FINANCIAL EVALUATION OF KIZILDERE GEOTHERMAL POWER PLANT

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ABSTRACT

FINANCIAL EVALUATION OF KIZILDERE GEOTHERMAL POWER PLANT

A capacity increase is of concern in the Kızıldere Geothermal Power Plant-the first geothermal plant in Turkey. In this study, the feasibility of possible future investments in Kızıldere has been analyzed financially using methods such as internal rate of return, net present value, payback and benefit-cost. Two scenarios with different financial structures have been formed and both scenarios have been applied to 20MW, 40 MW, and 60 MW power plants. The choice among different alternatives has been made according to the unit energy cost, which is a significant parameter in power plants.

The first scenario represents a government project which establishes the project finance on a debt ratio of 75%. The debt term has been taken as 12 years and the debt interest rate as 7%. In this scenario, unit energy cost has been estimated as 4,33 cent/kWh for 20 MW, 4,10 cent/kWh for 40 MW and finally 3,88 cent/kwh for 60 MW. The second scenario represents a private project with a debt ratio of 50%, where the debt term is 8 years and the debt interest rate is taken as 5%. As for the unit energy cost for this particular scenario, it has been estimated as 3.8 cent/ kWh, 3.59 cent/kWh and 3.40 cent/kWh for 20 MW, 40 MW and 60 MW respectively. Kızıldere geothermal Plant has been financially evaluated in this study and it has been concluded that although both scenarios are feasible, the best alternative is 60MW private project.

ÖZET

KIZILDERE JEOTERMAL SANTRALİNİN FİNANSAL DEĞERLENDİRMESİ

Türkiye'nin ilk jeotermal santrali olan Kızıldere Jeotermal Güç Santralinde kapasite artırımı sözkonusudur. Bu çalışmada, Kızıldere'ye yapılacak yatırımların fizibilitesi, finansman açısından analiz edilmiş ve yatırım değerlendirmede sıklıkla kullanılan finansal araçlardan internel rate of return, net present value, payback ve benefit-cost metodları kullanılmıştır. Farklı finansman yapılarında iki senaryo oluşturulmuş ve her iki senaryo 20MW, 40MW ve 60 MW santral güçleri için uygulanmıştır. Alternatifler arasındaki seçim, güç santrallerinde önemli bir kriter olan birim enerji maliyeti esas alınarak yapılmıştır.

Devlet projesi olarak tasarlanan ilk senaryoda, 75% yabancı kaynak kullanılmıştır. On iki yıl vadeli, 7% faizle, kredi alınan bu senaryoda enerji birim maliyetleri; 20 MW için 4,33 cent/kWh, 40 MW için 4,10 cent/kWh ve 60 MW için 3.88 cent/kWh hesaplanmıştır. Özel sektör projesi olarak planlanan ikinci senaryoda borç oranı 50% kabul edilmiş ve % faizle sekiz yıllık kredi kullanılarak birim enerji maliyetleri 20 MW, 40MW ve 60 MW güçler için sırasıyla 3.8cent/kWh, 3.59cent/kWh ve 3.40 cent/kWh bulunmuştur. Kızıldere jeotermal santralini finansal açıdan değerlendiren bu çalışma, her iki senaryonunda fizibil olduğunu ancak en iyi alternatifin 60 MW özel sektör projesi olduğunu göstermektedir.

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BCR:	Benefit-cost ratio
Cd: Ck:	Capital cost ($/kWh)
Cf:	Fuel cost ($/kWh)
Cm: Co:	Operating and Maintenance Cost (cent/kWh)
E :	Annual Energy Production(kWh)
EÜAŞ:	Electricity Generation Co. Inc.
EPDK:	Republic of Turkey Energy Market Regulatory Authority
g:	Unıt Energy Cost (cent/kWh)
I:	Interest Rate (%)
IRR:	Internal Rate of Return (%)
n:	The life of span
NPV:	Net Present Value($)
O&M:	Operation and Maintenance
P:	Plant (kW)
PBP:	Pay Back Period (year)
r:	Discount Rate
TEAS:	Turkish Electricity Generation and Transmission Co.
TEDAS:	Turkish Electricity Distribution Co.
TEİAS:	Turkish Electricity Transmission Co.
TEK:	Turkish Electricity Authority

CHAPTER 1

INTRODUCTION

Energy is the most essential indicator of economic and social development. The need for energy is gradually increasing due to the increasing world population, technological developments and the new demands that modern technology brings. As a result of globalization, energy has become more and more significant for sustainable development and consequently it has become crucial to find new energy sources and to use the existing ones more efficiently.

World energy consumption has reached 11.3 billion tonnes of oil equivalent in 2008 with 1.4% increase prior to 2007 (BP 2009). The global energy requirements was primarily provided by the combustion of fossil fuels. In 2008, the global share of energy from fossil fuels was 87% of the total primary energy consumption. This primary energy consumption consists of 34.7% oil (3927.9 million tons of oil equivalent (mtoe)), 24.1% natural gas (2726.1 mtoe), 29.2% coal (3303.7 mtoe), 5.4% nuclear (619.7mtoe) and 6.3% hydroelectricity (717.5 mtoe).

According to the 2009 International Energy Outlook by the Energy Information Administration,

> Renewables are the fastest growing source of world energy with consumption increasing by 3.0 percent per year. The increased attention on renewable energy sources can be attributed to a number of factors. The recent concerns over the volatility of oil prices, the dependency on foreign energy sources, and the environmental consequences of carbon emissions are all contributing factors to the current interest in renewable energy sources. Moreover, the emergence of government policies such as renewable energy production tax credits, installation rebates for renewable energy systems, renewable energy portfolio standards, and the establishment of markets for renewable energy certificates have been critical in the promotion of renewable energy as a viable component of the energy portfolio for various countries (Apergis, et al. 2009).

In Turkey, which has almost all sorts of conventional energy resources, only half of the total consumed primary energy is obtained from natural resources and the rest is imported. Turkey's primary energy sources include hydropower, geothermal, lignite, hard coal, oil, natural gas, wood, animal and plant wastes, solar and wind energy. In 2008, total installed capacity were 41.8 GW. The distribution of the produced electricity energy according to primary energy sources was as follows: natural gas 32%, coal 24%, hydropower 33%, geothermal 0.07% and wind 0.87%. Figure 1.1. gives this distribution (EPDK 2008).

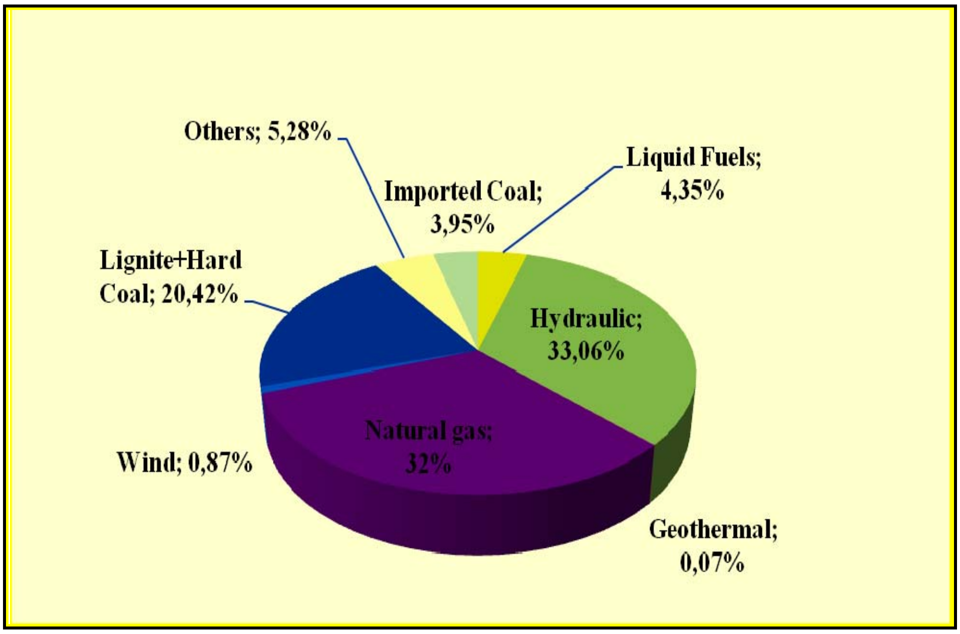


Figure 1.1. Distrubution of energy consumption in Turkey
(Source: EPDK 2008)

In Turkey, yearly energy demand increased by 1.2 % in 2008, reaching 102.6 million tonnes of oil equivalent. Projections indicate that Turkey's energy demand will reach to 126 million tonnes of equivalent oil in 2010 and up to 222 million tonnes of equivalent oil in 2020. Turkey is dependent on oil and natural gas and imported 58 million tonnes of oil equivalent natural gas and oil in 2007 resulting total dependency on imported energy sources to 72% (EÜAŞ 2008).

The geological research starting in 1960s accelerated between 1970 and 1980 with the discovery of new potential geothermal increased in 1990s with the increasing interest of municipalities and private enterprises. Since the first power production which started Kızıldere, in 1984, the demand for geothermal energy has increased and the macro reasons for this increase are as follows (Şener, et al. 2007):

1)The dependence of natural gas combined plants on natural gas, which were heavily invested in 1990s, has significantly increased. As a result, the dramatically increased prices of natural gas have increased electricity production costs.

2)This long term trend, seasonal fluctuations in natural gas prices have increased electricity cost prices especially in summer times and this reduced the popularity of electricity production based on natural gas as in 1990s and it also proved that natural gas on its own was not sufficient enough to produce baseload.

3)Law numbered 5346 regarding renewable energy sources was enacted in order to encourage investments in renewable sources. According to this law' each juridical individual with a licence of retail sale should buy an amount of electricity energy with YEK, and this amount is estimated so that what they sell in the previous calander year is proportional to what is totally sold in a year throughout the whole country. Energy purchase should last ten years and it is applied to the ones operating before 2012. As the law suggests, the price of electricity for each year is the average wholesale price of the previous year determined by EPDK. (The price for 2010 is 13.32 Ykr/kWh, which is the average wholesale price for 2009). However, this price cannot be lower than the Turkish Lira equivalent of 5 €/kWh and higher than 5.5 €/kWh. The producers of nenewable sources might benefit from free markets where they can sell over 5.5 E/kWh limit. Minimum price policy has seriously prevented cash flow uncertanities which stood as an obstacle in front of investments and enabled investors predict their future while planning their project financing. Minimum price serve as a protective shield against fluctuations in energy markets (Şener, et al. 2007).

4)Deregulation of energy markets in our country paved the way for independent power producers to invest in small scale power generation projects. Consequently, in addition to the big scale (600MW-2000MW) investors who take little risks, middle and small scale investors have become elecricity producers ready to take more risks and they have invested in recources in which no investments were made befores.

The reactions to worldwide increasing greenhouse emisssion have made geothermal energy more attractive as well as other renewable sources. In spite of its high investment cost, its operating and maitanence costs are low. Producing energy non-stop apart from their maintanance periods and unless are another advantages of geothermal energy. Besides, they are not effected by changes in fuel prices as in natural gas plants. The economics of geothermal energy are therefore more sensitive to discount rate and plant capital cost than, for example, are those of fosil or nuclear fuelled generation (Snodin 2001).

The present study focuses on the economics of geothermal power plant tecnology. The main parameters governing geothermal power plant economics are: (i) investment costs, including auxiliary costs for foundation, grid-connection, and so forth; (ii) operating and maintanence costs; (iii) electricity production; and (iv) discount rate.

In the second chapter in this thesis, geothermal status in the world and historical development of electricity market in Turkey is presented. Third chapter, a literature survey including the review on the geothermal power plant costs is explained. Fourth chapter consists of the methodology. Kızıldere geothermal field and its power plant are introduced in chapter five. The results of the analysis and scenarios related with cost power plant are given in chapter six. Finally, in the last chapter presented as conclusion part includes important findings from this thesis.

CHAPTER 2

GEOTHERMAL ENERGY STATUS

According to Wiesa et al. (2009);

The world geothermal power market has shown steady growth over the last two decades. Between 2005 and 2008 global installed capacity increased by more than 1.2 GW, with around 400 MW added in 2008 alone. By the end of 2008 the global cumulative installed capacity exceeded 10 GW. Fig.2.1 show cumulative installed capacity in the world. The US is the most dominant player in the global geothermal market with an installed capacity of more than 3 GW. Around 120 projects are under development, some of them – in the magnitude of 100s of MWs – currently under construction. The Philippines was ranked as the world's second largest generator of geothermal energy, with an installed capacity of 2 GW, followed by Mexico (1 GW), and Indonesia (0.8 MW).

