339	0.130113463	0.747538515	1150523.437	427.6825964	2665.520448	938.9276931	0.727.8800217	447.855578	280.481.127.212.831.00	19.270.817.437.705.50	299.751.944.650.536.00	29.155.320.360.057.60	15.161.95	7.136.42	1.5%
150	0.304073595	137.8026735	0.136673928	0.813823214	903625.8164	431.8735752	2667.855881	946.1546403	0.788.1822528	466.0380930	251.702.883.315.544.00	27.094.093.706.265.60	278.796.977.021.810.00	30.993.345.908.393.00	16.118.70	7.137.44	1.5%
151	0.164412002	117.313404	0.127027485	0.802351036	692610.2076	485.5775887	2633.4809198	961.6179734	0.611.6797346	410.5838548	218.629.188.704.727.00	8.050.588.687.990.59	226.679.777.372.718.00	23.103.346.717.819.90	12.014.68	7.143.88	1.5%
152	0.435101311	126.2896462	0.209210442	0.789530337	120986.39	384.9928005	2620.985773	939.7451524	0.690.0223232	436.0538410	911.864.208.966.490.00	31.922.832.935.877.00	223.787.041.892.367.00	36.964.693.886.892.10	19.223.14	7.146.72	1.5%
153	0.204556409	130.1950898	0.118903262	0.849375659	1238180.257	813.8527997	2669.844744	931.7590568	0.775.4644127	462.2628836	40.288.159.111.342.40	776.365.511.991.648.00	77.089.046.879.058.80	40.099.43	7.150.84	1.5%	
154	0.309509877	129.3092986	0.097262326	0.844552068	919230.1455	819.1470589	2667.906747	965.8223466	0.665.4601259	428.2221459	428.484.753.963.355.00	46.403.396.003.906.00	474.868.120.047.261.00	39.008.815.630.459.00	20.286.17	7.151.27	1.5%
155	0.423671278	136.582419	0.182962741	0.86295118	879035.7251	435.0887544	2650.07732	962.8739912	0.713.3674128	443.3683944	191.000.754.378.943.00	36.901.379.951.374.40	227.902.133.940.317.00	35.705.285.118.335.10	18.688.20	7.166.17	1.5%
156	0.516810779	139.2343768	0.158242575	0.732930902	1248047.96	686.4549847	2650.91729	970.039102	0.858.4559413	496.3688222	551.934.699.672.429.00	72.505.251.064.870.30	624.439.910.737.300.00	72.877.774.083.377.00	37.899.40	7.197.60	1.5%
157	0.210205986	137.8051528	0.163682966	0.853446811	1230782.64	533.871979	2655.293154	972.4271407	0.875.0715012	491.6548942	598.757.571.461.483.00	32.352.086.675.891.10	541.109.855.137.294.80	87.780.046.521.194.20	35.248.38	7.203.21	1.6%
158	0.162826124	138.4439818	0.165057167	0.841513457	1303104.584	579.7380271	2651.883286	963.0064106	0.657.9123869	425.7867722	341.921.155.968.003.00	14.579.959.787.723.00	356.501.114.455.728.00	46.952.226.945.273.30	24.417.06	7.205.02	1.6%
159	0.25103382	132.3073989	0.170448594	0.770449587	793083.344	582.2885841	2671.1565327	949.3483737	0.805.4131295	471.1047039	325.252.511.996.449.00	24.063.087.481.680.50	349.315.599.458.130.00	44.150.675.960.084.50	22.980.14	7.207.87	1.6%
160	0.348451879	122.352532	0.108193317	0.872802617	1481642.719	482.298419	2672.79594	945.6709393	0.722.4376707	467.149314	401.748.149.085.711.00	43.007.951.361.597.50	444.757.094.427.309.00	42.259.054.529.668.00	21.976.42	7.207.98	1.6%
161	0.527786276	134.4672286	0.149971663	0.747511895	1072550.133	314.292822	2636.114894	963.8183763	0.758.7306384	457.578110	110.389.498.392.640.00	45.965.707.760.1592.00	159.344.206.521.923.30	18.564.516.521.923.30	9.654.30	7.231.16	1.6%
162	0.152876331	120.689296	0.109394706	0.785230122	1052192.21	334.2398782	2656.612191	945.5799063	0.570.5091659	396.4965394	225.444.580.400.249.00	8.728.951.148.276.26	234.173.531.548.525.00	19.603.163.826.653.60	10.194.44	7.240.73	1.6%
163	0.053948633	124.4965305	0.190336365	0.918765987	833523.9737	396.551956	2648.524414	926.9689922	0.848.5316447	483.580804	297.331.343.527.846.00	302.429.849.169.55	300.373.633.770.1647.00	52.527.712.435.192.10	27.316.54	7.257.12	1.6%
164	0.04477878	137.8552689	0.168589764	0.768402985	891201.9081	930.62598	2660.072587	934.793027	0.694.8402152	437.5732141	650.877.117.265.960.00	15.932.789.764.909.10	666.810.507.030.899.00	85.357.314.721.244.00	44.389.27	7.275.15	1.6%
165	0.184747558	132.647710	0.156423659	0.797427704	1398456.825	429.7339403	2665.005311	938.3860111	0.838.3680182	495.190.812.00	505.888.423.179.302.00	61.302.388.991.195.00	549.190.812.074.897.00	68.492.645.501.831.40	35		

Table 49. (continued)

gözetlilik uçgen	sıcaklık uçgen	üretim faktörü uçgen	dönüşüm uçgen	yüzey alanı uçgen	kalınlık uçgen	kayac d		su d (yöğ)		denizlik uçgen	kayac sıcaklık	terleme sıcaklığı sabit	kayac öz ısı sabit	Htoplam	HtopUret'Dönüşüm	saha rezery	su öz ısı sabit	yük faktörü sabit
						unifrom	expect	min	max									
min	0.0275	100	0.07	0.7	50000	2600	2600	521	80	500			0.9				4.18	
max	0.7	145	0.24	0.93	200000	1000	2700	996	1100	1100								
mode	0.18	135	mode	mode	900000	350	2650	mode	mode	650	166	Hk	He					13835.17
																		26196.98
196	0.21695376	130.4332271	0.203644326	0.896436736	644489.5026	543.1749509	2666.453117	974.5200969	0.932.1121304	506.8064903	280.769.848.022.968.00	15.602.945.904.293.10	296.372.793.927.291.00	53.500.568.082.480.90	27.822.47	7.563.60	1.9%	
197	0.182518362	137.4264411	0.127850957	0.805343642	1126476.042	879.057182	2673.615301	975.8599647	0.894.6232773	496.5102117	811.305.039.501.729.00	42.337.123.040.084.00	853.642.162.541.813.00	87.894.373.768.387.50	45.708.64	7.565.59	2.0%	
198	0.293840325	142.5916125	0.104765874	0.775729912	565876.4256	413.1643476	2680.461076	975.6407337	0.848.8006405	483.6274439	160.769.112.167.179.00	17.537.219.577.882.80	178.306.331.745.062.00	14.490.959.497.835.00	7.535.89	7.569.26	2.0%	
199	0.550851919	133.4494223	0.148501998	0.748572465	1254625.297	433.1337044	2626.719576	934.5703869	0.923.8256501	504.5487054	244.967.873.418.210.00	62.503.192.178.408.40	307.471.165.596.618.00	35.823.643.326.571.00	16.829.75	7.571.85	2.0%	
200	0.19009238	122.6188727	0.172363969	0.759375141	1798338.043	484.4649457	2676.970202	967.6386662	0.705.5161469	440.9217951	613.575.952.470.063.00	28.253.929.353.823.10	641.829.881.823.886.00	84.008.425.568.398.30	43.687.79	7.582.86	2.0%	
201	0.306718973	132.4385786	0.174274563	0.888576736	1400348.298	405.2766796	2663.721242	931.3720708	0.769.1299764	460.3709986	358.786.156.007.660.00	35.536.834.284.035.30	334.322.990.291.695.00	60.870.379.256.197.50	31.655.07	7.595.99	2.0%	
202	0.2035130836	135.6715359	0.204514901	0.8319462307	1387548.771	628.3601877	2634.294215	965.0124446	0.634.554884	418.1601892	684.125.247.227.617.00	10.402.697.363.830.10	674.527.944.591.447.00	113.045.657.683.942.00	58.788.33	7.596.01	2.0%	
203	0.490670506	139.933091	0.188403617	0.805155239	1416327.197	556.9057284	2636.158509	932.0260289	0.540.7235269	386.074906	344.303.384.509.413.00	106.562.635.152.038.00	450.866.019.661.450.00	68.396.292.518.794.60	35.669.89	7.612.95	2.0%	
204	0.218545296	128.9676666	0.195139617	0.781652405	1214142.582	626.2205059	2606.224716	942.7006862	0.824.0542581	476.2533313	464.902.068.802.909.00	26.989.761.365.336.10	491.891.831.168.245.00	75.786.233.371.986.40	39.1412	7.613.26	2.0%	
205	0.296746207	126.7364683	0.154671926	0.879585413	908876.8698	612.3759296	2654.943831	978.0254768	0.675.221128	431.3512884	326.605.869.003.979.00	31.556.829.372.160.30	360.162.498.436.139.00	48.999.088.745.339.40	25.481.51	7.624.90	2.0%	
206	0.114543255	133.4116852	0.183574805	0.878698943	782327.5185	700.8565099	2669.676985	935.0256004	0.829.5560881	478.1139159	245.736.942.155.171.20	7.145.200.701.762.60	252.862.142.856.933.00	40.790.171.074.703.20	21.212.94	7.631.72	2.0%	
207	0.398937506	135.3218076	0.165796944	0.774047298	914072.3455	528.9689126	2631.782186	930.6145053	0.678.862558	432.5140291	241.370.362.408.770.00	41.272.267.189.925.30	282.642.629.959.695.00	36.272.681.318.659.70	19.863.27	7.632.44	2.1%	
208	0.162524965	120.0316875	0.197957274	0.826902953	1056586.458	432.8059831	2643.888323	929.5899260	0.717.091463	444.5241396	332.380.165.705.384.00	11.531.631.548.860.80	343.911.797.254.245.00	53.409.996.284.193.10	27.775.37	7.648.32	2.1%	
209	0.528348385	131.2251306	0.191427944	0.867711417	1232920.691	391.8989727	2643.133929	967.7929626	0.684.5436877	434.318839	191.516.395.755.007.00	52.744.573.358.962.30	244.260.969.113.899.00	36.785.339.391.751.40	19.129.86	7.689.00	2.1%	
210	0.285832205	126.1510557	0.131233685	0.770178581	1080445.536	899.339464	2678.584294	930.3895133	0.643.8459361	421.210382	580.281.881.775.854.00	45.843.884.232.685.60	628.125.746.006.540.00	43.284.641.273.848.30	32.910.59	7.671.01	2.1%	
211	0.225183142	132.3639372	0.145522136	0.720342591	1092878.459	600.534975	2635.487926	939.5644209	0.936.1254706	506.8963818	516.316.408.668.032.00	30.393.966.702.592.30	546.709.805.370.625.00	63.037.491.044.694.20	32.782.05	7.682.24	2.1%	