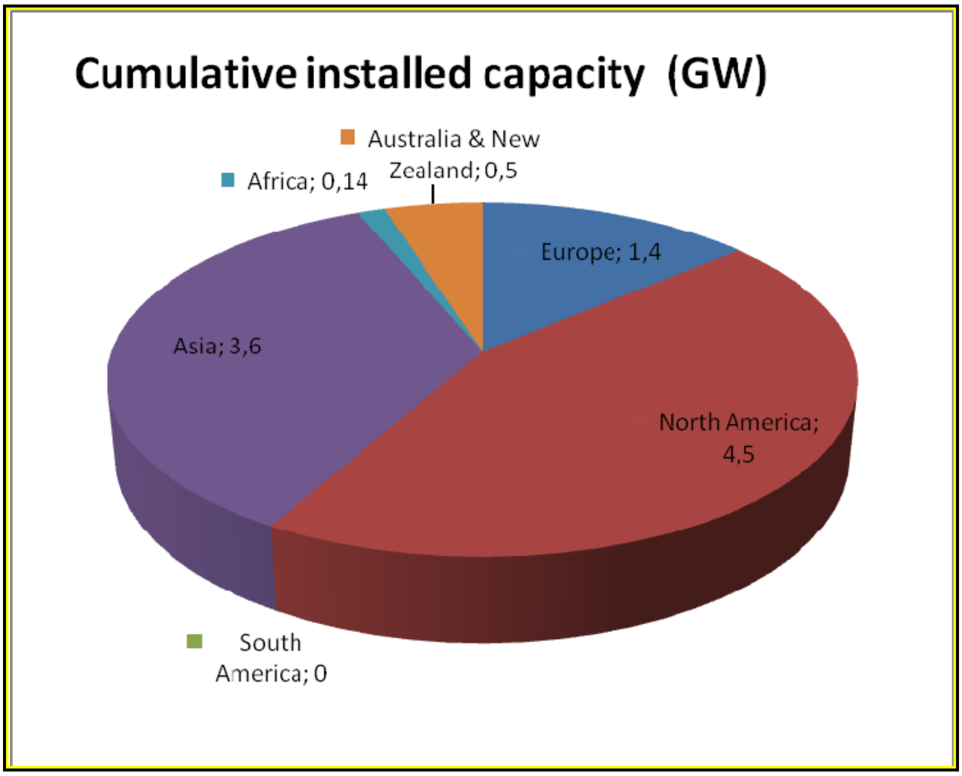


Figure 2.1.Cumulative installed capacity in the world.
(Source: Wiesa, et al.2009)

2.1. Historical Outline of Geothermal Energy in the World

People have used geothermal resources in many ways, including heating, cooking, physical therapy, and other applications. "*Electricity generation from geothermal steam is a much more recent industry, dating back to the beginning of the last century. In fact, commercial generation of electricity from geothermal steam began in Larderello, Tuscany, Italy, in 1913, with an installed capacity of 250 kW*" (Barbier 2002). The evolution in time of the world-wide geothermal installed electrical capacity is presented in Figure 2.2.

As of 2007, approximately 9800 megawatts (MW_e) of geothermal electrical generating capacity was present in more than 20 countries, led by the United States, Philippines, Mexico, Indonesia, and Italy. This represents 0.77% of worldwide installed generation electrical capacity. Table 2.1 shows installed geothermal generating capacities worldwide.

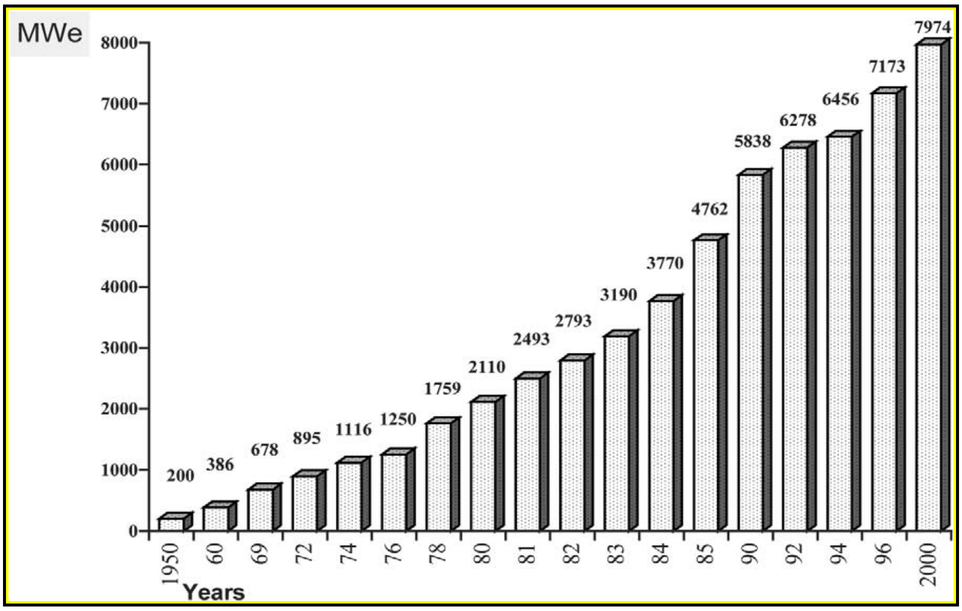


Figure 2.2. Evolution of world-wide electrical geothermal installed capacity.
(Source: Barbier 2002)

Table 2.1. Installed geothermal generating capacities worldwide
(Source : Geothermal Energy Association 2009)

COUNTRY	Installed Capacity in 2000 (MW)	Installed Capacity in 2005 (MW)	Installed Capacity in 2007 (MW)	Running Capacity in 2007 (MW)	Increment		Forecasting for 2010 (MW)
					(MW)	(%)	
AUSTRALIA	0.2	0.2	0.2	0.1			0.2
AUSTRIA	0.0	1.1	1.1	0.7			1.0
CHINA	29.2	27.8	27.8	18.9			28.0
COSTA RICA	142.5	163.0	162.5	162.5			197.0
El SALVADOR	161.0	151.0	204.2	189.0	53.0	35%	204.0
ETHIOPIA	7.3	7.3	7.3	7.3			7.0
FRANCE	4.2	14.7	14.7	14.7			35.0
GERMANY	0.0	0.2	8.4	8.4	8.0		8.0
GUATEMALA	33.4	33.0	53.0	49.0	20.0	61%	53.0
ICELAND	170.0	202.0	421.2	420.9	219.0	109%	580.0
INDONESIA	589.5	797.0	992.0	991.8	195.0	24%	1192.0
ITALY	785.0	791.0	810.5	711.0	20.0	2%	910.0
JAPAN	546.9	535.0	535.2	530.2			535.0
KENYA	45.0	129.0	128.8	128.8			164.0
MEXICO	755.0	953.0	953.0	953.0			1178.0
NEW ZEALAND	437.0	435.0	471.6	373.1	37.0	8%	590.0
NICARAGUA	70.0	77.0	87.4	52.5	10.0	14%	143.0
PAPUA NEW GUINEA	0.0	6.0	56.0	56.0	50.0	833%	56.0
PHILIPPINES	1909.0	1930.0	1969.7	1855.6	40.0	2%	1991.0
PORTUGAL	16.0	16.0	23.0	23.0	7.0	44%	35.0
RUSSIA	23.0	79.0	79.0	79.0			185.0
THAILAND	0.3	0.3	0.3	0.3			0.3
TURKEY	20.4	20.0	38.0	29.5	18.0	90%	83.0
USA	2228.0	2564.0	2687.0	1935.0	123.0	5%	2817.0
TOTAL	**7973**	**8933**	**9732**	**8590**	**800**		**10993**

2.2. Historical Development of Electricity Market in Turkey

In Turkey, the first electric production efforts started in Tarsus in 1902 in a tiny water mill, and in 1914 it was first produced in Silahtarağa Power Plant. This was realised by Osmanlı Elektrik Dağıtım A.Ş. (Osmanlı Electricity Distribution Joint Stock Corporation) and their foreign co-partners and helped İstanbul meet electricity (DEK-TMK 2007).

In 1926 and following years, 40-50 companies were established to produce electricity; however, except Kayseri and its environs Joint Stock Company, which was established in 1926 based on the law called 'Menafi-i Umumiye Müteallik İmtiyazat Hakkında Kanun, all others closed down without showing any considerable success.

Different public institutions participated in the construction of dams, power plants and distribution Networks until TEK (Turkish Electric Authority) was established in 1970 in order to centralize electricty production and transmission.

Following the law made in 1982 all elecricity transmission services were taken from municipalities and given to TEK. However, after the law of 1984, private enterprises were also given the right otoproduce, trade, and transmit electricity on a build-operate-and transfer model.

Based on the cabinet decision of 1993, TEAŞ and TEDAŞ which were seperately responsible for production and distribution of electricity started to function in 1994 instead of TEK.

Private enterprises, which were allowed to be established in 1984, gained the right to the ownership of the enterprises they established following the regulations numbered 4283 after the year 1997.

After private entreprises started to take a role in the production and transmisson of electricity, Electricity Market Regulatory Department a state department with financial and economical freedom was established in 2001 in order to protect the rights of consumer and to create a strong, equal, and competetive atmosphere. Table 2.2. gives annual development of installed capacity and generation in Turkey.

Table 2.2. Annual development of installed capacity and generation in Turkey
(Source: TEİAŞ 2008)

	INSTALLED CAPACITY (MW)					GENERATION(GWh)				
Years	**Thermal**	**Hydro**	**Geot. Wind**	**Total**	**Incre. (%)**	**Thermal**	**Hydro**	**Geoth. Wind**	**Total**	**Incre. (%)**
1984	4569.3	3874.8	17.5	8461.6	22.0	17165.1	13426.3	22.1	**30613.5**	11.9
1985	5229.3	3874.8	17.5	9121.6	7.8	22168.0	12044.9	6.0	**34218.9**	11.8
1986	6220.2	3877.5	17.5	10115.2	10.9	27778.6	11872.6	43.6	**39694.8**	16.0
1987	7474.3	5003.3	17.5	12495.1	23.5	25677.2	18617.8	57.9	**44352.9**	11.7
1988	8284.8	6218.3	17.5	14520.6	16.2	19030.8	28949.6	68.4	**48048.8**	8.3
1989	9193.4	6597.3	17.5	15808.2	8.9	34041.0	17939.6	62.6	**52043.2**	8.3
1990	9535.8	6764.3	17.5	16317.6	3.2	34314.9	23148.0	80.1	**57543.0**	10.6
1991	10077.8	7113.8	17.5	17209.1	5.5	37481.7	22683.3	81.3	**60246.3**	4.7
1992	10319.9	8378.7	17.5	18716.1	8.8	40704.6	26568.0	69.6	**67342.2**	11.8
1993	10638.4	9681.7	17.5	20337.6	8.7	39779.0	33950.9	77.6	**73807.5**	9.6
1994	10977.7	9864.6	17.5	20859.8	2.6	47656.7	30585.9	79.1	**78321.7**	6.1
1995	11074.0	9862.8	17.5	20954.3	0.5	50620.5	35540.9	86.0	**86247.4**	10.1
1996	11297.1	9934.8	17.5	21249.4	1.4	54302.8	40475.2	83.7	**94861.7**	10.0
1997	11771.8	10102.6	17.5	21891.9	3.0	63396.9	39816.1	82.8	**103295.8**	8.9
1998	13021.3	10306.5	26.2	23354.0	6.7	68702.9	42229.0	90.5	**111022.4**	7.5
1999	15555.9	10537.2	26.2	26119.3	11.8	81661.0	34677.5	101.4	**116439.9**	4.9
2000	16052.5	11175.2	36.4	27264.1	4.4	93934.2	30878.5	108.9	**124921.6**	7.3
2001	16623.1	11672.9	36.4	28332.4	3.9	98562.8	24009.9	152.0	**122724.7**	-1.8
2002	19568.5	12240.9	36.4	31845.8	12.4	95563.1	33683.8	152.6	**129399.5**	5.4
2003	22974.4	12578.7	33.9	35587.0	11.7	105101.0	35329.5	150.0	**140580.5**	8.6
2004	24144.7	12645.4	33.9	36824.0	3.5	104463.7	46083.7	150.9	**150698.3**	7.2
2005	25902.3	12906.1	35.1	38843.5	5.5	122242.3	39560.5	153.4	**161956.2**	7.5
2006	27420.2	13062.7	81.9	40564.8	4.4	131835.1	44244.2	220.5	**176299.8**	8.9
2007	27271.6	13394.9	169.2	40835.7	0.7	155196.2	35850.8	511.1	**191558.1**	8.7

2.3. Geothermal Energy in Turkey

Fields with high-enthalpy geothermal liquids are generally in the west of Turkey because of tectonic movements, and middle and low enthalpyt liquids are in central, eastern and northern Turkey owing to volcanisms and fault formations. (T.R. Prime Ministre State Planning Organization 2008). Turkey’s estimated geothermal energy potential is accepted as 31,500 MWt. Table 2.3. shows expected potential in fields appropriate for electricity production.

Hot water search and development started by General Directorate of Mineral Research&Exploration (MTA) in 1962, accelerated with the discovery of Denizli Geothermal Energy Field, which facilitated electricty production, and studies developed with the discovery of Aydın-Germencik and Çanakkale-Tuzla fields.

The discovery of Denizli-Kızıldere field in 1968 enabled electricity production from geothermal energy. For this purpose, the first piloting plant with 0,5 MW capacity started to function in 1974 and in 1984 another plant with 20,4 capacity was founded by TEK (Turkish Electricity Department). The electricity production of this plant is 12 MW and in 2004 9 million kWh electricity was produced after 7500 hours of operation. Besides, another plant with a capacity of 8,6 MW was established and started to operate in Aydın-Salavatlı.

Table 2.4. shows existing – and soon to be installed – power plants in Turkey; three are in operation, and another three will be on line soon (Serpen, et al. 2009).

Table 2.3. Turkey's geothermal power generation
(Source: Serpen, et al 2009).

Power plant	**Commissioned in (year)**	**Installed capacity (MWe)**	**Max. temp. (°C)**
Kızıldere-Denizli	1984	17.8	243
Dora-I Salavatlı-Aydın	2006	7.35	172
Bereket Enerji-Denizli	2007	7.5	145
Gürmat-Germencik-Aydın	2009	47.4	232
Tuzla-Çanakkale	2009	7.5	171
Dora-II Salavatlı-Aydın	2010	9.7	174

Table 2.4. Turkey's expected installed capacity in fields for electrity production (Source: MTA 2008).

	Tempreture	2010 Projection	2013 Projection
Field Name	**^{0}C**	**MWe**	**MWe**
Denizli-Kızıldere	200-242	75	80
Aydın-Germencik	200-232	100	130
Manisa-Alaşehir-Kavaklıdere	213	10	15
Manisa-Salihli-Göbekli	182	10	15
Çanakkale-Tuzla	174	75	80
Aydın-Salavatlı	171	60	65
Kütahya-Simav	162	30	35
İzmir-Seferihisar	153	30	35
Manisa-Salihli-Caferbey	150	10	20
Aydın-Sultanhisar	145	10	20
Aydın-Yılmazköy	142	10	20
İzmir-Balçova	136	5	5
İzmir-Dikili	130	30	30
Aydın-Hıdıbeyli	143	5	10
Aydın-Atça	124	2	5
Total		**462**	**565**

2.4. Kızıldere Geothermal Power Plant

The Kızıldere geothermal field is located 40 km west of the city of Denizli, in the eastern part of the Büyük Menderes Graben. It was the first one to be discovered as an electricity production field in Turkey. The first research was carried out in the area by the Mineral Research and Exploration General Directorate (MTA). In 1984, the Turkish Electricity Authority (TEAS) installed a single-flash power plant with 20 MW_e capacity (Şimşek, et al. 2005).

The first well with a heat of 198 ^{0}C was drilled at a depth of 540 meters. Between the years of 1968 and 1973, 16 more wells were drilled at the depths ranging from 370 to 1241. The test results showed that six of these wells were appropriate for electric energy production. In 1974, a prototype of tribune generator of 0.5 MWe capacity was installed in KD-13 well and nearby villages were provided with free electricity. In 1984, a plant with 17,4 MW capacity was installed and operated by EUAS. Between 1985 and 1986 KD-20, KD-21 and KD-22 wells were drilled and the total number of wells reached 9. In 2001, 242 ^{0}C R-1 well, with the highest heat and enthalpy, was discovered while re-injecting a well. R-1 well was used for production and R-2 was drilled as a re-injecting well at 1428 meters in 2002 (Kaya, et al. 2009).

In 1986, Karbogaz, a liquid CO_2 and dry ice producing factory with 40,000 tons/year capacity, was established in Kızıldere geothermal field. The capacity fo the facility was increased to 120,000 ton/year in the following years (Dağdaş, et al. 2005).

The most outstanding feature of the field whose reservoir temperature is 200-242 ^{0}C is that it has high potential of non condensable gases. 96-99% of these gasses consist of CO_2. The gasses are taken from the condenser by an air pump and pumped into Karbogaz and some is discharged into River Meander, which causes pollution in the river (Dağdaş, et al. 2005).

Geothermal power plant can be examined in two sections;

a) steam area

b) power production unit.

Steam area includes production and injection wells, separators, steam line and other equipment in the field. Power production unit, on the other hand, covers the tribune, condenser, gas receiving system and cooling tower (Gökçen, et al. 2004) .

Kızıldere geothermal power plant was purchased for 28.7 million dollars in 1982. 45% of the financing is a 20-year bank loan, 1,5% is a credit, and the rest is export credit (Serpen, et al. 2007) Although the gross power of the plant is 20,4 MW_e, its net power generatıon had been 10 MW_e. The plant has been generating electricity for 24 years and has produced about 1.86×10^6 MWh of electricity to date. So far, the average annual electricity production is 76×10^6 kWh. (Serpen, et al. 2007). Figure 2.3. shows the changes in net and gross productions in different years.

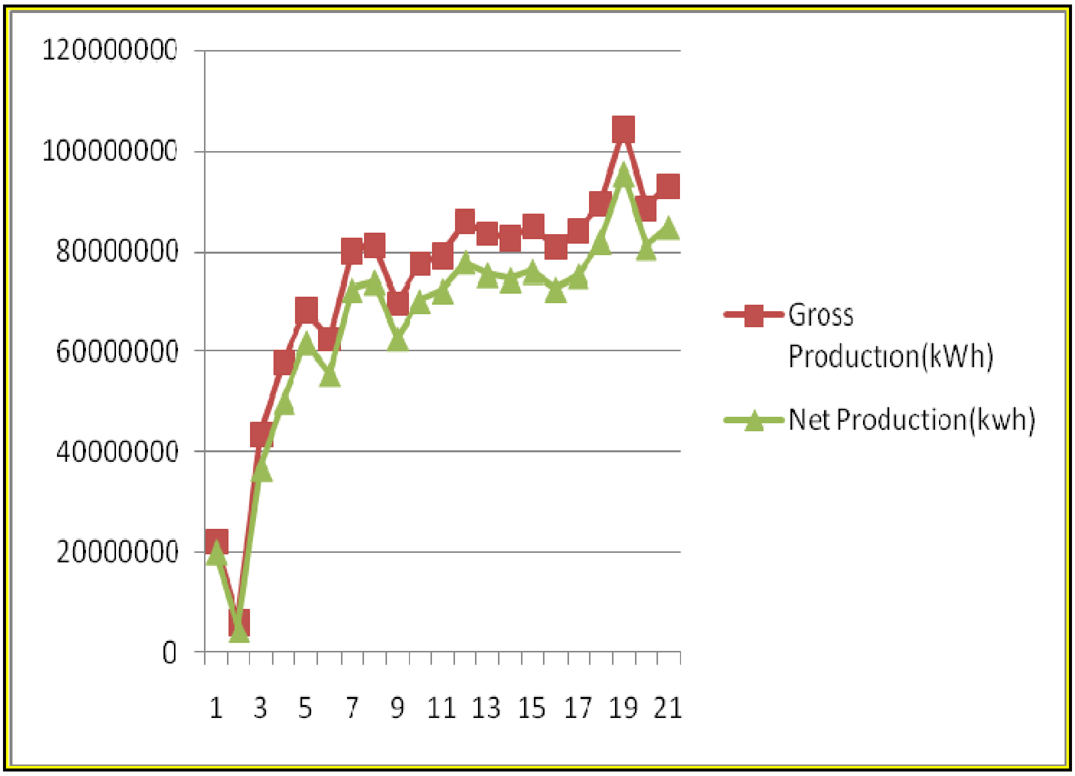


Figure 2.3. Kızıldere power plant gross and net production

CHAPTER 3

LITERATURE SURVEY

Geothermal power projects include several technical and economical risks because of the use of new technologies, lack of expertise and know-how. The literature was examined under two major subtitles deterministic studies and stochastic studies.

The first study on geothermal power plant analysis with a deterministic approach was carried out by Bloomster in 1975. This study did not only meet the needs of those years but also enlightened later studies. Battella Northwest program, also called GEOCOST, funded by U. S. Energy Research and Development Administration is based on calculating potential costs of geothermal power fast and systematically.

GEOCOST combines both tecnical and economic factors into one systematic cost accounting framework (Bloomster 1975). This program consists of two major models as reservoir model and power plant model. Reservoir model includes discovery, development and operation costs of geothermal reservoir whereas power plant model includes design, construction and operating costs. Energy production system is a combination of the these major componets. Figure 3.1. shows the major cost elements of the geothermal energy project.

Discounted cash flow analysis is used to calculate the present value of income and expenditure costs of GEOCOST reservoir or plant during their economic life span.

In 2004, Sanyal is studied in a deterministic format with most likely values and detailed sensivity analysis. This study presents an analysis of power cost and calculates the levelized power cost of geothermal energy projects. Geothermal power cost includes to: capital cost, operating and maintenance cost, make-up well drilling cost, resource characteristics, development and operational options, and macro-economic climate.

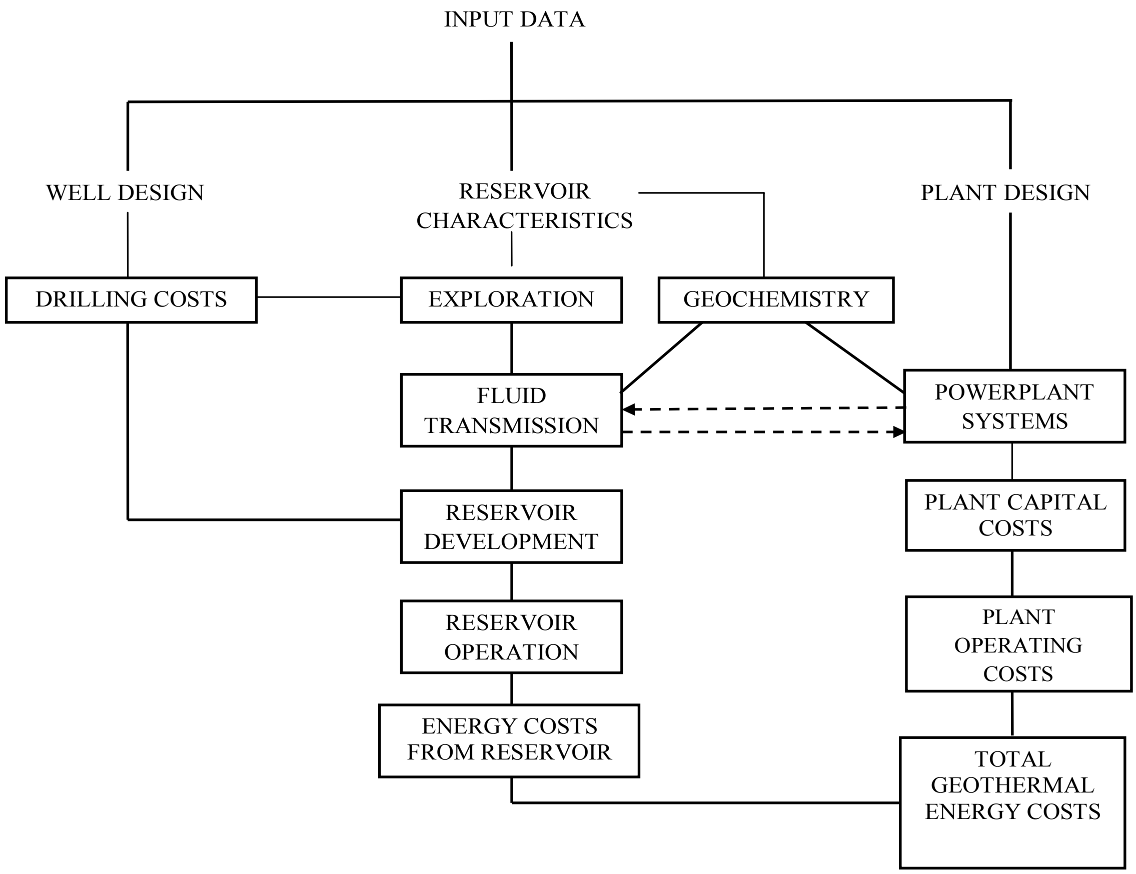


Figure 3.1. The cash flow form the basis for the GEOCOST
(Source: Bloomster 1975)

The results of the analysis show that the power cost is insensitive to plant capacity but it is sensitive to unit operations and maintenance cost. In addition, macro economic climate affects have minor impact on power cost. This study considers power costs rather than power price or Project profitability. The analysis considers a power capacity range of 5 to 150 MW_e with 50 MW_e as the base case.

Sanyal's study clearly indicates the new trend in geothermal energy evaluation projects. Based on the past experience O&M cost models may provide more accurate financial models for geothermal projects (Şener, et al. 2007).

The U. S. Department of Energy (DOE) has developed a spread sheet model to describe as to how its research activities can impact of cost of producing power from geothermal energy. The initial model development was completed in 2006. This model 'Geothermal Electricity Technologies Evaluatıon Model' (GETEM). The model calculates power generatıon cost that estimates of costs associated with exploratıon, well field development, and power plant constructıon. In addition, it allows the user to evaluate how reductions in cost, or increasse in performance or productivity will impact the predicted power generation cost. Both costs and performance are described in the model for currently avaible tecnologies, and then used to Levelized Costs of Electricity (LCOE).

Utilization of stochastic approaches to model the risk in geothermal energy projects begins with Juul-Dam and Dunlap in 1975. The approch mainly orginates from the conventional oil and gas development studies. The required durations for the activities are modeled are triangular distributions. Authors tried to build very detailed economic model to capture all possible uncertainties in the geothermal projects. The study is certainly the Pioneer of the geothermal energy risk assessment studies and deserves appreciation for introducing Monte Carlo simulation technique to the geothermal energy project evaluatıon area (Dorp, et al. 2005). Table 3.1. shows activity durations and cost. Table shows base chance factors and paremeter values.

Table 3.1. Activity durations and cost
(Source: Dorp, et al. 2005).

	Duration (Years)			**Cost(Thousand Dollars)**	
	Min	**Mode**	**Max**	**Time Dependent ($/year)**	**Time Independent ($)**
Geological, geochemical and geophysical work	0.5	1.0	2.0	120	200
Exploratory and appraisal drilling	0.5	0.9	1.8	Exploratory and four appraisal wells	
Reservoir testing and evaloation	0.5	0.8	1.3	350	250
Delineation drilling	0.4	1.0	1.5	4 delineation producers	
Contract negotiation and litigation	0.2	0.5	1.2	300	200

Hirakawa studies conduct economic risk analysis by using Monte Carlo simulation model in 1981 in Japan. In this study uncertainties were modeled as triangular distribution or single valued chance factor (Dorp, et al. 2005). Table 3.2 presents the assumptions of this model.

Table 3.2 Geothermal activity durations
(Source: Dorp, et al. 2005).