212	0.401997823	109.6659994	0.163413724	0.75740801	883299.4473	721.7295632	2638.780499	931.4302911	0.577.589638	519.0224707	397.450.743.968.618.00	29.597.708.929.849.30	427.048.452.896.667.00	52.856.155.901.620.90	27.487.35	7.684.60	2.1%	
213	0.687825769	119.9644296	0.197907326	0.742343935	933889.3206	787.7105074	2612.144346	942.2929311	0.501.501884	371.7463125	469.877.544.615.870.00	7.954.682.822.775.68	477.832.207.438.646.00	70.200.863.712.121.50	36.507.30	7.695.63	2.1%	
214	0.138720841	129.5341636	0.196935312	0.743489659	1827005.79	644.13586	2656.583942	949.4223568	0.897.7018297	497.3637665	1.012.206.144.278.170.00	32.092.214.346.655.60	1.044.298.358.624.830.00	152.905.506.989.155.00	79.517.07	7.700.73	2.1%	
215	0.17695902	124.8540561	0.146208189	0.824904191	1117497.027	568.7461808	2622.781867	968.4606169	0.651.3904237	423.8170341	424.359.511.889.132.00	20.422.421.020.247.40	444.781.932.909.379.00	53.644.412.279.311.00	27.897.27	7.701.65	2.1%	
216	0.323082335	133.7779679	0.121436841	0.847509631	1280483.249	527.5060486	2641.124221	929.4563822	0.868.605209	489.2370128	398.742.837.113.384.00	46.565.980.593.498.00	486.307.927.707.828.00	50.050.273.239.111.60	26.028.17	7.712.47	2.1%	
217	0.114760615	119.0872711	0.188598121	0.823858267	992095.6838	707.8609393	2646.793746	940.0516124	0.833.878027	493.981313	524.237.796.080.365.00	12.374.113.243.262.60	536.611.909.323.628.00	83.377.745.526.311.80	43.859.81	7.712.43	2.2%	
218	0.087551123	120.2739944	0.163034937	0.848990739	1564779.81	417.9780227	2658.111127	932.5384397	0.573.9912244	397.5664043	453.382.599.179.187.00	6.989.487.084.130.01	462.372.446.623.803.00	71.852.117.436.913.00	37.366.02	7.713.20	2.2%	
219	0.093495869	111.808484	0.133442872	0.748490172	878957.5504	847.5875062	2635.351806	944.689537	0.573.9912244	508.4024667	684.595.702.596.423.00	8.862.237.929.379.21	693.457.940.525.803.00	69.263.049.690.393.10	36.019.60	7.714.97	2.2%	
220	0.372523338	136.9267591	0.169491261	0.876342518	780012.1733	700.1865198	2651.796915	935.0580605	0.930.1309038	506.2602411	186.685.957.364.564.00	24.255.734.585.468.40	210.940.791.950.033.00	31.331.671.121.547.00	16.293.74	7.721.85	2.2%	
221	0.360427284	136.0352968	0.159579367	0.825516032	1176792.534	573.3787117	2644.132972	926.2549877	0.868.1534332	489.1103262	420.142.997.331.235.00	43.363.711.746.481.00	483.505.809.077.716.00	81.059.579.876.236.90	31.753.46	7.739.94	2.2%	
222	0.471113887	129.9777284	0.182549492	0.841732932	1045331.207	781.954471	2670.950292	969.3831104	0.740.1828965	451.6245652	385.275.462.004.764.00	77.822.977.323.049.50	463.086.439.327.804.00	47.357.236.117.239.50	24.827.88	7.741.49	2.2%	
223	0.34858536	115.4268987	0.165867854	0.772838784	957243.9595	717.5771186	2643.888975	954.7529099	0.628.4024411	415.464530	347.611.915.362.311.00	35.533.286.339.477.20	383.145.301.701.788.00	53.467.527.803.372.70	27.805.28	7.744.18	2.2%	
224	0.121895808	130.8149064	0.103783005	0.834943349	1211298.819	407.234693	2638.630566	927.8206901	0.607.8206901	447.8447102	402.209.659.153.125.00	11.870.565.292.042.90	414.080.223.445.168.00	35.876.966.921.543.30	18.657.48	7.747.94	2.2%	
225	0.105883341	120.5769091	0.137859237	0.866112944	1431982.47	660.8353718	2680.748234	952.367534	0.913.1051961	501.6126972	854.254.403.124.061.00	16.134.989.834.359.80	470.439.402.048.421.00	131.072.276.107.040.00	68.182.90	7.751.84	2.2%	
226	0.095190243	133.3057949	0.091664329	0.868059455	1077131.521	355.054345	2624.881147	931.2333632	0.495.800951	339.932.252.364.371.00	7.547.327.963.076.36	347.479.579.827.411.00	27.648.890.580.050.00	14.378.59	7.757.83	2.2%		
227	0.09456694	140.5352414	0.155794517	0.895154656	811253.9564	403.3340889	2629.447723	927.5727647	0.772.5658878	461.3981355	288.063.943.543.917.00	7.388.152.360.317.09	275.452.118.904.234.00	38.414.604.157.290.60	19.977.15	7.763.19	2.3%	
228	0.674675393	107.6263259	0.207583269	0.859461623	1798813.384	679.0441613	2607.47996	924.575163	0.649.4363966	498.819476	614.133.432.963.335.00	58.801.530.621.365.00	672.934.963.584.000	120.064.011.940.441.00	62.348.16	7.763.59	2.3%	
229	0.361924129	103.2980024	0.179505829	0.742806403	1113361.198	462.4313883	2664.60845	941.172146	0.750.3160771	454.7055071	295.203.830.902.136.00	17.073.820.951.290.30	312.277.451.853.426.00	41.638.475.488.212.00	21.653.70	7.765.91	2.3%	
230																		

Table 49. (continued)

gözetimlik uçgen	sicaklik uçgen	üretim faktörü uçgen	dönüşüm uçgen	yüzey alanı		kalınlık uçgen	kayac d uniform	su d (yöğ)		denizlik uçgen	kayac sicaklik	terleme sicaklığı sabit	kayac öz ısı	su öz ısı	yük faktörü sabit			
				min	max			min	max									
min	0.0275	100	0.07	0.7	50000	min	250	2600	521	500	80	0.9	4.18	0.41				
max	0.7	145	0.24	0.93	200000	max	1000	2700	898	1100								
mode	0.05	135	0.18	0.8	900000	mode	350	2650	930	650	166	Hk	He	Höglam	Htop'Üret'Dönüşüm	saha rezerv	13835.17	26196.58
261	0.538698479	123.229373	0.172401347	0.836302276	793134.467	335.8422533	2669.950992	949.6420704	0.535.2267119	384.0404572	89.772.686.312.053.40	24.623.135.826.310.60	114.995.822.138.364.00	16.493.548.323.783.600	8.577.31	8.017.48	2.6%	
262	0.16938546	124.207966	0.131170497	0.916825411	1014120.251	427.7193814	935.9876088	0.794.5398239	467.9138744	537.237.547.562.269.00	12.707.782.803.665.70	349.945.330.366.135.00	42.084.580.996.511.20	21.885.69	8.016.63	2.6%		
263	0.30640506	128.005036	0.181850592	0.865498578	1085451.279	894.8552556	2623.99721	956.5824675	0.738.0054619	450.9586486	590.203.184.916.333.00	57.127.496.281.360.30	647.330.681.197.693.00	101.884.300.716.804.00	52.983.97	8.022.10	2.6%	
264	0.047273059	135.2912103	0.201685958	0.749343336	898620.0579	483.9976661	2646.443768	952.5184985	0.796.0936377	468.6101991	383.536.937.708.272.00	4.526.253.543.408.36	388.063.191.251.681.00	58.645.777.558.005.90	30.499.74	8.022.14	2.6%	
265	0.477730064	108.3010547	0.167668512	0.776826684	847628.9122	318.1958426	2696.994712	929.5672885	0.1017.079007	529.4018239	153.657.132.670.025.00	14.169.105.433.938.10	167.826.238.103.963.00	21.859.262.507.328.20	11.367.70	8.038.62	2.6%	
266	0.36238386	115.5384227	0.21590368	0.868625377	830667.1796	450.0463669	2656.503088	963.7897132	0.647.1128729	19.420.097.703.559.90	194.235.225.804.485.00	19.420.097.703.559.90	214.345.235.508.045.00	41.040.438.394.129.10	21.342.69	8.051.78	2.6%	
267	0.372332362	134.1182816	0.16692186	0.880749654	1532604.367	683.3973377	2664.948814	947.6850689	0.603.2592514	407.7160572	510.074.244.636.226.00	83.600.684.525.004.40	595.674.939.161.230.00	87.573.987.542.723.50	45.542.03	8.062.87	2.7%	
268	0.645882589	111.8511477	0.180417872	0.846930562	1448790.847	374.2379674	2660.794583	956.7603207	0.1075.152433	544.3059841	219.942.746.645.895.00	46.977.266.239.480.90	266.919.927.885.376.00	40.785.741.362.681.00	21.210.24	8.072.74	2.7%	
269	0.208191854	111.9753934	0.177284533	0.863195233	1118738.303	498.2259331	2632.239387	938.010351	0.957.1877633	513.7629084	147.552.956.118.476.853.00	14.755.837.641.545.90	474.542.956.118.399.00	72.616.547.110.606.50	37.763.55	8.079.26	2.7%	
270	0.064823456	123.6946421	0.115497416	0.803705019	770452.5903	488.8222135	2612.190306	951.1272171	0.965.8536994	515.8979448	346.162.365.896.748.00	4.067.495.270.400.68	350.229.860.937.148.00	32.510.385.509.814.70	16.906.72	8.081.76	2.7%	
271	0.293992397	138.0694657	0.098364742	0.983694742	649955.4533	356.4609639	2624.890613	937.5453355	0.875.4627098	491.1644371	159.900.779.575.691.00	14.953.030.209.074.50	173.853.809.784.786.00	13.074.760.530.329.50	6.799.41	8.082.30	2.7%	
272	0.033230452	119.037708	0.185400095	0.78675406	1443717.666	896.5367875	2947.049814	976.0106194	0.626.2109879	416.0648923	990.659.900.947.891.00	6.799.037.228.275.41	997.458.338.176.166.00	145.558.334.977.051.00	75.686.24	8.091.70	2.7%	
273	0.296330695	120.4568441	0.200517492	0.948682607	690429.0528	590.9625422	2639.501001	939.9878999	0.741.8962562	452.1439788	240.348.459.374.134.00	16.367.052.535.875.00	258.615.509.910.0209.00	44.019.041.488.229.20	22.891.88	8.104.05	2.7%	
274	0.140282759	116.2228159	0.118235936	0.855970561	1182258.003	733.4186027	2867.199296	974.7510301	0.835.3067389	437.0899278	616.308.289.878.820.00	17.256.628.296.628.60	631.564.817.275.449.00	63.918.462.228.083.40	33.240.19	8.113.93	2.7%	
275	0.236818543	112.9411864	0.194605963	0.8144491398	785446.4459	500.8447917	2611.203372	936.8102497	0.835.4294192	418.4479122	242.293.402.576.862.00	12.267.659.898.826.80	254.561.061.475.689.00	40.349.064.193.179.50	20.983.14	8.114.99	2.7%	