Activity	Min (Years)	Mode (Years)	Max (Years)
Geological, geochemical and geophysical work.	2	3	4
Exploratory drilling.	0.5	0.9	1.8
Reservoir testing and delineation drilling.	0.9	1.75	2.75
Time between the initiation of development well drilling and the start of commercial operation.	4.0	4.5	5.5

Stochastic approach is improved by Parker in 1987. This method name is ‘Geothermal Electricity Venture Analysis Model (GEVA).’ GEVA models geothermal projects in a more detail and uses higher number of sample simulations than the older models.

Goumas improves the Parker’s study in terms of decion analysis. This study employs multicriteria decision methods to optimize the exploitation of a low enthalpy geothermal resources (Dorp, et al. 2005).

Reports published by DiPippo (1998), Barbier (2002), Kutscher (2000), and the DoE’s Office of Energy Efficiency and Renewable Energy (EERE) contain general survey about history, technology, and status of geothermal development. These studies are herded to explain plant desing parameters and cost ranges which are associated with 23 different plant types.

Gawlik and Kutscher (2000) worked on 17 sites which they thought would be promising considering temperature and flow rate. These sites had previously been identified among 271 geothermal resources in the west of the U.S.A. The analysis of each site was done in order to figure out whether a binary cycle power plant would perform well and afterwards cost variables were estimated. The estimation was done taking into consideration the idea that the construction of the plants would take place in the areas which are potentially rich.

Stefansson (2000) applied statistical methods to work out investment costs of geothermal power plant construction and in this study he used a stepwise development, which suggested that it was not a must to know exactly whether the area was potentially rich. Instead of building a huge plant, a smaller one is preferred as the beginning phase to examine and find out the features of the resource. Stefansson then made use of data obtained from plants in Iceland so that he could estimate construction costs in other geothermal fields which were not known. While doing this, he tried to work out surface costs as well as subsurface costs that would appeal to generic geothermal plant with no specified type.

Lovekin (2000) tried to find relations between different size plant development scenarios in an imaginary geothermal field. In his study, he revealed that there is a benefit-loss relation between the size of the plant and the costs of making the field sustainable over time.

In a report written by Entingh et al. (1994), cost and performance figures for a 300 kW geothermal power plant have been given. Here, the possible effects of different field conditions on the production cost of elecricity are discussed. Entingh tries to find out the factors that make a small-scale off-grid geothermal plant feasible.

Goumas et al. (1999) use methodologies from operations research to evaluate the economic viability and impact of different approaches to geothermal systems. The authors use stochastic analysis of performance parameters combined with success criterion to determine the probability of success. The inputs and outputs of the model are defined as probability distributions. The model is designed to evaluate the net present value of imlementing a geothermal system given the specific conditions.

CHAPTER 4

ECONOMIC ASSESSMENT OF GEOTHERMAL ENERGY

Geothermal power production costs examine under two headings: amortization of the initial capital investment and power production operation and maintenence cost (Hance 2005). This section explains the steps that should be taken to develop a geothermal power production. It is not possible to show in detail, so the chapter provides a summary for activities to be done. In another words, each geothermal energy project is unique and have different characteristics. By this way it is possible to describe the basic features of a geothermal project.

4.1.Cost of Capital Investment: Up-front Capital Investment

Geothermal resource is more uncertain, a long and expensive process. The conditions and level of utilization are uncertain for example, the reservoir capacity, pressure, tempereture, and salinity can not be precisely gauged in advance. In this reason, initial development steps are risky and upfront capital costs are important (Stoltzfus 2003). In 2001,EPRI estimated that capital reimbursement and associated interest account for 65% of total cost of geothermal power (Simons 2001).

Geothermal plant investments are examined in four stages (Şener, et al. 2007).

1. Exploration: Exploration is the first step. At this stage the existence and properties of geothermal reservoir is searched. This stage begins with varius kinds of prospecting and field analysis and ends with the drilling of the first commercial geothermal well. Table 4.1. gives exploration cost values in the literature.

Table 4.1. Exploration cost values in the literature
(Source: Geothermal Energy Assosiciation 2005).

Authors	Exploration cost values
Nielson (1989)	107.2 $/kW
EPRI (1996)	125.9$/kW
EPRI (1997)	101.1-130.8 $/kW
GeothermEx (2004)	88.5-142 $/kW

2. Confirmation: Drillings for production wells in the field continue at this stage. This stage ends with the confirmation of the 25% of the capacity of the project. For instance, for a project to produce 20 MW production, enough wells should be drilled to meet the need for 5-MW production before the project is confirmed. This stage is not a requirement for all geothermal projects. However, some financiers make this stage a prerequisite for projects needing outside financing. In geothermal cost calculation it is assumed that until this stage expenses are paid from the main capital.
3. Site Development: The site development phase includes all the remaining activities. This involves power plant design and associated technological choices, driling and well testing. In the literature, site development is reviewed three main subtitles.
    3.1. Drilling: According to Enting et al. (1997); Drilling cost 600-800 $/kW installed for a flash plant project, 323 $/kW for binary project (Hence 2005).
    3.2. Project Permitting: Geothermal power project consist of legislative requirements such as environmental and construction issues
    3.3. Steam Gathering System: The steam gathering system is the network of pipes connecting the power plant with all production and injection wells. The cost of the steam gathering system corresponds to 5% of total capital cost. Transmission lines are quite expensive. The table 4.2. provides cost estimates for new transmission lines (Hence 2005).

3.4. Power Plant Design and Construction: Production of electricity is the most important parameter in a plant and while comparing a plant to others. Each plant and field in geothermal energy has its own characteristics, that's why the productivity of a plant is of secondary importance. Cost analyses regarding geothermal power plants is not a very common subject matter in national and international literature. There are many factors that inflence the cost of geothermal power plant. In general, they are affected by the cost of steel, other metals and labor, which are unıversal to power industry (DiPippo 1999). Geothermal power plant costs depend on such factors;

- Resource type (steam or hot water),
- Resource temperature,
- Reservoir productivity,
- Power plant size,
- Power plant type,
- Environmental regulations,
- Cost of capital,
- Cost of labor.

The first three factors influence the number of wells which are concern with plant capacity. The next three items determine the capital cost, and the last two affect the cost of running the plant.

Capital cost of geothermal contains the cost of land, drilling wells, and including buildings and power plant. The capital cost for geothermal power plants ranges from \$1150-3000 \$/kW, depending on the resource chemistry, tehcnology, and tempereture employed (Shibaki, et al. 2003). Table 4.3. suggests that capital costs of binary projects are higher than those of flash technologies. Although it is generally agreed that the power equipment of binary systems is more expensive than flash systems, other cost components of the project (e.g. drilling cost, difficult brine chemistry, etc.) may compensate for this cost advantage.

Table 4.2. Construction cost of transmission lines
(Source: Geothermal Energy Association 2005)

Sifford&Beale (1991)	$ 360.000 /mile (58%labor cost&42% material cost)
Lesser (1993)	$ 340.000/mile (61% labor cost& 39% material cost)
GeothermEx (2004)	$ 268.000/mile
Developer's interview	$ 350.000-450.000 /mile

Note: All cost figures appearing in this table are expressed in 2004 $

Analyses of the investment costs for geothermal developments are not often found in the literature. It is frequently assumed that development costs are difficult to predict because of the uncertainy involved in geothermal drilling. The investment cost of geothermal power plants is divided into the cost of surface equipment and activities and the cost of subsurface investment (Stefanson 2002). Figure 4.1. gives typical cost breakdown of geothermal power project.

Table.4.3. Capital cost of geothermal power technologies
(Source: Hance 2005).

Author	Technology	Capital Cost($/kW)	Cap. Cost Range($/kW)
Enting&McVeigh(2003)	Binary	2400	
Owens(2002)	Binary	2112	
Kutsher(2000)	Binary	2100	
EPRI(1997)	Binary	2112	
Average Capital Cost Binary		**2181**	**2100-2400**
Owens(2002)	Flash	1444	
Stefanson(2002)	Flash	1750	
Kutsher(2000)	Flash	1450	
EPRI(1997)	Flash	1444	
Enting&McVeigh(2003)	Flash(Dual)	1800	
Average Capital Cost Flash		**1578**	**1444-1800**
Sanyal(2004)	Ns	2184	
Worldbank	ns	1675	
EPRI(2001)	ns	1400	
DiPippo	ns	1700	
Average Capital Cost non specified		**1740**	**1675-2184**

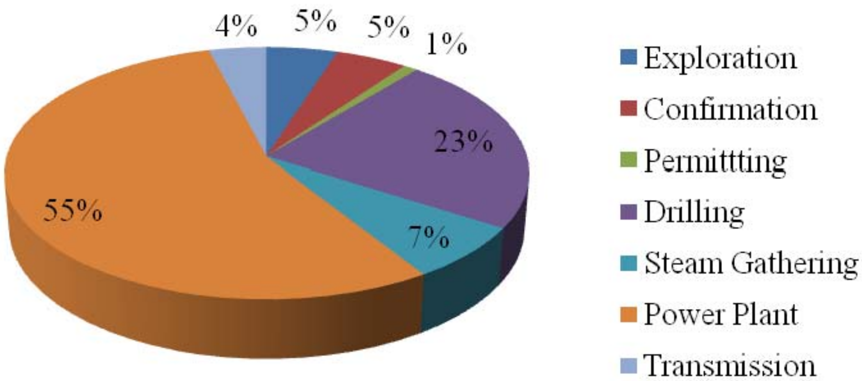


Figure 4.1. Typical cost breakdown of geothermal power Project
(Source: Hance 2005)

Most geothermal power projects go into production in 5 to 7 years depending on legislative ts and other licensing issues. Each geothermal project phase covers different risk profiles.*"For economic success, it is important to understand that the subdivision in project phases reduces the risk because go/no go decisions can be made at the end of each phase*" (Samatinger 2009).

4.2. Operating and Maintenance Cost

Operation and Maintenance (O&M) costs consist of all costs incurred during the operational phase of the power plant. Operation costs cover all expenses related to the operation of the power plant. Labor is the most important part of these costs. Other cost components involve spending for consumable goods (such as lubricants, chemicals for H_2S abatement, scaling and corrosion control, vehicle fuel, spare parts), and and other miscellaneous charges. Maintenance costs hold all expenses related to the maintenance of the equipment (field pipes, turbine, generator, vehicles, buildings, etc.) in good working status. The following Table 4.4. provides representative O&M cost values and ranges found in the literature.

Table.4.4. O&M costs value and ranges (Inflation adjusted $/MWh).
(Source: Hance 2005)

Source:	**O&M Cost**
Sanyal (2004)	14 - 20*
Owens (2002)	18 - 21
EPRI (2001)	[16 - 27]
Lovekin (2000)	20 - 22
http://www.eere.energy.gov/geothermal/faqs.html	[10 - 30]
http://www.saintmarys.edu	[15 - 45]

*These values do not include well make-up drilling costs

4.3. Financing Geothermal Energy Project

"The costs of electric power projects utilizing renewable energy technologies are highly sensitive to financing terms. It is important for policymakers to consider the impacts of renewables policy design on project financing." (Wiser, et al. 1997). Renewable power generation shoots up in the electricity market for increasing green houses gases and rising volatile oil prices. Small scale power units can be dominant in the future electricity market from cost improvements and electricity market liberalization (Fleten, et al. 2007). Unfortunately, the share of geothermal energy is less than 1% of the pie, or about $66 million. Figure 4.2. illustrates the worldwide renewable energy investment market and geothermal's room for improvement (Department of Energy Office of Energy Efficiency and Renewable Energy 2008).

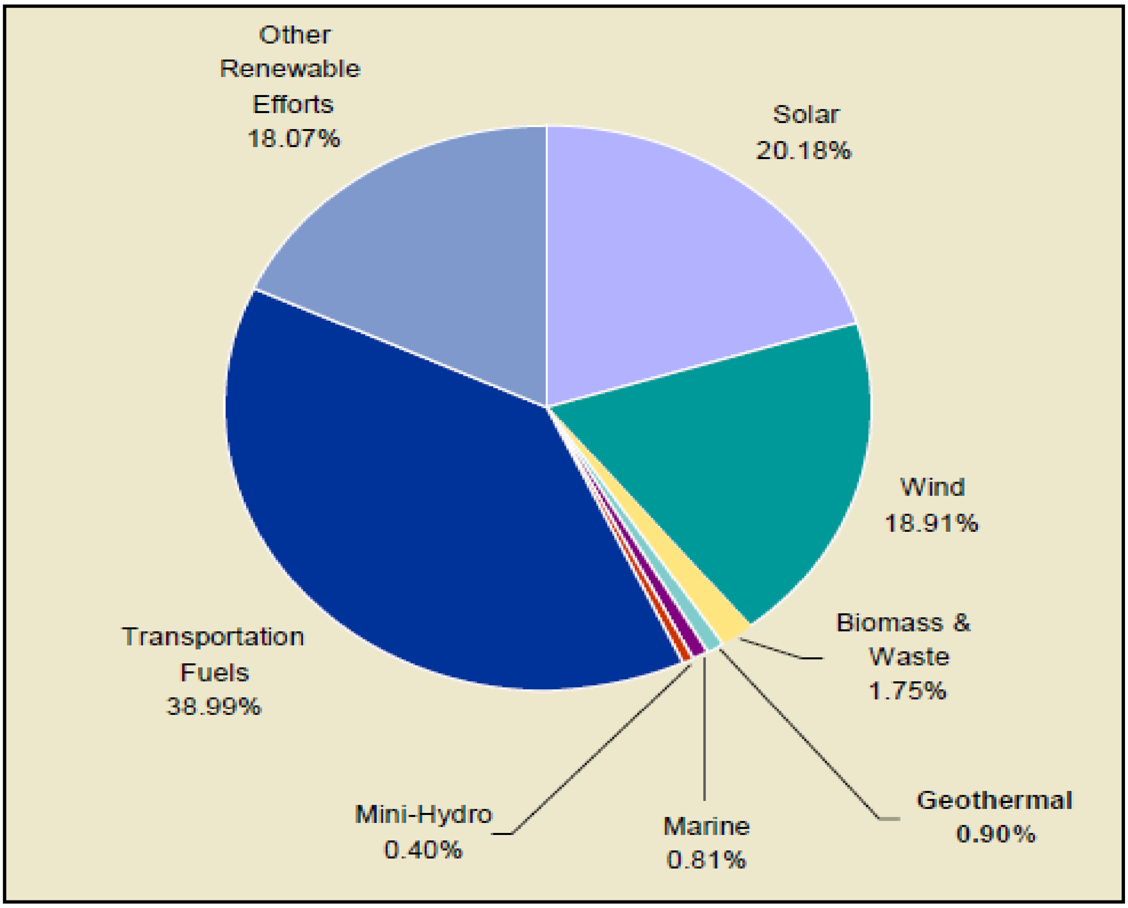


Figure 4.2. The worldwide renewable energy investment

4.4. Sources of Capital:

The general purpose of the financial evaluation of projects is to quantify the respective investment returns and associated risks. According to Khatib,(1996)

> Financial evaluation for large capital-intensive projects is normally conducted at two levels. First is the project owner's evaluation which is concerned with cash flow looks at all money flowing in as positive (e.g., sales) and all money going out as negative (e.g., project costs). This evaluation looks at the project's net benefit in comparison to the investment (equity), i.e., the return on equity. Second is the banker's evaluation which analyzes the project for loan consideration by evaluating the return on the total investment (equity plus loans) together with profitability.