276	0.192165891	129.8497074	0.160820493	0.854028503	803084.2125	503.6547531	2688.003396	936.7357926	0.613.957835	411.1378706	259.641.903.120.266.00	15.183.747.420.024.10	274.825.650.540.290.00	37.747.052.453.875.60	19.630.00	8.118.99	2.7%	
277	0.036202029	123.7349733	0.12972124	0.863283318	1550923.887	613.9541166	2638.514234	957.1747785	0.525.4267418	380.508335	654.895.400.707.014.00	6.031.618.528.125.36	660.926.659.235.140.00	74.014.653.627.361.70	38.490.62	8.120.71	2.8%	
278	0.579170577	133.74541	0.145016932	0.730379699	12048757.427	769.2621211	2627.7347116	937.7347116	0.625.1061921	432.2543717	336.289.360.267.00	116.487.874.307.070.00	452.623.963.667.337.00	47.940.763.796.496.60	24.931.14	8.130.07	2.8%	
279	0.22038154	111.2932169	0.187774771	0.752979629	1384474.627	378.023556	2697.09006	951.7744035	0.645.5412295	421.7645566	338.492.800.878.636.00	14.359.802.008.035.10	352.852.602.886.671.00	49.890.033.254.861.10	25.944.84	8.134.23	2.8%	
280	0.196239851	120.3583734	0.129319846	0.819319846	1168695.66	316.4049852	2625.494869	927.6054185	0.585.2390552	401.5824623	227.678.283.987.687.00	11.407.825.135.764.90	239.065.909.123.452.00	24.639.597.820.857.20	12.813.59	8.160.24	2.8%	
281	0.467330664	134.113916	0.162106977	0.871716902	752390.0767	487.8523497	2670.51472	935.9294677	0.761.2055806	457.9932421	170.824.898.548.389.00	37.681.043.894.191.50	280.506.302.442.580.00	29.464.315.787.988.10	13.322.64	8.165.99	2.8%	
282	0.381532274	136.8955861	0.178308662	0.800192371	838774.0265	756.4287312	2650.429355	931.7081874	0.813.707527	502.9828809	311.276.293.438.312.00	38.707.658.667.519.30	349.983.952.105.832.00	49.935.636.975.803.00	29.568.56	8.170.06	2.8%	
283	0.087874653	118.162826	0.207772798	0.785379536	1368734.859	566.0628987	2644.16457	938.0836995	0.682.1172304	433.5841002	594.591.116.285.445.00	10.188.272.780.961.60	604.779.389.066.437.00	98.688.205.474.866.60	51.321.87	8.184.93	2.8%	
284	0.121816758	129.850106	0.213865133	0.862847819	888673.3497	321.9562496	2665.256972	961.9191563	0.860.4527599	486.9263961	245.264.323.172.560.00	17.311.255.866.284.52	252.395.779.058.844.00	47.659.398.081.985.00	24.784.82	8.183.23	2.8%	
285	0.279582876	113.9725293	0.232399983	0.718505851	1361942.356	275.5589992	2623.417141	935.6336242	0.732.5980014	449.3048909	236.920.584.399.444.00	13.759.002.739.648.70	250.679.597.139.093.00	45.075.489.967.973.20	23.441.08	8.187.91	2.8%	
286	0.194233074	135.2215374	0.162895712	0.789489837	1000186.701	543.3674759	2649.842705	946.9344732	0.648.863151	422.4961629	361.775.880.201.811.00	22.252.294.072.203.90	394.027.874.274.015.00	43.262.817.996.042.90	22.496.42	8.195.12	2.8%	
287	0.39298985	119.037708	0.185400095	0.78675406	1443717.666	896.5367875	2947.049814	976.0106194	0.626.2109879	416.0648923	990.659.900.947.891.00	6.799.037.228.275.41	997.458.338.176.166.00	145.558.334.977.051.00	75.686.24	8.091.70	2.7%	
288	0.335249768	120.6189803	0.161687726	0.875412123	1595896.119	406.2744448	2685.216027	933.3478722	0.641.4396152	420.422556	355.378.659.534.131.00	34.521.414.270.704.90	389.900.072.804.936.00	55.187.780.227.158.70	26.899.89	8.205.72	2.9%	
289	0.102638063	118.0739025	0.173526991	0.904673601	957223.8348	365.7323587	2652.530247	967.8361493	0.597.7012007	405.838602	242.167.210.812.587.00	6.658.196.458.815.33	248.825.407.269.043.00	39.078.838.486.305.00	20.321.54	8.206.36	2.9%	
290	0.159371014	116.2921038	0.171493986	0.781400798	1136613.185	864.904866	2630.678624	931.2201769	0.896.0493612	496.904955	815.705.899.899.617.00	22.132.589.958.632.30	837.838.279.958.250.00	112.274.901.716.638.00	59.387.51	8.206.64	2.9%	
291	0.178293494	134.2159684	0.143089758	0.898163062	8547.36.2282	71.864.968.007	2654.278305	965.4544607	0.71429284	446.9521133	469.937.189.404.808.10	25.490.599.494.808.10	495.427.735.351.275.00	63.073.909.904.153.20	33.114.46	8.208.27	2.9%	
292	0.34471233	133.162352	0.078103454	0.823004958	1397963.932	392.2727475	2635.232574	926.9007491	0.932.9655602	504.58691	359.819.824.265.295.00	38.657.733.648.662.30	398.477.597.914.157.00	25.613.952.820.870.90	13.320.30	8.218.76	2.9%	
293	0.42659334	141.0740276	0.202030321	0.802813222	841351.1151	599.2738053	2608.698086	932.7564942	0.628.96517	416.2916336	229.282.873.949.399.00	50.864.086.173.555.70	280.146.760.122.955.00	45.499.111.839.982.90	23.661.38	8.204.86	2.9%	
294	0.17902927	126.843482	0.14355233	0.833730746	1603124.115	476.1991068	2606.244027	935.7511283	0.699.5853796	439.064276	527.291.987.120.557.00	25.164.011.334.112.40	552.455.998.454.670.00	52.671.969.145.365.90	27.391.56	8.238.28	2.9%	
295	0.46302491	129.6387562	0.174200488	0.714200488	1411682.163	475.6254051	2667.921033	931.4450727	0.866.214517	488.5632736	349.71							

Table 49. (continued)

gözetimlik	sıcaklık	üretim faktörü	dönüşüm	yüzey alanı	kalınlık	kayac d	su d (yö)	derinlik	kayac sıcaklık	terletme sıcaklığı		kayac öz ısı		su öz ısı	yük faktörü		
üçgen	üçgen	üçgen	üçgen	üçgen	üçgen	üniform	üçgen	üçgen	sabit	sabit		sabit		sabit	sabit		
min	0.7	100	0.07	0.7	50000	250	2600	921.7	500	80	0.9		4.18		0.41		
max	135	145	0.24	0.93	200000	1000	2700	986.7	1100			Htoplam	Htop*Üretim	saħa rezerv	13835.17		
mode	0.05	mode	0.18	mode	900000	350	2650	930.6	650	166	hk		Ha		26196.98		
9686	0.269802585	122.4344617	0.209684371	0.739691396	1245970.282	730.1895355	2619.71937	968.924225	0.664.0399916	427.7649557	536.505.900.917.169.00	43.906.536.819.798.00	580.412.437.736.967.00	90.022.946.041.811.90	46.815.59	58.256.42	96.9%
9687	0.258916324	139.7060211	0.167276781	0.824907014	948091.0009	670.2994245	2698.315504	979.7197163	0.603.7578121	407.8886297	375.407.457.039.798.00	40.274.707.446.855.40	415.862.164.466.653.00	57.359.063.124.173.40	29.829.04	58.321.02	96.9%
9688	0.2464570838	128.2086559	0.193093219	0.809653155	1304674.395	712.9024597	2630.135624	948.1238192	0.594.2033701	404.6463649	682.907.594.741.170.00	7.920.441.995.965.12	690.828.036.737.135.00	66.557.644.113.715.00	34.612.88	58.352.24	96.9%
9689	0.53811239	140.6195555	0.210441271	0.820848647	1129956.631	438.3184877	2690.689911	947.8637869	0.682.5198685	433.6763482	189.958.338.731.255.00	64.008.977.395.222.20	253.967.316.126.477.00	43.870.423.939.113.30	22.814.40	58.497.20	96.9%
9690	0.151043259	120.404365	0.194572863	0.80326809	1454411.597	526.946303	2699.430701	953.3794945	0.697.1010143	438.2843318	562.607.334.272.118.00	18.496.291.472.183.40	580.565.625.744.301.00	90.739.023.888.207.50	47.187.98	58.504.70	96.9%
9691	0.096597248	123.9609147	0.178679903	0.740529866	886161.7252	313.6218011	2641.552211	926.5224973	0.781.5749675	464.0805943	228.750.570.586.738.00	4.678.597.962.545.34	233.429.168.579.283.00	30.866.835.108.938.40	16.062.41	58.515.43	96.9%
9692	0.313710049	104.6261247	0.17637073	0.785588062	1339853.769	531.1471475	2661.16829	966.9400719	0.610.3027798	410.0918287	386.126.420.050.937.00	22.221.480.612.883.80	408.347.880.663.821.00	37.737.175.302.834.30	19.624.96	58.537.72	96.9%
9693	0.167250369	129.7985447	0.099152908	0.85603065	1114379.047	666.818466	2621.215392	952.3653943	0.732.004476	467.1661399	566.883.481.681.681.00	24.710.630.575.135.60	591.594.088.346.817.00	50.213.290.621.064.40	26.112.94	58.576.94	96.9%
9694	0.371279997	135.5294612	0.156603974	0.756017417	1535943.029	573.023632	2660.456329	948.6489576	0.797.0896467	450.6796263	491.035.989.186.723.00	71.939.093.455.766.50	562.975.082.644.489.00	49.862.912.670.276.80	25.826.73	58.580.99	96.9%
9695	0.1724625	114.3562054	0.133892105	0.820390306	1324567.256	304.8201991	2661.224021	942.123901	0.731.9460767	446.0263007	296.901.329.278.399.00	9.546.230.937.418.15	306.449.560.215.818.00	33.661.715.015.818.10	17.505.46	58.594.66	96.9%
9696	0.429831196	126.1457909	0.115853375	0.678119382	1004.192.889	648.3042697	2632.83061	931.4009377	0.698.4019812	426.4007911	307.993.240.392.478.00	49.531.871.064.094.00	357.525.111.456.572.00	36.237.773.136.097.30	18.845.11	58.596.08	96.9%
9697	0.083414031	129.1598763	0.173969972	0.857245199	1226476.046	462.0674096	2665.555392	940.0205313	0.523.3091007	414.4379089	416.757.413.276.842.00	9.130.606.994.079.91	425.898.020.272.922.00	63.522.078.986.190.10	33.034.06	58.607.85	97.0%
9698	0.32959191	115.7789268	0.168275521	0.779330993	1128.361.577	592.762578	2649.561636	936.9914057	0.791.9419227	467.1482098	413.994.033.759.944.00	30.890.119.937.235.00	444.875.053.697.179.00	57.846.540.720.713.00	29.979.59	58.616.23	97.0%
9699	0.208113863	125.0338892	0.178024551	0.768021862	1197311.855	330.208958	2693.903899	968.0217296	0.794.9046239	468.0217296	296.150.041.270.576.00	17.788.315.771.552.00	303.938.357.042.128.00	41.623.602.884.333.50	21.845.96	58.677.69	97.0%
9700	0.318891298	138.2120337	0.208963934	0.803738559	1399464.591	806.986176	2642.303494	934.8996187	0.638.8852589	419.5757164	620.037.654.044.291.00	81.778.211.341.450.70	701.815.865.385.742.00	116.739.193.260.102.00	60.709.12	58.682.94	97.0%
9701	0.06407756	116.4200473	0.13291943	0.870446678	1320609.434	749.368549	2633.932998	958.1657229	0.1027.64635	532.1442326	996.537.200.678.00	8.732.040.040.729.98	1.005.269.266.741.300.00	116.319.521.203.202.00	60.490.87	58.690.95	97.0%
9702	0.23479075	136.0845892	0.154383248	0.781304779	951.257.432	375.325496	2672.263397	978.9032846	0.681.6445295	433.9881617	141.867.034.545.954.00	11.730.829.172.189.90	153.617.863.718.144.00	138.530.297.826.822.00	9.836.51	58.722.74	97.0%
9703	0.419638405	136.3904608	0.169442569	0.789486009	1567018.285	392.6396919	2672.823596	929.3268619	0.901.6662311	498.4552211	469.809.340.502.168.00	28.774.862.834.326.50	498.584.222.884.494.00	66.311.209.939.414.10	34.464.47	58.731.13	97.0%
9704	0.246161148	109.7873461	0.121257667	0.807362211	727247.7174	936.5419036	2640.268612	950.0423511	0.717.492764	502.8163796	515.858.418.698.734.00	16.832.767.777.993.60	535.691.186.446.231.00	52.443.555.369.609.30	27.272.78	58.733.68	97.0%
9705	0.292359069	120.873252	0.197833657	0.880175936	1345425.243	531.525787	2666.647353	978.2865033	0.787.057148	465.7053443	472.383.266.746.120.00	33.655.383.019.601.50	506.038.690.783.721.00	88.115.717.809.603.00	45.823.75	58.779.41	97.0%
9706	0.503981089	138.1692856	0.124495597	0.812951326	720014.3233	349.7094511	2690.365959	958.0416513	0.692.0253144	436.6943276	107.888.675.513.009.00	29.591.724.596.851.60	137.460.401.109.861.00	13.912.210.639.372.00	7.234.91	58.817.48	97.1%
9707	0.126436346	131.7356434	0.203431433	0.751639568	125257.577	512.705621	2641.436724	962.7489794	0.578.421946	456.1840366	550.754.181.480.386.00	22.731.877.713.701.00	573.486.059.194.087.00	87.690.098.332.543.00	45.602.41	58.843.25	97.1%
9708	0.096212529	143.5793373	0.168628344	0.833500393	1137821.221	316.8013003	2680.493433	933.9722298	0.560.7720541	393.0983398	241.483.810.661.349.00	8.604.711.854.864.02	250.088.522.516.213.00	35.150.389.818.127.80	18.279.83	58.853.76	97.1%
9709	0.17593752	127.32492	0.140458828	0.777367034	1725972.814	664.0816696	2625.379672	940.3782423	0.756.6624749	456.804755	858.945.317.381.389.00	33.679.026.563.803.00	892.624.377.965.100	97.485.111.127.500	50.696.22	58.873.32	97.1%
9710	0.313344179	116.600855	0.187684891	0.815923909	876832.9507	327.476651	2667.822938	978.9795669	0.572.2299048	455.2805454	183.088.247.965.186.00	13.887.477.226.414.30	196.975.725.211.580.00	31.771.362.886.030.00	16.522.40	58.960.92	97.1%
9711	0.083437151	124.0074798	0.152590982	0.851739023	1588931.747	839.5994149	2625.33076	968.8606305	0.663.7603423	427.6748764	1.004.134.905.527.800.00	19.966.549.300.593.90	1.023.100.954.828.380.00	187.919.295.800.437.00	97.726.96	59.054.84	97.1%
9712	0.381204357	125.1903078	0.133041145	0.873299717	874720.659	430.9220337	2666.253176	951.2420779	0.661.89305	427.0728947	148.470.361.043.426.00	19.911.064.965.946.20	166.381.426.007.372.00	19.330.979.599.692.00	10.052.89	59.070.77	97.1%
9713	0.07246524	111.9693271	0.175196494	0.625971038	1291285.289	399.379598	2654.196395	977.5463	0.898.388734	467.5401703	473.393.733.408.599.00	4.843.550.929.519.99	478.237.294.338.105.00	68.294.392.736.959.20	35.989.09	59.070.77	97.1%
9714	0.52854549	123.0456849	0.201531026	0.810370349	910973.4246	372.0074472	2671.443636	962.451169	0.774.7037725	462.088115	144.618.826.893.877.00	29.638.056.833.568.60	174.555.893.527.447.00	28.461.875.803.158.20	13.771.65	59.212.89	97.1%
9715	0.048730375	130.5504174	0.151697844	0.787538982	704973.3193	323.2495826	2648.07941	968.6958564	0.645.7894667	421.8391094	151.514.801.007.098.00	2.341.225.281.064.78	183.856.128.318.163.00	24.503.951.595.179.00	12.742.53	59.227.01	97.1%
9716	0.128043008	116.843459	0.121426766	0.87312516	969311.7703	366.5045522	2621.71845	962.4259862	0.618.4246688	419.833628	247.644.506.720.102.00	6.497.980.200.005.43	254.362.496.920.157.00	26.942.605.743.858.00	14.011.25	59.289.96	97.1%
9717	0.40916896	131.5543395	0.15597937	0.766215601	965246.7963	681.0140143	2655.65197	958.7908297	0.697.022887	438.2532942	332.553.545.240.225.00	55.630.297.339.699.70	388.183.752.579.225.00	46.393.325.819.745.90	24.126.41	59.272.66	97.2%
9718	0.196852405	129.821276	0.110190843	0.766562908	1075160.319	392.0560053	2619.020563	930.7210899	0.912.719228	501.1028977	335.655.330.746.357.00	16.081.554.896.297.90	351.736.895.644.655.00	29.710.596.109.107.00	15.450.71	59.366.99	97.2%
9719	0.391805496	135.4812742	0.206579738	0.797.819348	867712.2034	351.8466571	2685.232725	930.831925	0.733.4917666	449.678825	165.898.182.309.766.00	25.825.836.925.192.00	191.724.019.234.958.00	31.573.401.734.250.80	16.419.45	59.417.95	97.2%
9720	0.40007564	122.1907944	0.168157292	0.867896672	1293911.004	271.8446777	2651.082324	935.009716	0.629.0409442	416.394319	169.329.131.859.932.00	23.202.844.192.935.80	192.531.976.052.859.00	28.096.820.996.110.00	14.612.53	59.438.35	97.2%
9721	0.25398352	131.9325804	0.123946915	0.756126552	1431885.044	396.574169	2661.379104	941.0864335	0.626.4281513	415.4783757	340.819.905.525.091.00	29.357.541.296.422.30	370.177.446.821.513.00	34.692.686.077.729.90	18.041.60	59.471.61	97.2%
9722	0.167674023	137.8112114	0.14127042	0.803626289	1748412.715	940.1137431	2654.788526	928.2679386	0.613.3								

Table 49. (continued)

gözetimlik uçgen	sıcaklık uçgen	üretim faktörü		dönüşüm uçgen	yüzey alanı		kalınlık uçgen	kayac d uniform		su d (yöğ) uçgen		derinlik uçgen	kayac sıcaklık	terleme sıcaklığı sabit	kayac öz ısı	su öz ısı	yük faktörü sabit
		min	max		min	max		min	max	min	max						
min	0.0275	100	0.07	0.7	500000	min	250	2600	521.7	min	500						
max	0.7	145	0.24	0.53	2000000	max	1000	2700	898.7	max	1100						
mode	0.05	135	0.18	0.6	9000000	mode	350	2650	930.6	mode	650						
9751	0.164072579	131.4394045	0.205639436	0.81547998	810390.0318	522.410677	2662.807481	939.5989156	0.653.0014996	424.1946277	291.896.517.077.482.00	14.031.099.926.376.60	305.927.617.003.859.00	51.333.481.356.997.90	26.695.49	60.972.30	97.5%
9752	0.113028907	109.3979149	0.19381651	0.81475616	917555.1401	643.0479001	2657.61861	936.5758904	0.636.1944296	418.7000555	442.106.333.003.383.00	13.861.771.173.600.90	462.768.104.176.984.00	73.077.100.182.563.80	38.003.06	61.010.97	97.5%
9753	0.090517765	129.3221112	0.141366134	0.809328394	1154728.177	544.727724	2688.436651	949.5086055	0.715.7847376	444.1189506	504.009.894.220.761.00	6.626.296.975.548.23	510.636.191.196.309.00	58.422.716.208.945.10	30.382.18	61.063.49	97.5%
9754	0.114361588	137.3596675	0.141523578	0.723211787	1346980.717	322.5127344	2657.045299	971.5765586	0.674.8962929	431.2475188	318.782.881.501.222.00	11.573.063.700.595.90	330.355.945.201.818.00	33.812.433.131.442.90	17.583.84	61.093.79	97.5%
9755	0.385779533	133.4514008	0.150796952	0.833434623	1006878.186	601.0869244	2657.521416	931.95883	0.756.5730764	456.5947999	334.888.762.812.801.00	48.616.702.252.585.20	383.505.465.065.386.00	48.198.737.067.034.20	25.065.30	61.125.68	97.5%
9756	0.162890741	134.9646393	0.158501806	0.708410912	646602.2361	322.408011	2627.777532	937.5092414	0.951.264125	511.9818236	216.972.594.490.256.00	8.907.266.510.365.02	225.879.861.000.621.00	25.362.786.741.795.90	13.189.68	61.150.57	97.6%
9757	0.12767878	131.574088	0.185281986	0.818281986	1466260.301	328.5821589	2659.177996	964.0179579	0.954.5766277	356.701.882.240.831.00	27.202.179.580.586.70	383.903.861.831.418.00	58.316.467.055.90	30.326.76	61.171.08	97.6%	
9758	0.122162626	105.683754	0.21242767	0.80703729	1096320.795	610.825294	2605.66635	947.937923	0.693.756368	437.2344735	499.728.794.323.872.00	8.415.328.034.037.67	506.144.122.357.910.00	86.997.887.028.336.80	45.243.43	61.225.94	97.6%
9759	0.201114447	129.1857497	0.187769393	0.722673792	793791.8963	579.8581807	2693.548626	935.5114002	0.752.3161961	455.3111584	329.308.256.453.743.00	17.433.281.452.887.00	346.741.537.906.630.00	47.051.446.376.244.60	24.468.66	61.268.21	97.6%
9760	0.187913296	135.1809235	0.122591074	0.857340988	896789.364	655.5625207	2644.318759	941.7485075	0.594.1982624	404.8493484	344.180.819.357.093.00	22.385.689.850.367.50	366.566.489.207.460.00	36.526.994.904.387.40	20.035.60	61.273.87	97.6%