According to Kachienga (2008) "*for the project or investment to be viable, the project's return must be greater than the cost of capital and its risk must be acceptable. The cost of capital is the rate of return that a company must earn on the projects in which it invests to maintain its market value and attract funds.*"

Capital structure differs from financial structure which accounts for long –term debt and equity. Generally, in the capital structure of geothermal energy project consists of a combination of debt and equity. Equity investors will therefore frequently take high-risk investments if the potential rewards are large. In contrast to equity investors, lenders bear less risk. For this reason, unlike equity investors, lenders mostly analyze a project from a worst-case perspective.

CHAPTER 5

METHODS

The economic aspect of investment projects is independent from sectors in which investment is made. How much the investment will cost and profitibility issues should be examined for each investment project. The definitions of related concepts are as follows:

Investment: It can be described as additions made to real production means in certain periods. Or, it is using some of the unused portion of the production made for a certain purpose. Investments are groupped into three according to their qualities:

- New Investment Projects (investments in a new product or premises)
- Enlargment Projects (investment to increase capacity in an installed premises)
- Renovation and Maintenance Investments(investment made to renovate methods or premises without changing the capacity and quality of production

Investment Project: It is a suggestion to create, develop and improve new chances in order to increase production of goods and services in a society in a certain period of time. Generally it should meet the following criteria:

- it should create a production capacity
- it should take physical input from the economy
- it should be able to deliver goods to domestic and outside markets

Feasibility Study: Feasibility analysis is needed in order to determine the financial criteria regarding an industrial project. These fall into three headlines as the following:

- Economic (Market) analyses (supply-demand, production capacity, choosing location etc)
- Tecnical analyses (properties of the product, machinery-equipment, standards etc)
- Financial Analysis (All investment costs, capital cost) Project Evaluation: All parameters should be considered before an investment

project starts and decisions should be made accordingly. Feasibility studies generally introduce financial and technical parameters. The project should be evaluated after examining these data carefully.

While evaluating a Project, the following is taken into consideration:

- The distrubitıon of input and output within the economic life of the investment
- The range of income and expense within a year
- Examination of relation between income and expense

Decisions are made according to the above criteria and the project is either refused or accepted and physical investment start.

Evaluation of investment projects is divided into two as economical evaluation and finacial evaluation. The purpose in economic evaluation is to check the profitabilty of the project without considering where resources come from and they go; and respectively accept or refuse the project looking at how profitable it is. Economic evaluation consists of comercial or social profitability analyses depending on the purpose of the enterpreneur (Kula, et al. 2004).

Financial evaluation, on the other hand, aims at searching whether projects estimated to be profitable will smoothly run or not with their current financial positions. In this type of evaluation, where the financial sources of the project come from and its cash flow are also examined (Aytekin 2005).

According to Sudong et al. (2000): the project evaluation methods may be classified into three categories: Methods based on return, methods based on risk, and methods based both on return and risk. Figure 5.1. shows methods and decision rules for capital investment decisions The methods based on return contain the payback period, the average accounting rate of return, NPV, and IRR. The payback period and the average accounting rate of return methods do not take on board the time value of money (Sudong, et al. 2000).

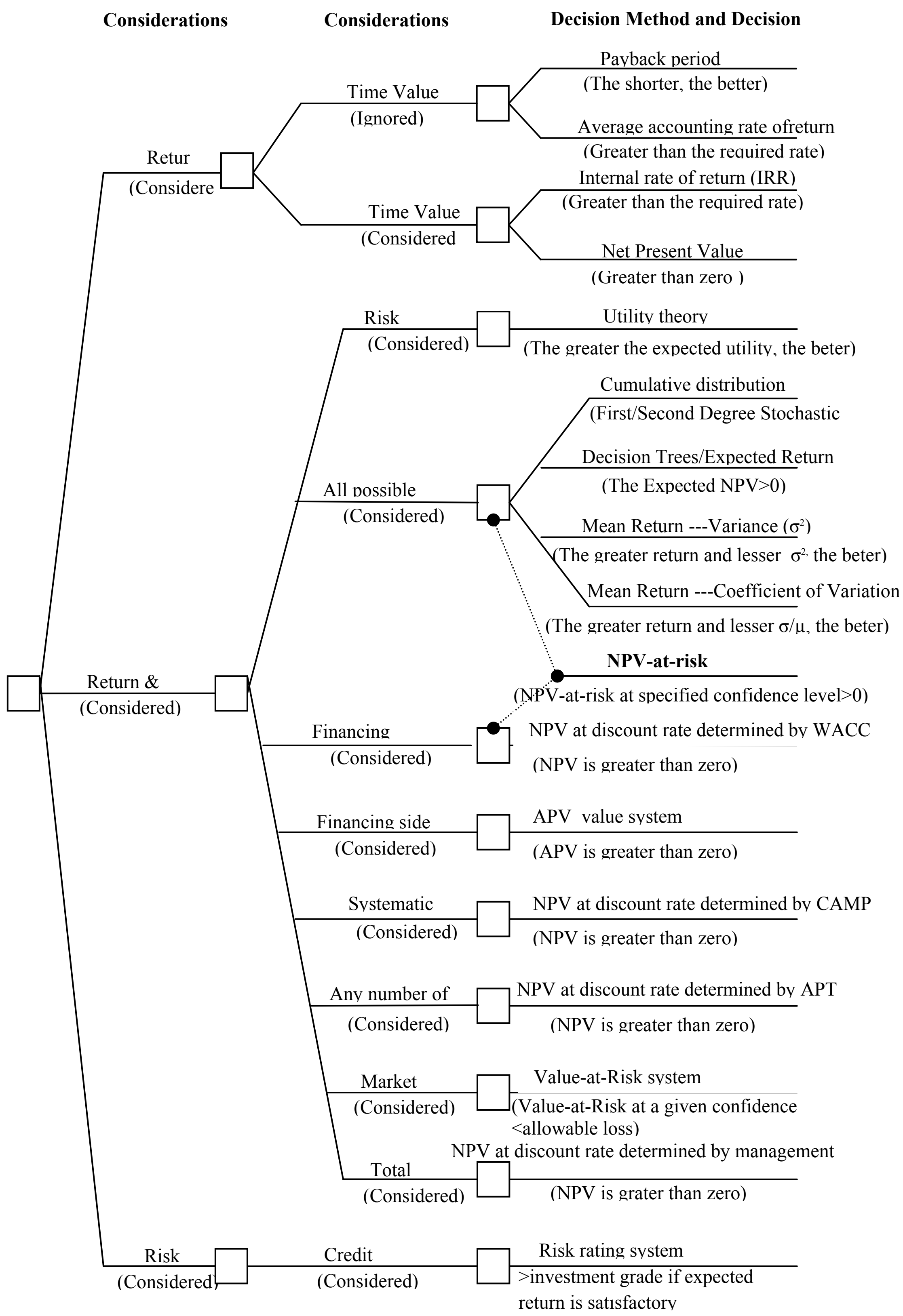


Figure 5.1. Methods and decision rules for capital investment decisions.
(Source: Sudong, et al. 2000)

Geothermal investments are costly investments. Some evaluation criteria is needed before an investment decision is made. This is associated with the time value concept of money in literature.

The time factor between today's and tomorow's Money makes today's Money more valuable compared to others (Ercan, et al. 2002). When we look at the case from the points of view of the demander and suplier of the money, there must be something to pay for the receiver of the money as he can use the money today that he can use in the future. This is generally called 'interest'. When we see it from the other perspective, it is a value equal to the total risks that the lender of the Money shoulders.

Investment making decision techniques are divided into two:

Techniques that do not consider the time value of money

- Average productivity method
- Payback period method

Techniques that consider the time value of Money

- Net Present Value Method(NPV)
- Index of Profitability(IP)
- Internal rate of return(IRR)

5.1. Methods That Do Not Consider The Time Value of Money

5.1.1. Average Productivity Method

This measures the average productivity of investments. The expected and calculated values are compared. If the calculated value is higher than the expected value the project is accepted; otherwise it refused. To choose between different investments, the one with higher productivity rate is preferred. The method seems adventageous in that it is simple and easy to calculate and it makes use of accounting data; however its drawbacks are that it does not use cash flows and consider the time value of money (Eroğlu 2008).

5.1.2. Payback Period Method

The simple economic payback period calculated by the model is a measure of the amount of time required to recover the initial capital costs of plant construction. The method used to calculate simple economic payback is shown in Equation 5.1.

$$\text{Payback} = \frac{\text{Initial Capital Cost(\$)}}{\text{Annual Reveneu(\$/yrs) - Annual O \& M Cost (\$/yrs)}} \qquad (5.1)$$

As can be seen from the equation, large annual revenues (either from high annual output or high electricity sales rates) result in smaller payback periods. The same is true if Annual O&M fees are small (Fitzgerald 2003).

Payback period measures how many years later the invested money will be taken back. Among different investments, shorter ones are given priority. If there is only one project waiting for a decision, the time expectance of the investor determines the decision. If the payment period shorter than the time limit, the project is approved. The expexted time is generally the life span of the investment (Kabukçuoğlu 1999). The negative aspect of this method is that it does not consider the time value of money or net cash flows in the years following the payback period. This method can be used in investments in risky sectors and for investors who care about liquidity. Besides, though not used alone, it is one of the most commonly used methods together with other methods with the assumption that payback period shortens as the risk reduces.

5.2. Methods That Consider The Time Value of Money

5.2.1. Net Present Value Method

Net present value of an investment is the calculation of the difference between the obtained cash entries of the investment over a a pre-defined discount of its economic life and the expenses reduced to a definite time point. The fixed discount rate is the minimum profit expectancy of the investor and it is generally the weight average cost capital. It is the most preferred method as it considers the time value of money and meets the financial needs of investors.

The net present value of an investment should be positive so that it is meaningful and acceptable. Between investments the one with higher net present value is chosen. NPV has become the most popular method for investment evaluation (Lu, et al. 2010).

While applying this method, analyists have the most difficulty in determining discount rates. Generally, weighted cost of capital used to determine discount rates. Apart from this, expected rate, current interest rate, debt rate and average profitibality of similar investments can be used as reduction rate. In addition, inflation rate in the country, current interst rate and expected risks should also be taken into consideration while determining the discount rate (Kabukçuoğlu 1999, Özkan 2004).

The Net Present Value is equal to the present value of the future cash flows return by a project, minus the initial investment; it is an assessment of the expected addition to the investment wealth, and used to decide whether an investment is worthwhile and better than alternative investments. The NPV can be expressed as below:

$$NPV = CF_0 + \frac{CF_1}{(1+r)} + \frac{CF_2}{(1+r)^2} + \frac{CF_3}{(1+r)^3} + \ldots + \frac{CF_N}{(1+r)^N} \quad (5.2)$$

This equation discounts each year’s cash flow back to the present, then deducts the initial investment, which gives a net value of the investment in today’s dollars. The acceptance criteria for NPV evaluations are quite simple, whenever the project’s NPV is greater than zero, the project will be accepted; otherwise, the project will be rejected. If the project’s net present value equals to zero, then it will satisfy the required rate of return and should be accepted, see the accept-reject criterion below:

NPV $\geq$ 0 Accept

NPV $<$ 0 Reject

5.2.2. Profitability Index

Profitability index method is a different application of net present value method. It is frequently used since it is easily applicable and easy to understand. It is obtained from the division of annual cash flow with a predetermined discount rate in a certain time period by the total investment. It is expected that the profitability index is higher than 1. Between different alternatives, the one with a bigger profitability index is preferred

5.2.3. Internal Rate of Return

Internal rate of return is the discount rate that equates expenditures for the investment in a certain time period with the cash inflows from the investment. In other words, it is the discount rate that equates the net present value of the investment to zero. It is equal to or above the oppurtinity cost for private project or social rate for the government project. The fact that it takes the time value of money into consideration and that cash inflows and outflows are scrutinized in the same time period are its advantages. However, if there exist outflows even after the investment period, there appears two internal profitability rate and this is the biggest disadvantage of the method (Gedik, et al. 2005). IRR is discount rate which NPV is equal to zero. It is equal to or above the oppurtinity cost for private project or social rate for the government project.