9761	0.36516774	102.5495439	0.196676237	0.86798064	1452478.336	597.1099263	2603.489439	939.8592576	0.1015.81079	529.0718599	589.638.248.506.236.00	27.586.573.422.534.00	597.222.821.930.770.00	101.952.804.466.026.00	53.019.49	61.284.39	97.6%
9762	0.20419376	134.9627804	0.192961183	0.729578294	1630379.837	417.8744632	2686.377088	942.7372224	0.680.3485531	432.8699666	462.625.250.516.178.00	30.139.397.468.157.30	492.964.847.684.334.00	89.399.705.497.935.90	36.090.66	61.305.09	97.6%
9763	0.155257076	132.1028904	0.175846159	0.835012725	1545873.133	388.0443169	2639.405594	942.8409307	0.841.9874388	420.8629594	380.744.267.281.393.00	26.547.953.187.984.00	407.262.220.469.387.00	60.984.588.043.355.20	31.719.66	61.331.32	97.6%
9764	0.356057539	110.6599276	0.1953789	0.74198233	813611.9169	678.9058749	2623.335579	933.1958987	0.819.5387248	492.8653568	347.421.854.407.733.00	23.418.899.914.017.60	370.840.754.321.750.00	53.759.878.361.095.40	27.957.21	61.378.59	97.6%
9765	0.55194151	136.5095862	0.205645594	0.78328668	16977.707.407	526.8372431	2686.756231	936.698677	0.699.63877	439.0813522	347.966.671.589.675.00	112.245.633.830.982.00	480.212.305.420.658.00	74.130.367.455.056.70	38.550.80	61.392.49	97.6%
9766	0.254966139	116.9161168	0.165121749	0.757774341	1046357.092	710.5777494	2635.319015	978.0212684	0.815.3017194	473.9879131	561.230.960.966.321.00	31.002.915.313.835.70	592.235.278.280.157.00	74.103.453.633.535.10	38.536.80	61.482.05	97.7%
9767	0.183200802	132.3795635	0.234849103	0.863507453	1829830.72	489.6911916	2610.093213	926.7617322	0.716.5519762	444.356909	626.432.159.546.634.00	33.309.959.343.738.60	659.741.118.890.373.00	133.791.507.717.926.00	64.577.01	61.519.29	97.7%
9768	0.067430278	139.9159865	0.125842426	0.893107933	1133764.558	597.9351234	2635.041812	963.3883598	0.616.4518187	464.1032912	575.469.830.945.634.00	11.021.400.609.808.30	586.491.231.454.976.00	65.916.258.991.415.90	39.279.13	61.531.61	97.7%
9769	0.35667559	130.7562384	0.180213509	0.720442304	678718.0461	314.7405561	2643.313762	937.2890548	0.576.2017125	398.1238299	104.167.950.184.878.00	116.108.680.518.468.50	119.276.630.703.345.00	15.486.094.671.996.70	8.053.40	61.560.14	97.7%
9770	0.19560162	133.038959	0.1797625143	0.83315438	83381.5438	876.3161666	2641.714258	965.7525557	0.736.0033126	450.3477244	313.557.800.957.792.00	42.594.178.526.155.60	356.151.979.485.948.00	55.553.904.202.369.40	28.890.29	61.575.95	97.7%
9771	0.190366997	122.735651	0.156164047	0.813619598	1311235.691	813.9279561	2627.285889	934.2989047	0.836.9996586	480.2537206	817.786.809.252.911.00	33.908.532.048.841.10	851.695.341.301.752.00	108.214.816.513.998.00	56.276.10	61.613.02	97.7%
9772	0.24304855	132.7296003	0.191664473	0.774304892	1735005.288	351.5015638	2623.530455	950.8524455	0.904.5104499	504.5144794	318.331.804.782.685.00	61.293.702.400.501.90	379.585.307.183.186.00	56.332.958.994.583.50	29.295.43	61.645.94	97.7%
9773	0.08398005	113.1600723	0.202470888	0.859895729	839678.766	790.639561	2654.896641	935.4803345	0.682.4110409	433.641772	519.312.317.805.740.00	7.222.032.317.420.15	521.134.349.923.160.00	90.318.935.940.414.90	46.969.51	61.780.94	97.7%
9774	0.42589631	130.2571398	0.160615183	0.838486526	712.9780843	412.9780843	2663.88644	959.8016503	0.1071.096878	543.5778862	200.489.171.805.419.00	27.626.200.401.741.10	228.115.918.735.160.00	30.721.207.251.103	15.976.27	61.808.58	97.7%
9775	0.178919191	131.1104443	0.165457919	0.774879503	1757518.967	370.6928022	2603.28863	964.3939646	0.573.2539882	397.451075	402.777.024.580.223.00	22.657.143.483.157.00	425.434.168.063.380.00	54.550.912.200.873.40	28.368.69	61.811.27	97.7%
9776	0.128978086	128.6213087	0.204059963	0.792146898	794958.4802	348.0152305	2668.703154	937.3375835	0.883.3024534	433.924958	205.082.498.551.792.00	6.689.673.105.840.78	211.772.171.657.833.00	34.232.002.483.495.90	17.802.03	61.870.48	97.7%
9777	0.155207518	118.5475765	0.164378573	0.8278518	155445.903	572.3918333	2601.398178	961.9322484	0.527.3782184	381.2135756	533.521.952.358.114.00	21.957.528.889.008.00	555.478.481.047.120.00	84.246.352.391.774.00	43.811.52	62.077.97	97.8%
9778	0.154502928	129.034155	0.099895501	0.763313062	862116.812	971.0882322	2633.261302	948.618008	0.572.4252127	397.1617953	606.096.718.114.899.00	29.647.935.780.837.30	334.744.051.895.717.00	49.683.290.842.045.00	28.837.02	62.104.34	97.8%
9779	0.334341106	136.688811	0.143142175	0.909867236	518781.7842	490.2703527	2649.881109	979.7599216	0.813.3390155	473.4142186	161.190.966.342.462.00	18.144.855.944.772.00	180.335.822.287.234.00	23.466.354.307.390.70	12.203.46	62.112.92	97.8%
9780	0.096930064	114.5989889	0.17863408	0.725304682	1285316.079	363.9730879	2623.378056	945.2918163	0.788.710963	466.194343	383.918.659.772.949.00	6.394.542.794.161.33	390.313.202.567.111.00	50.570.592.407.575.70	26.298.76	62.214.82	97.8%
9781	0.133099943	137.230921	0.183825292	0.747.70553	1446568.681	466.7517497	2623.270439	941.5713373	0.543.9335343	597.665.433.697.238	18.238.256.643.534.00	620.853.730.480.531.00	86.317.898.558.641.30	44.888.81	62.245.40	97.8%	
9782	0.450599111	125.834158	0.155965991	0.781671416	1602827.975	371.0842395	2664.249845	928.1507272	0.656.4088837	425.9463987	288.865.105.185.034.00	48.129.638.919.448.30	316.994.743.378.821.00	38.846.146.862.533.20	20.097.56	62.262.56	97.8%
9783	0.230931339	128.5659165	0.174227536	0.771654413	1618125.233	387.0731952	2660.678119	924.4006128	0.617.658689	425.5434101	389.884.461.200.001.00	47.027.358.076.819.70	47.027.358.076.819.70	56.066.595.630.751.40	29.156.91	62.376.37	97.8%
9784	0.07211307	135.305554	0.203192979	0.74683655	583831.1772	419.6917243	2611.681266	931.0691326	0.894.7025143	496.5321942	222.536.923.956.401.00	3.801.066.102.012.65	226.337.900.058.414.00	35.627.916.845.594.70	18.237.96	62.422.67	97.8%
9785	0.186848103	117.1039936	0.14685226	0.861064246	1020775.808	666.8615731	2623.221538	9									

Table 49. (continued)

gözeneklilik	sıcaklık	üretim faktörü	dönüşüm	yüzey alanı	kalınlık	kayac d	su d (yöğ)	demirlik	kayac sıcaklık	terkime sıcaklığı		kayac öz ısı		su öz ısı	yük faktörü		
üçgen	üçgen	üçgen	üçgen	üçgen	üçgen	uniform	üçgen	üçgen		sabit		sabit		sabit	sabit		
min	0.0275	100	0.07	0.7	50000	250	2600	921.7	500		80		0.9	4.18	0.41		
max	0.7	145	0.24	0.93	200000	1000	2700	986.7	1100								
mode	0.05	135	0.18	mode	900000	350	2650	930.6	850	166	Hk	Hs	Höplam	Höpu*Üret*Dönüşüm	saha rezerv	13835.17	26196.98
9816	0.144470545	130.7369852	0.169029131	0.79126116	152273.612	314.788235	2654.626256	936.9846629	0.794.4060853	467.6744926	390.024.602.635.441.00	13.761.053.619.728.80	393.785.656.255.170.00	52.667.331.027.641.70	27.389.05	64.292.40	98.2%
9817	0.107374511	122.7415423	0.1519972	0.89602345	93823.6824	577.0470632	2699.790908	960.6104379	0.741.5183972	452.0316678	475.523.909.139.328.00	7.149.036.225.702.49	482.672.945.365.031.00	65.883.433.202.926.50	34.262.05	64.392.69	98.2%
9818	0.186796991	119.6879079	0.186518766	0.880356326	1968914.786	374.0055719	2662.91282	939.8199319	421.1297287	373.240.452.535.730.00	8.617.712.570.243.53	381.858.165.105.973.00	62.702.246.808.008.00	32.607.71	64.404.74	98.2%	
9819	0.248526644	136.7910588	0.143661044	0.816800862	1901593.187	550.6775272	2661.05666	954.8879733	0.687.0266487	435.1058071	669.241.645.991.636.00	59.992.471.699.687.40	728.234.117.691.324.00	85.452.796.311.457.90	44.438.92	64.440.50	98.2%
9820	0.575518021	140.2315512	0.120488303	0.784860062	1183727.986	629.0167928	2611.81658	951.1012841	0.840.5466244	481.2702233	298.123.032.307.041.00	102.612.479.229.510.00	400.735.511.536.550.00	37.896.137.426.177.30	19.707.53	64.481.84	98.2%
9821	0.07063316	124.6956604	0.121891316	0.785970596	870353.6168	976.2040138	2683.064722	952.2176622	0.575.9601048	398.3827441	600.874.214.853.757.00	10.567.292.118.036.00	611.441.506.971.793.00	58.577.924.884.411.80	30.462.90	64.505.42	98.2%
9822	0.190704008	130.0051841	0.101537557	0.885573987	1319627.449	362.3148711	2633.428897	0.929.9732897	0.929.9732897	447.875.330.606.363.00	8.871.901.405.070.84	456.747.232.011.434.00	41.070.448.536.050.50	21.358.30	64.659.99	98.2%	
9823	0.241452815	109.064166	0.16530044	0.890523917	590727.829	650.2546679	2679.498399	948.8255775	0.707.8871395	441.6620656	254.129.462.518.272.00	10.691.194.987.268.10	264.820.657.505.540.00	38.962.888.869.365.20	20.772.88	64.705.64	98.2%
9824	0.511778221	120.625624	0.138162122	0.802173171	1067613.601	338.2022569	2689.226071	928.320625	0.604.7287443	408.2144891	212.422.505.769.666.00	45.229.010.289.010.00	262.651.516.058.676.00	29.109.653.740.736.10	15.138.20	64.719.86	98.2%
9825	0.587115761	110.152902	0.109840587	0.827719635	143004.706	488.5165603	2635.26272	934.4675327	0.651.2783744	423.6459455	235.126.717.602.965.00	48.308.122.749.546.30	283.434.840.352.511.00	25.781.649.486.270.10	13.407.50	64.794.02	98.2%
9826	0.126251728	135.7559077	0.179429677	0.980629324	837347.8594	900.2229343	2640.095116	935.8107156	0.681.1325406	511.1432313	681.240.799.054.821.00	19.973.582.042.079.40	681.241.391.096.900.00	111.243.631.520.141.00	57.851.31	64.991.16	98.2%
9827	0.325813629	135.2293866	0.159478749	0.842297249	927276.9577	390.3657314	2617.110876	925.0530034	0.783.2170959	464.5678402	225.099.148.351.999.00	25.743.221.281.087.00	250.841.369.633.096.00	40.244.498.196.929.70	20.928.77	65.008.67	98.3%
9828	0.225182025	116.6773317	0.18928925	0.81688395	714252.7257	649.9082959	2649.32035	928.6722805	0.708.5461034	441.7768892	310.267.200.054.752.00	15.002.572.835.567.00	325.269.862.890.319.00	50.418.736.648.157.00	28.219.79	65.038.48	98.3%
9829	0.058462489	126.8972152	0.085319093	0.810147846	1797928.811	479.0054478	2613.846693	941.4398623	0.400.1529844	439.3248821	681.561.574.634.475.00	9.240.645.737.265.52	690.802.220.371.741.00	47.748.995.149.377.70	24.831.42	65.084.81	98.3%
9830	0.21511712	118.4237433	0.153366132	0.860394273	1378955.457	572.7949669	2638.05888	937.8784691	0.682.0644428	433.5259136	520.196.536.629.299.00	25.445.931.104.345.60	545.632.467.733.645.00	71.998.281.712.845.00	37.442.03	65.096.69	98.3%
9831	0.150821882	112.821682	0.152722658	0.856450029	766051.8775	555.85122	2669.528399	936.1558622	0.937.9736467	508.3975001	372.389.630.979.338.00	8.220.718.911.905.86	380.610.349.891.243.00	49.783.642.130.129.90	25.891.51	65.146.10	98.3%
9832	0.089998997	117.2425426	0.179359516	0.853473491	1227560.695	526.5552564	2648.175972	935.9049126	0.813.6562237	473.5091801	554.304.294.170.138.00	6.830.983.763.194.33	562.935.278.473.332.00	86.173.340.168.231.00	44.813.63	65.233.03	98.3%
9833	0.508281822	112.4575759	0.142294494	0.788878994	949687.6794	587.2008964	2609.913951	946.6401995	0.717.2522124	444.5739822	235.473.265.161.92.00	36.306.336.693.738.00	271.779.601.855.668.00	30.508.109.106.282.20	15.865.46	65.321.74	98.3%
9834	0.10376619	132.8574376	0.190528128	0.802835959	1393872.639	400.8275447	2647.388782	961.2989156	0.857.76285	486.1739719	484.590.087.461.432.00	12.313.388.685.095.60	496.903.476.146.528.00	76.007.763.192.504.20	39.727.12	65.344.89	98.3%
9835	0.11930284	127.260666	0.163554567	0.761371423	757456.063	466.8162916	2656.86748	972.7296857	0.640.42262	420.0891839	253.224.501.648.649.00	8.106.348.764.634.36	261.330.850.413.280.00	32.900.572.037.372.00	19.102.63	65.470.45	98.3%
9836	0.514058865	134.3388737	0.168754828	0.841376662	1411491.121	765.5415502	2630.416865	942.0853132	0.564.0191428	394.2351173	389.443.305.207.568.00	118.048.726.697.798.00	511.492.031.905.354.00	71.764.269.980.786.10	37.320.33	65.477.51	98.4%
9837	0.292839201	125.2688508	0.148231025	0.870549871	1252000.918	480.7824056	2613.77875	945.6718541	0.881.1709482	492.7480229	489.816.067.823.456.00	37.382.171.587.218.40	527.198.239.014.675.00	68.030.968.288.181.40	35.378.87	65.477.70	98.4%
9838	0.25670761	128.7060752	0.216106467	0.824638495	967395.3469	353.9324184	2666.031285	964.852346	0.677.7083881	459.9458313	232.013.235.140.792.00	17.265.683.684.670.70	249.278.918.835.462.00	44.423.924.301.378.50	23.102.24	65.572.05	98.4%
9839	0.08830518	107.1517006	0.154914206	0.893825396	717979.859	353.9069748	2694.592528	934.4268874	0.639.942511	419.938115	191.209.393.597.468.00	2.341.904.552.585.03	26.800.322.749.233.00	13.937.26	65.609.87	98.4%	
9840	0.436381695	129.7951749	0.204292526	0.803425267	1064797.512	534.0539599	2615.704545	974.481942	0.866.7323025	488.7092727	308.377.454.220.633.00	50.333.334.967.800.30	358.710.789.188.433.00	58.876.556.646.356.50	30.618.20	65.763.71	98.4%
9841	0.418257387	109.0579692	0.161778987	0.805823134	1642968.141	338.1153626	2671.437958	953.5367939	0.904.0883733	499.1234141	325.655.201.680.771.00	27.163.939.147.991.20	352.819.140.828.788.00	45.995.379.452.123.30	23.919.46	65.823.79	98.4%
9842	0.563983689	128.1898137	0.163295163	0.819639304	721267.3797	558.194574	2639.31417	933.8183796	0.834.8918714	479.878524	169.911.672.165.065.00	210.898.290.385.107.00	210.898.290.385.107.00	14.959.69	65.914.55	98.4%	
9843	0.274186284	138.5419174	0.165886807	0.744518771	1093313.214	293.9807046	2620.06847	967.7524045	0.695.583113	429.2017594	192.558.679.452.055.00	20.978.685.134.892.10	213.733.344.587.547.00	28.388.876.059.943.50	13.728.49	66.010.89	98.4%
9844	0.576557056	130.8230316	0.168986471	0.777885246	1589728.089	279.856052	2659.981652	975.0126655	0.755.553771	450.2101699	162.862.012.962.931.00	91.981.172.754.546.20	214.843.185.717.478.00	28.249.069.019.888.10	14.890.66	66.165.07	98.4%
9845	0.291142320	102.729855	0.161059796	0.819607919	1234968.294	373.1920316	2650.858322	928.2049285	0.900.2323868	498.0085842	238.503.892.805.983.00	8.674.283.279.334.86	247.178.175.885.387.00	32.628.973.467.277.00	16.968.39	66.178.66	98.4%
9846	0.613716261	120.9843314	0.147704426	0.760745652	1532647.82	611.0073317	2666.190929	949.9534788	0.725.6204968	447.1610038	303.848.047.217.00	94.246.712.410.971.90	398.094.759.628.487.00	44.732.645.977.320.00	23.262.79	66.295.98	98.4%
9847	0.363961063	106.0671064	0.214234619	0.798972757	1467338.49	346.9031003	2683.819508	931.2520806	0.716.1260614	444.2248276	285.098.889.564.340.00	18.767.794.544.908.50	303.867.684.109.249.00	52.012.309.561.357.00	27.048.51	66.363.05	98.5%
9848	0.05428251	122.778959	0.160916719	0.591755229	1585464.094	471.8524902	2614.522111	953.8516946	0.512.042871	403.5687965	539.075.823.963.00	6.689.529.582.327.83	546.424.793.393.320.00	69.969.913.843.988.20	36.387.20	66.440.85	98.5%
9849	0.097828384	129.5474392	0.094503863	0.72970663	1263779.438	384.7193883	2611.984829	928.9339364	0.765.4626225	458.27212	391.084.199.719.093.00	9.258.150.782.161.21	400.342.350.501.254.00	27.607.646.780.725.70	14.357.10	66.611.55	98.5%
9850	0.352894087	113.1575887	0.133458199	0.797353797	1459353.176	387.1910909	2679.904011	953.205008	0.672.2436711	432							

Table 49. (continued)

gözetilenlik uçgen	sıcaklık uçgen	üretim faktörü uçgen	dönüşüm uçgen	üzey alanı uçgen	kalinlık uçgen	kayac d uniform	su d (yöğ) uçgen	derinlik uçgen	kayac sıcaklık	terketme sıcaklığı sabit	kayac öz ısı	su öz ısı	yük faktörü				
min max mode	0.0275 min 0.15 mode	100 min 145 max 135 mode	0.07 min 0.24 max 0.16 mode	0.7 min 0.93 max 0.8 mode	min max mode	250 min 1000 max 350 expect	2600 min 2700 max 2650	92.1 min 96.6 max 93.0 6	500 min 1100 max 650	80	0.9	4.18	0.41				
									166	Hk	Hs	Htoplam	Htop*Üret*Dönüşüm	saha rezerv	13835.17	29110.07	26196.98
9881	0.044307887	121.9372142	0.123068998	0.783958554	1207856.438	741.1723453	2686.504951	945.788167	0.877.9374177	491.858145	851.961.845.857.607.000	6.576.216.448.998.28	858.558.062.306.605	82.834.535.226.480.20	43.077.32	69.589.40	98.8%
9882	0.059701127	124.2828935	0.154547259	0.747345725	1475230.439	171.1719396	2696.711956	956.6400889	0.760.217067	457.6957688	524.797.710.638.008.000	6.429.794.513.527.85	531.227.905.15.536.00	61.356.900.720.794.70	31.008.08	69.576.71	98.8%
9883	0.182835645	142.4589157	0.189219891	0.862752515	1632146.937	677.6523291	2676.7962007	952.1206571	0.551.681302	389.898099	674.898.624.657.081.000	50.240.792.525.206.60	725.139.417.182.288.00	124.638.395.646.319.00	64.871.02	69.629.81	98.8%
9884	0.142574446	134.2836534	0.198887104	0.812791152	1469410.704	516.1977359	2625.550438	956.3064425	0.612.9251078	410.9715838	508.638.582.519.667.000	23.466.235.237.296.10	532.104.817.756.963.00	86.016.701.071.81.00	44.732.18	69.921.00	98.8%
9885	0.146821042	130.0082542	0.214919895	0.74965282	1125382.997	607.0190237	2621.072816	936.991079	0.600.452084	406.7684554	493.674.195.086.507.000	21.586.404.286.582.60	515.260.599.373.089.00	83.016.369.962.935.80	43.171.88	70.005.85	98.8%
9886	0.060580882	127.5329302	0.157601196	0.804579483	1572903.054	460.5568881	2609.888929	959.6608962	0.581.6556451	400.3511328	495.726.024.875.028.000	12.511.574.466.436.50	508.237.599.341.464.00	64.445.894.054.773.90	33.514.48	70.029.74	98.9%