CHAPTER 6

RESULTS AND DISCUSSION

Kızıldere geothermal plant was sold to Zorlu Energy Group during privatizations in 2008 (Kaya, et al. 2009). The group is planning to increase its installed power to 60 MW with new investments. Considering these developments it would be more realistic to accept the installed power plant expansion from 20 to 60 MWe in Kızıldere.

In order to achieve the research objectives, different design scenarios will be analyzed a geothermal power plant. Within each design scenario, net present value techniques will be used to evaluate the impact of variables influencing geothermal power plant construction and operation costs. Discounted payback periods and IRR will be calculated for each scenario.

This study starts with finding the capital cost and O&M cost which are essential parameters this analysis.Then, net production and revenue are calculated.Third step, economic analysis is done for two alternative scenarios. And lastly, sensitivity analysis is done for all two scenarios and each power.

6.1.Capital Cost and O&M Cost

According to Sanyal (2004) , unit capital cost and O&M cost decline exponentially with plant capacity. This assumption leads to the following correlation between unit capital cost in $ / kW (C_d) and plant capacity in kW (P):

$$C_d=2500e\text{-}^{0,003(P-5)} \qquad (6.1)$$

Similiarly, O&M cost in ¢ / kWh (C_o) with plant capacity in kW (P);

$$C_o=2e^{-0,0025(P-5)} \qquad (6.2)$$

Table 6.1. give capital cost and O&M cost for each scale power plant which calculate equation (6.1) and (6.2);

Table 6.1. Capital cost and O&M cost data 20-40-60 MW

Power (kW)	Capital cost ($/kW)	Total capital cost ($)	O&M (cent/kWh)
20.000	2390	47.799.874	1,93
40.000	2251	90.032.452	1,83
60.000	2120	127.184.056	1,74

The cost of energy associated with geothermal energy resolved into components of capital cost. The estimated percentage values are portrayed in Fig.6.1. ,Fig.6.2, and Fig.6.3. Power plant cost is the dominant factor which is 26.289931,49.517.849 and 69.951.231 dolars.

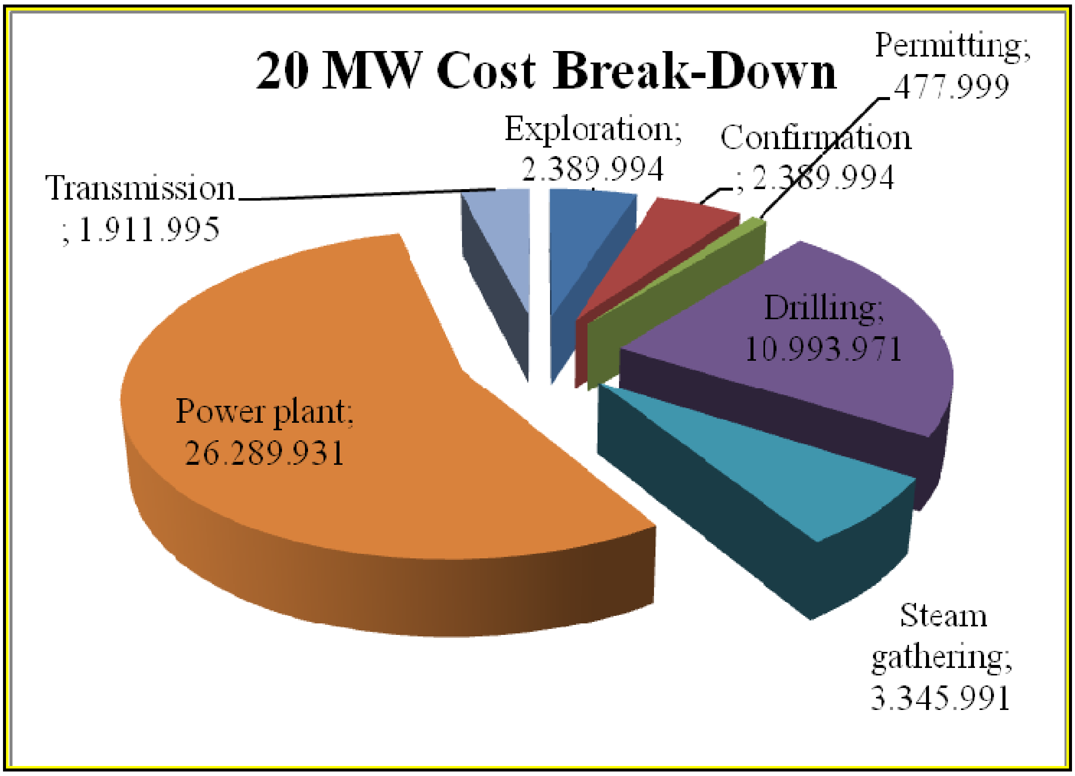


Figure 6.1. The cost break –down for 20 MW

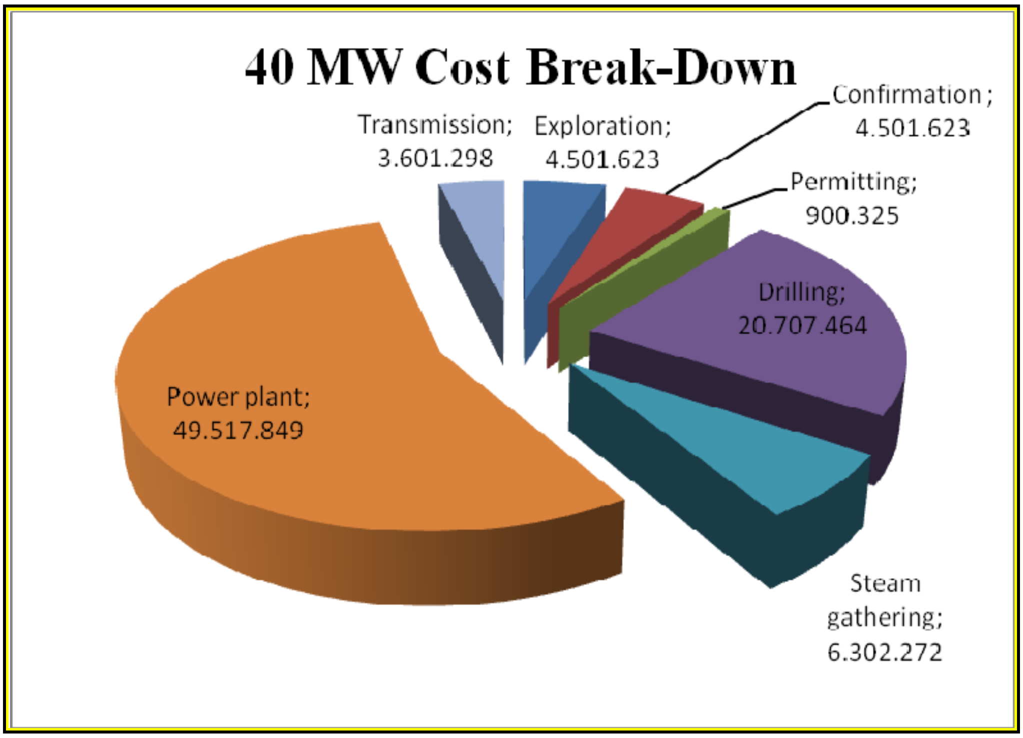


Figure 6.2.The cost component distribution of 40 MW power plant.

The graphic explained below highlights which variables have the great on the project.

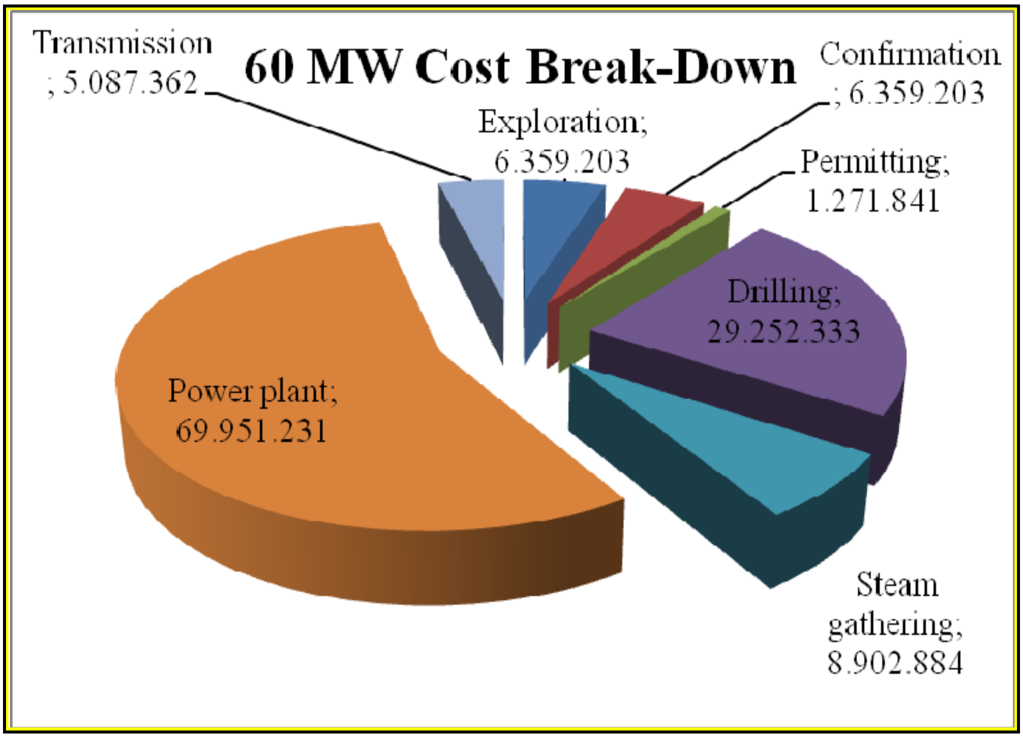


Figure 6.3.The cost component distribution of 60 MW power plant.

Next step should be economic assessment. Economic evaluation is referred to estimate the overall project cost according to various paramaters, e.g. interest rates, interest rate of returns, economic life span, and sales price of electricity. Cost analysis is done by choosing different cost parameters because the cost of every single geothermal project is specified to that geothermal area only. Cash flow models are frequenly used to find out the net present value and interest rate of return. Parameters such as capital cost, O&M and money costs, and taxes have been used in this study.

Two scenario are illustrated for each power. First scenario is a government project which establishes the project finance to be a debt of about 75% and equity of 25%. Second scenario is a private project. The project finance is assumed to be a debt of 50% and equity of 50%. The assumption of money costs is linked with the opportunity to gain benefits in the current time investment, whereas the inflation rate is neglected. This thesis is an example of a static structure study. The changes in factors such as sales price, operating and maintanenence cost and renovation cost over time have not been taken into consideration. In addition, the terms of cost does not contain the risk factors such as country risk, local risk, project risk, and market risk, as well.

Table 6.2. The estimated financing structure

	Scenario 1	Scenario 2
	Government Project	Private Project
Debt (%)	75	50
Equity (%)	25	50
Economic life span (year)	40	40
Interest rate (%)	7	5
Debt term (4 years non resource loan)	12	8
Capacity factor (%)	85	85
Discount rate (%)	6	6
Depreciation (%)	2,5	2,5
Tax (%)	20	20
Electricity sales price (cent/kWh)	8,8	8,8

It is assumed power plant construction 5 years, and expens distrubition are 35%,30%,20%,10% and 5%.

SCENARIO 1: Government Project

Scenario 1 is a government project. The analysis is conducted for an energy escalation rate of 0%, inflation rate of 0%, Project life time 40 years, debt ratio 75%, debt term of four grace total 12 years, debt interest rate of 7%, and discount rates of 6%. (personal communication: Seyhan Ayanlar, Development Bank of Turkey). The depreciation rate is assumed 2,5% and tax rate 0, 20%. (Tax Procedure Law, number 213, Declaretion 333,Corparete Tax Law5520).

SCENARIO 2: Private Project

Scenario 2 is private a project. The analysis is conducted for an energy escalation rate of 0%, inflation rate of 0%, Project life time 40 years, debt ratio 50%, debt term of four grace total 8 years, debt interest rate of 5%, and discount rates of 6%.(personal communication: Seyhan Ayanlar, Development Bank of Turkey). The deprecation rate is assumed 2,5% and tax rate 0, 20%. (Tax Procedure Law, number 213, Declaretion 333, Corparete Tax Law5520).

Capacity factor is an important variable in investment calculations. According to Shibaki et al. (2003), geothermal plants generally run 90 % of the time. When they can be run up to 97-98% of the time, maintenance costs increases. Although some high capacity factors are observed in the first years of the plants, 85% capacity factor is correct and a frequently used rate in long termsin literature (Şener, et al. 2009). The next step done for the net production data is capacity factor analysis. Table 6.3. shows net production data for 20-40-60 MW with 85% capacity factor.

Table 6.3.Net production data summary.

Power (kW)	Net production (kW/year)
20.000	148.920.000
40.000	297.840.000
60.000	446.760.000

6.2. Revenue Calculation

Revenue is the total amount of money received by a company for goods or services sold before deducting expenses. It is equal to net production multiplied by electric sales price.

Electric price: the price of electricity for each year is the average wholesale price of the previous year determined by EPDK (The price for 2010 is 13.32 Ykr/kWh) (8,8 cent/ kWh is assumed). Table 6.4. gives revenue for each power.

Table 6.4.Revenue Summary for each power

Power(kW)	Revenue($/year))
20.000	13.104.960
40.000	26.209.920
60.000	39.314.880

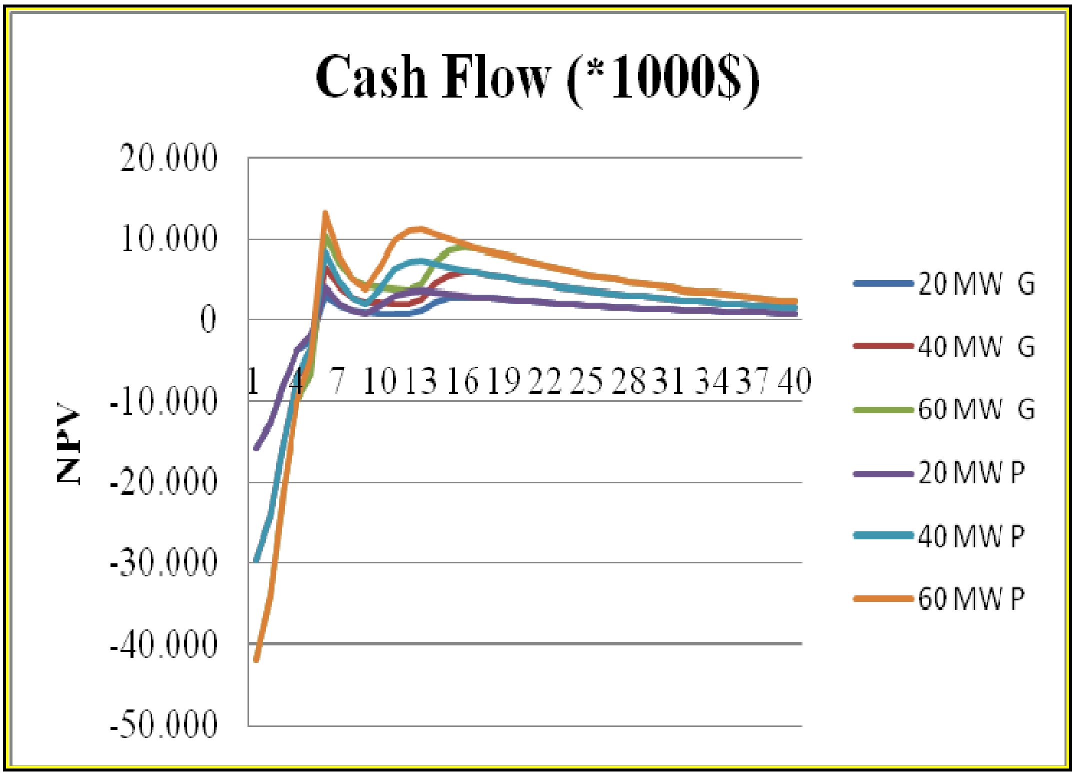


Figure 6.4.Cash flow graph for each project.

The break-even point is generally described as the point in which total revenue obtained is the same as the total costs related to the sale of the product (TR = TC). This break-even point is essential in determining whether selling a proposed product will be more profitable instead of trying to modify an existing product in order to make it profitable. The potential profitability of an expenditure in a sales-based business can be analyzed by break-even analysis as well.According Figure 6..4. sixth year is break-even point.

6.3. Cost of Money Calculation

It assumed that the power plant construction lasts 5 years, and the expens distrubition is as follows: 35% in first year, 30% in second years,20% third years, 10% fourth years and 5% last years. In addition, it was accapted debt term of four grace loan total 12 years. First four years, repayment of principal amount, and repayment of interest are not. Table 6.5. gives a this flow.

Table 6.5.Repayment of principal amount and repayment interest amount

Year	Loan		Interest payment	Principal payment
0	A			0
1	B			0
2	C			0
3	D			0
4	E		A_1	A_1
5			A_2+B_1	A_2+B_1
6			$A_3+B_2+C_1$	$A_3+B_2+C_1$
7			$A_4+B_3+C_2+D_1$	$A_4+B_3+C_2+D_1$
8			$A_5+B_4+C_3+D_2+E_1$	$A_5+B_4+C_3+D_2+E_1$
9			.	.
.			.	.
.			.	.
.			.	.
n			.	.

It is calculated for two scenario principal payment and interest payment. Fig. Fig.6.5., Fig.6.6., Fig6.7., Fig.6.8., Fig.6.9., and Fig.6.10. give project payment.

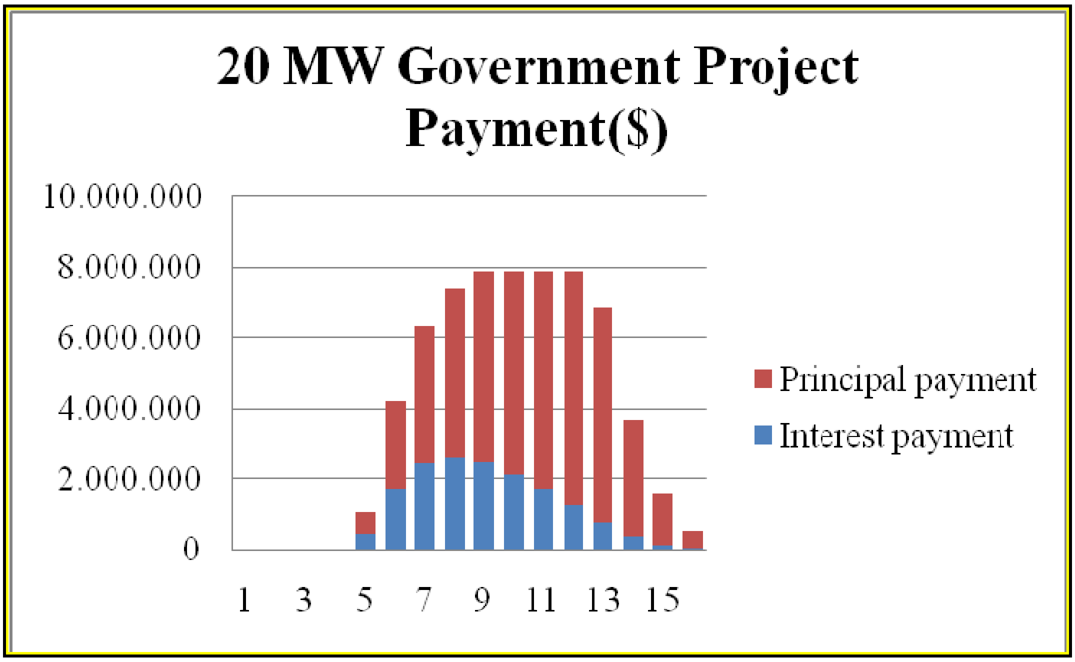


Figure 6.5. 20 MW government project payment

Extending the period of repayment can be considered as increasing the number of deferences. In this case, the smaller each deferred annuity is, the smaller the total amount of reimbursement becomes. However, if the debt period is reduced, the value of the capital reimbursement increases and this means that the amount of each annuity payment increases as well.

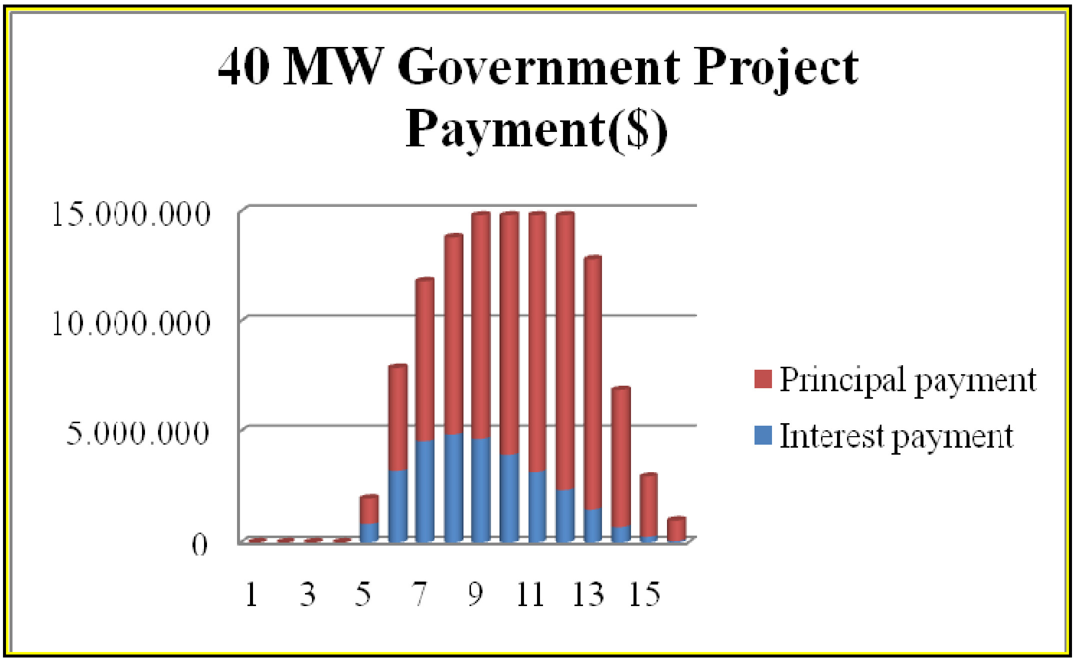


Figure 6.6. 40 MW government project payment

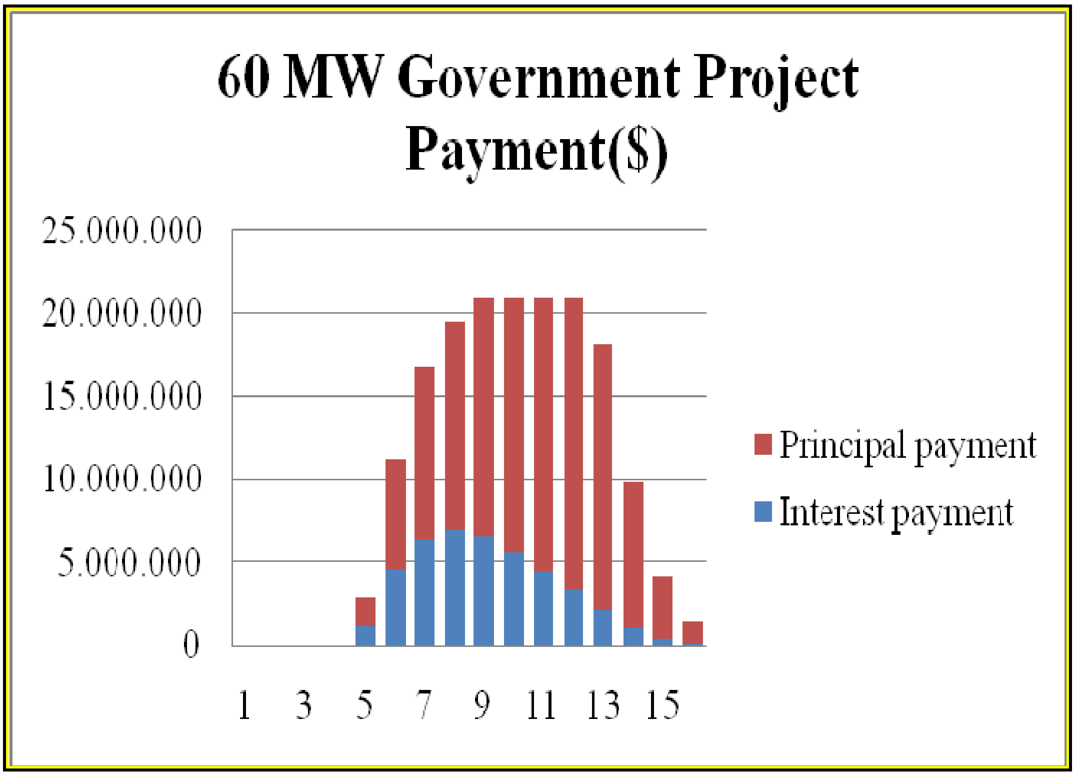


Figure 6.7. 60 MW government project payment

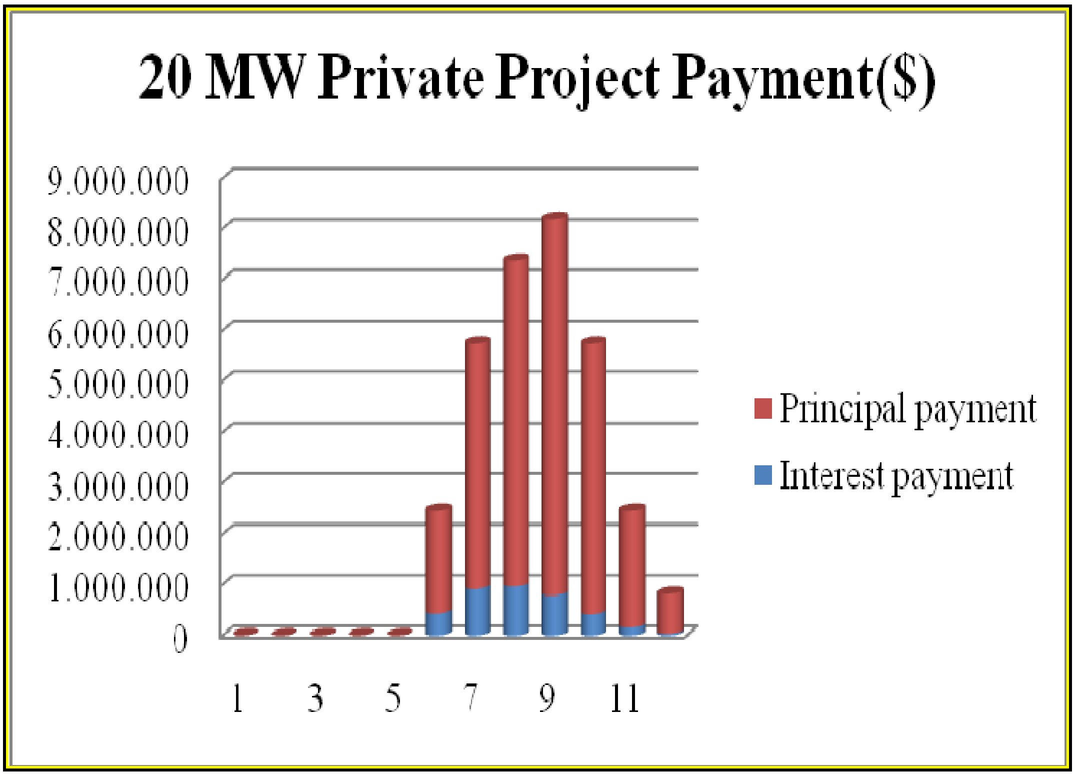


Figure 6.8. 20 MW private project payment

Factors such as the amount of the initial capital investment, where the invested money comes from and how it is protected are bound to effect the final cost of the power plant. The cost of the borrowed money is related to the interest rate and the length of the debt period, both of which might vary considerably according to changing conditions and circumstances.