9887	0.478497699	0.193477362	0.779908555	0.78793755	472.9679825	930.3017142	2630.762845	930.3017142	0.572.9625965	397.3481762	146.063.654.965.789.000	28.322.993.969.821.10	174.386.648.935.590.00	26.314.022.501.689.10	13.684.36	70.124.46	98.9%
9888	0.565736828	109.0503562	0.188354416	0.809334263	1124653.917	478.8919024	2673.762884	929.8423086	0.509.9959005	374.8792744	188.689.830.393.721.000	32.057.582.631.938.10	220.747.413.025.659.00	33.651.107.035.281.80	17.499.94	70.125.62	98.9%
9889	0.557914041	121.2008868	0.180384729	0.827505043	680187.149	488.2000992	2681.165158	960.3965204	0.802.8817318	470.3051967	135.430.105.160.080.000	30.015.031.217.576.30	165.445.136.377.657.00	24.695.875.252.063.70	14.824.86	70.231.33	98.9%
9890	0.044514622	135.0741638	0.130786562	0.824123292	901794.6085	643.1807945	2663.990709	967.3102163	0.785.3013915	465.1860997	512.003.154.548.462.000	5.703.321.857.452.51	517.706.476.405.915.00	55.800.805.391.370.20	29.018.58	70.252.33	98.9%
9891	0.350111274	133.8278884	0.214740046	0.812440746	1144501.818	613.3525898	2664.275549	940.4519954	0.662.1365242	427.1514317	379.757.368.077.636.000	52.006.619.414.410.10	431.763.988.942.046.00	84.613.957.318.144.30	44.002.69	70.296.75	98.9%
9892	0.101963038	132.4744904	0.139495521	0.834639759	848194.2651	350.2873613	2637.296941	941.4984162	0.800.089426	483.9941804	255.881.573.553.375.000	6.250.007.504.354.68	262.131.581.057.730.00	30.519.652.425.519.90	15.871.41	70.372.82	98.9%
9893	0.373811684	123.5690062	0.145012233	0.830639891	105918.109	839.7705452	2601.1987799	945.8194036	0.615.9959992	412.0006838	428.087.795.778.090.000	56.573.718.540.928.90	484.861.516.319.028.00	58.378.696.153.304.00	30.359.29	70.497.45	98.9%
9894	0.103559556	124.8829881	0.169487889	0.86271593	825320.6243	680.6431220	2943.901359	928.8269373	0.861.7257829	497.2579579	474.050.708.347.280.000	9.802.843.753.882.91	453.853.352.101.163.00	85.193.649.855.689.70	44.304.16	70.664.36	98.9%
9895	0.540329433	134.4135714	0.211986056	0.786969696	824078.7584	691.2804377	2600.09084	968.9604236	0.784.9482978	468.0335478	237.769.324.155.057.000	65.597.381.544.412.50	303.368.885.699.489.00	50.610.349.616.836.60	26.319.44	70.684.36	98.9%
9896	0.228374973	136.7021016	0.137397691	0.858461883	829074.0954	515.7089268	2661.877096	928.8601192	0.702.7491817	440.0563197	319.708.525.823.478.000	23.873.498.909.875.80	343.582.022.733.353.00	40.525.733.377.382.80	21.073.04	70.684.99	98.9%
9897	0.536030688	114.8156552	0.166719305	0.795487032	1243559.756	268.0032168	2657.819316	960.1699797	0.768.2357443	432.3131388	130.312.217.506.591.000	24.961.657.541.398.20	155.273.929.407.890.00	20.592.901.314.708.20	10.709.14	70.760.04	99.0%
9898	0.043909056	109.5927169	0.125071894	0.789589791	1020470.949	872.0910771	2639.413045	946.8833941	0.965.3178025	523.7061393	1.057.887.441.974.080.000	5.291.407.573.456.31	1.062.978.849.547.530.00	104.974.489.646.893.00	54.591.00	70.845.08	99.0%
9899	0.068297463	127.9862517	0.184669465	0.827609781	1682576.71	638.9033757	2667.299985	931.9964662	0.846.2536865	482.901811	971.798.088.085.804.000	13.768.854.547.035.000	995.566.942.633.830.00	150.628.390.21.288.00	79.322.88	70.968.80	99.0%
9900	0.026095144	126.9349853	0.179379293	0.79980577	869858.0532	284.2953033	2695.82328	964.9229691	0.813.036165	473.3288963	221.308.582.972.850.000	2.851.636.211.554.94	224.229.890.184.405.00	32.169.946.681.208.00	17.628.67	71.016.07	99.0%
9901	0.358952745	134.9540738	0.136371825	0.813915598	1077415.54	816.2589766	2601.06653	933.9663323	0.802.9859704	470.3942883	533.950.467.648.480.000	71.121.885.948.759.80	609.072.353.597.240.00	75.910.111.530.398.20	39.476.34	71.186.71	99.0%
9902	0.195160272	135.2704201	0.116150473	0.817178616	789166.5115	852.0696008	2665.863626	935.1195481	0.1013.217465	528.3967467	465.089.913.127.809.000	11.643.475.061.112.30	476.733.388.188.921.00	48.273.262.364.553.90	25.104.06	71.233.99	99.0%
9903	0.443035518	118.7175641	0.095815752	0.790920699	733854.2268	477.1090189	2674.078279	952.4223899	0.881.3774495	492.820456	193.746.142.655.034.000	23.847.068.840.790.70	217.693.211.495.825.00	16.497.370.283.807.00	8.579.30	71.284.26	99.0%
9904	0.216850452	120.6588245	0.152355679	0.81407785	1066243.581	719.4402478	2648.158306	935.365458	0.806.842065	471.5252454	560.725.082.419.048.000	26.319.740.248.966.200	587.044.822.668.014.00	72.810.807.452.764.50	37.648.58	71.317.31	99.0%
9905	0.181107066	125.4890005	0.098286004	0.740570817	1103900.447	493.1334123	2622.057445	929.9519049	0.652.4396077	424.0121791	363.692.502.246.890.000	17.519.723.698.426.400	381.212.225.945.310.00	27.747.571.267.951.00	14.929.86	71.597.81	99.0%
9906	0.208996922	114.5848703	0.147971744	0.898989245	1067359.134	773.8381273	2678.981374	939.9180299	0.939.9180299	508.9245666	685.544.265.236.690.000	29.709.255.931.227.40	895.253.21.168.036.00	119.039.308.639.141.00	61.905.27	71.601.83	99.0%
9907	0.178854683	139.2211196	0.200068388	0.877382384	1359827.444	449.2608282	2623.217254	945.1128604	0.822.517033	476.0806791	470.239.313.076.261.000	25.277.548.912.588.90	495.516.679.988.849.00	86.281.298.111.756.70	45.233.81	71.624.19	99.1%
9908	0.219330016	123.8914376	0.136823237	0.801271178	1689710.955	637.4959238	2688.420953	958.854217	0.680.8505842	433.1485979	718.120.058.541.125.000	41.537.801.911.314.30	759.667.980.452.439.00	83.283.784.572.22.00	43.310.69	71.786.77	99.1%
9909	0.219093328	136.977197	0.124577919	0.851165558	1650291.84	384.2462215	2633.357203	930.4881024	0.688.9300457	429.3371209	459.189.427.149.548.000	34.648.274.724.959.000	483.837.701.874.570.00	51.044.347.864.394.00	26.545.13	71.848.59	99.1%
9910	0.33570079	133.5015147	0.151734195	0.794263396	1495518.368	396.9494136	2871.337396	957.5594235	0.897.1502893	498.639107	397.592.295.387.413.000	42.865.585.945.033.000	430.277.832.212.446.000	51.855.757.778.217.20	26.897.16	72.058.99	99.1%
9911	0.184026246	128.1442985	0.145086771	0.814632377	1145086.513	550.0621186	2632.811052	960.8995847	0.723.755398	446.5910743	446.426.715.016.267.000	22.180.181.888.741.40	468.668.997.007.005.00	57.570.913.664.165.70	29.839.16	72.071.99	99.1%
9912	0.103015459	132.1967269	0.169015553	0.798025391	1642717.423	765.8614986	2603.560489	938.7623552	0.854.978321	485.3825998	1.071.667.103.181.850.000	26.538.574.063.075.90	1.098.205.677.072.230.00	95.541.893.733.117.70	49.685.71	72.142.93	99.1%
9913	0.207312313	135.8276528	0.092405047	0.897384929	1063406.309	341.5808727	2661.801675	939.9887006	0.591.5798566	403.7520196	223.127.009.159.267.000	16.405.664.365.101.00	239.533.226.246.899.00	19.871.008.608.840.90	13.034.04	72.284.48	99.1%
9914	0.421852065	134.1231432	0.108674419	0.770278615	551499.0639	397.4088403	2630.190854	933.3038347	0.632.991174	417.6464433	1.01.376.346.947.502.000	19.525.152.891.649.90	120.901.499.639.151.00	10.100.587.601.641.80	5.263.12	72.297.38	99.1%
9915	0.295756967	138.5548719	0.156115129	0.759154663	1144022.224	385.6007249	2621.26071	946.8762221	0.733.617214	449.6338904	271.293.876.747.640.000	30.891.638.887.835.70	302.185.403.635.285.00	35.841.548.189.861.90	18.639.06	72.360.29	99.1%
9916	0.215507735	121.154905	0.183696881	0.791762359	1007.107.199	515.3535441	2686.893282	956.7790883	0.767.315414	458.8324472	371.393.609.551.585.000	14.284.035.650.655.20	385.677.645.202.220.00	56.174.031.336.420.50	29.212.78	72.764.68	99.2%
9917	0.565918352	121.5050793	0.186112949	0.796015519	1275437.352	753.9600895	2687.238029	927.1359956	0.700.9183718	439.4827092							

Table 49. (continued)

gözetileklik uçgen	sıcaklık uçgen	üretim faktörü uçgen	dönüştürüm uçgen	yüzey alanı		kalınlık uçgen	kayac d uniform	su d (yoğ) uçgen	derinlik uçgen	kayac sıcaklık	terketme sıcaklığı sabit	kayac öz ısı sabit	su öz ısı	yük faktörü sabit																							
				min	max										min	max	min	max	min	max	min	max	min	max													
min	0.0275	min	100	min	0.07	min	500000	min	250	min	2600	min	921.7	min	996.7	min	1100	min	166	min	80	min	0.9	min	4.18	min	0.41										
max	0.15	max	145	max	0.24	max	2000000	max	1000	max	2700	max	996.7	max	1100	max	166	max	166	max	Hk	max	Hs	max	Htop	max	Uret	max	Dönüştürüm	max	saha rezerv	max	13635.17	max	29410.07	max	26196.98
mode	0.05	mode	135	mode	0.18	mode	900000	mode	350	mode	2650	mode	930.6	mode	650	mode	166	mode	166	mode	Hk	mode	Hs	mode	Htop	mode	Uret	mode	Dönüştürüm	mode	saha rezerv	mode	13635.17	mode	29410.07	mode	26196.98
9946	0.067674815	114.6151498	0.168764739	0.783165004	1552507.311	294.1865795	2626.125799	947.4462019	0.755.7894272	456.3609986	370.654.083.416.509.000	5.469.444.812.863.35	376.143.528.229.372.00	49.715.129.855.127.80	25.853.89	77.296.20	99.5%																				
9947	0.114555987	126.5879956	0.175813335	0.749528736	1017000.594	650.3579313	2626.077771	945.7909875	0.692.1405484	427.1527239	490.441.392.895.289.00	14.441.635.304.854.70	504.883.017.999.944.00	68.531.985.896.408.60	34.599.27	77.393.30	99.5%																				
9948	0.162871106	124.5369337	0.153800861	0.840778388	938600.2777	703.4283374	2646.4126689	977.3640494	0.962.3483211	514.9603404	559.468.671.486.087.00	21.944.403.170.753.70	581.413.074.636.841.00	75.183.762.849.556.20	39.088.61	77.507.55	99.5%																				
9949	0.131235391	106.8560173	0.215590396	0.883793807	1675364.7033	327.3138551	2642.173891	937.5439431	0.670.6840122	429.8028395	396.394.099.706.740.00	8.136.212.445.836.85	404.532.312.162.576.00	77.074.989.826.693.80	40.082.11	77.595.72	99.5%																				
9950	0.258386993	140.2008481	0.166897741	0.770250285	1094595.466	534.9065734	2648.073974	937.3155639	0.636.3632148	418.7555939	340.956.509.258.355.00	34.705.263.955.879.60	375.661.793.114.235.00	48.234.591.988.734.70	25.083.95	77.749.48	99.5%																				
9951	0.124998589	118.6378102	0.185157049	0.794862087	721928.8496	319.8488544	2623.774094	967.4119509	0.771.6211456	461.1159538	181.833.558.685.880.00	4.509.688.980.794.15	186.343.225.666.674.00	27.424.937.213.403.70	14.262.08	77.770.13	99.5%																				
9952	0.127042118	140.9218896	0.20560214	0.840495442	1198728.167	315.7089575	2631.962985	952.577475	0.969.9145139	516.9812796	341.892.963.811.612.00	11.682.898.985.943.40	353.555.262.807.555.00	61.097.058.268.441.90	31.772.95	77.794.00	99.5%																				
9953	0.264035953	133.3548729	0.197324784	0.814485337	1718762.8459	306.9613165	2645.339904	930.1082958	0.789.7544192	466.5028557	149.417.801.456.618.00	12.084.154.420.059.90	161.501.955.876.677.00	25.955.657.037.342.00	13.496.00	78.415.16	99.5%																				
9954	0.088530899	135.188208	0.185134007	0.799630396	961862.2347	335.8088243	2639.43475	967.7535557	0.1026.34909	531.8089461	315.974.916.044.884.00	6.383.877.254.863.75	322.356.793.303.758.00	47.721.602.168.528.20	24.617.17	79.105.42	99.5%																				
9955	0.088234675	118.8044269	0.152620598	0.780936465	1335157.979	444.7711751	2649.456841	939.6120386	0.884.5994346	493.7180011	534.082.690.070.172.00	7.994.782.094.561.62	542.077.472.164.733.00	64.608.582.500.391.80	33.599.09	79.106.83	99.5%																				
9956	0.20232044	135.773736	0.142750182	0.840638402	743124.1629	653.1147319	2667.269543	937.371465	0.709.7046771	442.2286974	337.526.684.349.044.00	21.237.250.514.964.90	358.763.934.864.009.00	43.052.133.110.527.50	22.368.86	79.122.95	99.6%																				
9957	0.201385669	120.8787609	0.187429839	0.788488717	1431619.465	335.7381514	2605.700913	954.8847418	0.758.72296	457.2457751	339.591.528.828.586.00	15.793.624.545.014.30	356.385.153.373.600.00	52.521.081.510.452.00	27.130.08	79.489.53	99.6%																				
9958	0.63629589	127.30729	0.10121401	0.816233.718	445.0772162	2643.12348	2643.12348	944.7079191	0.727.471839	447.7316033	164.872.931.906.699.00	61.450.585.937.711.90	226.323.517.843.781.00	18.541.616.775.591.00	9.642.39	79.734.62	99.6%																				
9959	0.286090969	134.4197823	0.17237262	0.736.128479	1374045.487	695.2116192	2626.011589	930.374889	0.553.4743714	390.5321981	500.846.630.021.454.00	57.963.011.230.082.00	558.829.641.251.537.00	70.910.905.428.166.90	36.876.55	80.012.75	99.6%																				
9960	0.312031667	124.0992452	0.154253914	0.821387592	1627099.026	660.5508741	2697.765526	960.9444682	0.1040.548905	635.4751688	106.825.010.808.848.00	58.975.418.517.042.80	875.498.429.325.891.00	109.732.594.115.873.00	57.065.40	80.463.54	99.6%																				
9961	0.046851709	126.3631628	0.169449717	0.800414218	916488.5609	817.5071657	2669.440183	932.942865	0.907.3479568	500.0288201	720.795.063.128.064.00	6.316.575.435.818.88	727.111.938.564.683.00	98.618.164.836.372.90	51.265.45	80.468.32	99.6%																				
9962	0.128452922	127.819647	0.200467917	0.815484692	1180979.559	504.6274863	2649.471661	937.1585385	0.658.0404424	425.8281629	446.037.262.088.028.00	12.134.276.009.850.30	458.171.338.097.879.00	74.901.171.195.068.80	38.951.65	80.475.41	99.6%																				
9963	0.12746462	120.182546	0.147618357	0.837343962	1443775.924	534.7064739	2606.897073	934.878505	0.676.7885147	431.8510067	565.420.591.598.398.00	15.712.008.489.416.00	581.132.600.088.815.00	71.832.254.683.516.20	37.355.69	80.721.27	99.6%																				
9964	0.303505584	131.8598214	0.18920189	0.745100343	893683.7516	395.4458451	2617.982272	946.6684362	0.757.0289955	456.7350436	218.490.899.815.417.00	22.011.173.743.878.30	240.502.783.559.259.00	33.904.633.843.159.90	17.631.79	81.123.89	99.6%																				
9965	0.146628896	136.5132995	0.181240652	0.762863932	1144617.877	421.6000588	2640.62827	938.887819	0.628.1896988	416.0578326	328.899.641.404.554.00	15.693.537.071.838.30	344.592.578.476.492.00	47.644.044.134.196.70	24.776.84	81.279.00	99.6%																				
9966	0.131677679	115.6029041	0.180794406	0.763659754	811177.074	285.491882	2642.865344	926.8168732	0.664.3922977	427.8784191	166.393.145.822.986.00	4.214.245.314.006.56	170.607.391.736.982.00	23.554.979.731.633.10	12.249.55	81.869.90	99.6%																				
9967	0.289055774	139.0771703	0.127637438	0.712708792	1459134.841	344.4686796	2657.050277	947.8797899	0.734.8192126	449.9853133	316.605.099.123.426.00	33.711.187.060.221.30	350.316.286.183.647.00	31.867.685.503.841.40	16.572.49	81.921.78	99.7%																				
9968	0.128452922	131.2677293	0.165116134	0.764569778	912906.1831	355.044745	2649.991661	949.8514462	0.755.9911601	456.4128707	238.419.265.939.117.00	11.403.556.865.216.50	249.822.822.804.334.00	31.538.334.041.131.60	16.401.21	82.533.95	99.7%																				
9969	0.415517539	113.1082998	0.222345434	0.869500245	650483.649	574.8618012	2603.620995	936.3071969	0.835.0239468	479.8666311	210.986.446.285.966.00	20.134.174.894.093.20	231.120.621.180.060.00	44.682.413.199.008.20	23.236.67	82.940.86	99.7%																				
9970	0.430213667	113.9796716	0.102796965	0.824308235	935509.6606	748.9305478	2685.535682	962.8876703	0.962.7331977	515.0639407	407.281.209.304.684.00	41.223.523.479.019.00	448.504.732.783.703.00	38.004.674.965.431.20	19.763.97	83.037.94	99.7%																				
9971	0.358793229	123.4177449	0.094104066	0.777758706	1426805.159	829.6788605	2653.301386	932.1280502	0.872.2088852	517.5918559	793.067.856.741.701.00	71.841.836.967.861.20	864.909.493.709.562.00	63.302.947.428.256.20	32.920.10	83.112.30	99.7%																				
9972	0.366529888	118.4020407	0.090744393	0.797771564	1032128.851	714.0914623	2688.418908	939.7241003	0.742.5391197	452.3428786	400.706.957.883.210.00	44.085.252.569.781.90	444.792.210.432.982.00	32.199.974.122.902.80	16.745.29	83.300.00	99.7%																				
9973	0.34723684	141.9314715	0.15791036	0.781814924	875267.3248	440.7404772	2683.160036	936.9859286	0.591.6257241	403.7677359	196.880.155.611.821.00	32.491.532.645.203.00	229.371.898.257.023.00	28.317.466.204.227.20	14.726.23	83.671.52	99.7%																				
9974	0.193210494	132.4330576	0.110804877	0.794693982	1489966.202	281.9451932	2661.366483	967.5993558	0.679.3157215	432.6571856	286.113.843.802.214.00	17.202.297.220.365.60	303.315.141.032.579.00	26.708.792.764.592.40	13.869.66	83.808.29	99.7%																				
9975	0.078264033	125.2032461	0.167300909	0.806970178	1061124.611	355.0132705	2683.97246	962.7771002	0.879.3222857	492.2459233	345.775.679.324.771.00	5.363.101.716.529.21	351.138.791.041.301.00	47.406.139.597.709.90	24.653.12	83.855.01	99.7%																				
9976	0.20227698	126.7580703	0.201939767	0.800381251	1335327.028	396.3270445	2646.483447	960.830011	0.686.5306929	434.948073	354.380.989.951.186.00	19.855.551.981.558.90	374.336.530.942.743.00	68.551.797.342.969.60	34.609.64	84.373.14	99.8%																				
9977	0.264170089	135.0758339	0.127681839	0.802726724	1127288.568	572.5620897	2617.852336	951.4850936	0.756.895411	441.7501542	349.989.382.209.352.00	51.488.089.369.740.50	401.479.471.579.083.00	45.245.161.988.835.40	23.528.32	84.801.51	99.8%																				
9978	0.1890711	133.4169839	0.196547002	0.809449025	1730986.105	579.0812432	2680.118371	967.7099488	0.673.7099488	430.8673657	679.950.852.000.407.00	41.183.435.329.776.10	721.134.7																								