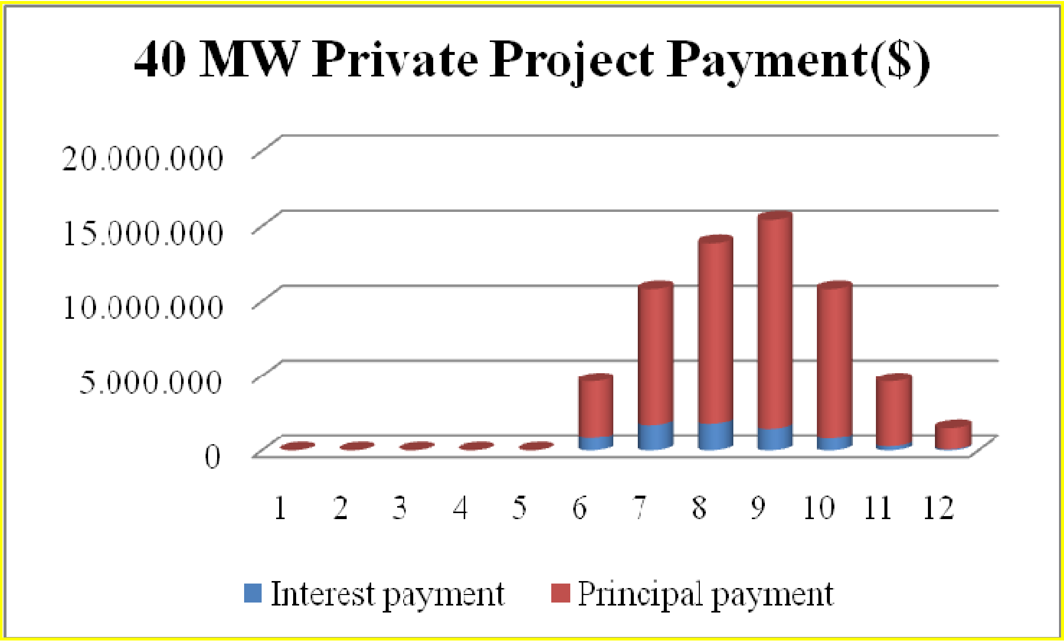


Figure 6.9. 40 MW private project payment

It is widely known that debt is usually obtained from sources which prefer to stay away from risks. That's why, money lenders, for example commercial banks, are always the first to recover their money if a project fails. For this reason, their interest rate is low at about 5-8%.

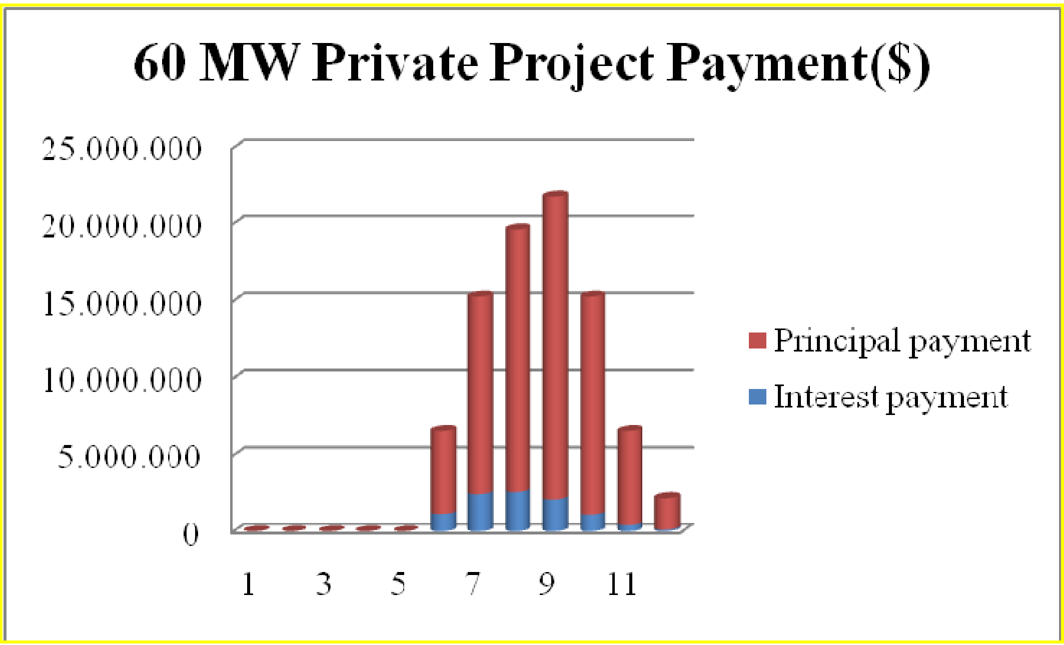


Figure 6.10. 60 MW private project payment

6.4. Sensitivity Analysis

After having established a base case it is important to determine how each of major componenets of the project such as revenue, operating and maintanence cost and capital cost affect its value. Sensitivity analysis can project how changes in the selected cost items would impact on the cost analysis of the different size power plant under consideration An example varience analysis is presented Table 6.6.,Tablo 6.7. and Fig 6.11., Fig. 6.12 and Fig 6.13.

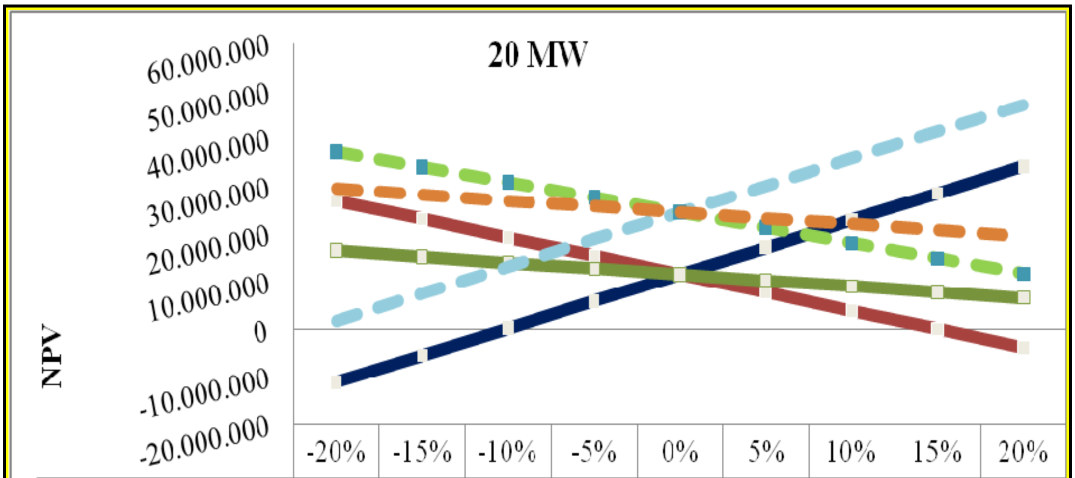
Table 6.6.Varience analysis summary for government project

		Government 20 MW		Government 40 MW		Government 60 MW	
Variable&Varience		NPV($)	IRR	NPV($)	IRR	NPV($)	IRR
Base Case		0,00	7,29%	0,00	8,01%	0,00	8,74%
Price	-20%	11.150.083,83	4,66%	-10.737.819,80	5,33%	64.492,31	6,00%
	-15%	-5.470.953,44	5,35%	620.440,98	6,04%	17.101.883,48	6,73%
	-10%	208.176,95	6,02%	11.978.701,76	6,72%	34.139.274,65	7,42%
	-5%	5.887.307,34	6,67%	23.336.962,54	7,38%	51.176.665,81	8,09%
	0%	11.566.437,73	7,29%	34.695.223,32	8,01%	68.214.056,98	8,74%
	5%	17.245.568,12	7,89%	46.053.484,10	8,62%	85.251.448,15	9,37%
	10%	22.924.698,51	8,47%	57.411.744,87	9,22%	102.288.839,32	9,99%
	15%	28.603.828,90	9,04%	68.770.005,65	9,80%	119.326.230,49	10,58%
	20%	34.282.959,29	9,59%	80.128.266,43	10,37%	136.363.621,65	11,16%
Capital Cost	-20%	26.987.525,53	9,54%	63.741.213,94	10,35%	109.245.782,70	11,17%
	-15%	23.132.253,58	8,90%	56.479.716,28	9,68%	98.987.851,27	10,48%
	-10%	19.276.981,63	8,32%	49.218.218,63	9,08%	88.729.919,84	9,85%
	-5%	15.421.709,68	7,78%	41.956.720,97	8,52%	78.471.988,41	9,28%
	0%	11.566.437,73	7,29%	34.695.223,32	8,01%	68.214.056,98	8,74%
	5%	7.711.165,78	6,83%	27.433.725,66	7,53%	57.956.125,55	8,25%
	10%	3.855.893,82	6,40%	20.172.228,01	7,09%	47.698.194,12	7,79%
	15%	621,87	6,00%	12.910.730,35	6,68%	37.440.262,69	7,36%
	20%	-3.854.650,08	5,62%	5.649.232,70	6,29%	27.182.331,27	6,96%
O&M Cost	-20%	16.548.583,93	7,82%	44.143.231,15	8,52%	81.689.084,54	9,24%
	-15%	15.303.047,38	7,68%	41.781.229,19	8,40%	78.320.327,65	9,12%
	-10%	14.057.510,83	7,55%	39.419.227,23	8,27%	74.951.570,76	8,99%
	-5%	12.811.974,28	7,42%	37.057.225,27	8,14%	71.582.813,87	8,87%
	0%	11.566.437,73	7,29%	34.695.223,32	8,01%	68.214.056,98	8,74%
	5%	10.320.901,18	7,15%	32.333.221,36	7,88%	64.845.300,09	8,62%
	10%	9.075.364,63	7,02%	29.971.219,40	7,75%	61.476.543,20	8,49%
	15%	7.829.828,07	6,88%	27.609.217,44	7,62%	58.107.786,31	8,36%
	20%	6.584.291,52	6,74%	25.247.215,49	7,48%	54.739.029,42	8,23%

Table 6.7. Varience analysis summary for private project

		Private 20 MW		Private 40 MW		Private 60 MW	
Variable&Varience		NPV($)	IRR	NPV($)	IRR	NPV($)	IRR
Base Case		0,00	9,02%	0,00	9,78%	0,00	10,55%
Price	-20%	1.834.820,91	6,25%	13.719.561,29	6,96%	34.614.133,44	7,67%
	-15%	7.513.951,30	6,98%	25.077.822,06	7,71%	51.651.524,61	8,43%
	-10%	13.193.081,69	7,69%	36.436.082,84	8,42%	68.688.915,78	9,16%
	-5%	18.872.212,08	8,37%	47.794.343,62	9,11%	85.726.306,95	9,87%
	0%	24.551.342,46	9,02%	59.152.604,40	9,78%	102.763.698,11	10,55%
	5%	30.230.472,85	9,65%	70.510.865,18	10,43%	119.801.089,28	11,21%
	10%	35.909.603,24	10,27%	81.869.125,96	11,05%	136.838.480,45	11,85%
	15%	41.588.733,63	10,86%	93.227.386,74	11,66%	153.875.871,62	12,48%
	20%	47.267.864,02	11,44%	104.585.647,51	12,25%	170.913.262,79	13,08%
Capital Cost	-20%	37.375.449,32	11,38%	83.307.118,81	12,23%	136.885.495,60	13,09%
	-15%	34.169.422,61	10,72%	77.268.490,20	11,54%	128.355.046,23	12,37%
	-10%	30.963.395,89	10,11%	71.229.861,60	10,91%	119.824.596,86	11,72%
	-5%	27.757.369,18	9,54%	65.191.233,00	10,32%	111.294.147,49	11,11%
	0%	24.551.342,46	9,02%	59.152.604,40	9,78%	102.763.698,11	10,55%
	5%	21.345.315,75	8,54%	53.113.975,80	9,28%	94.233.248,74	10,03%
	10%	18.139.289,03	8,09%	47.075.347,20	8,81%	85.702.799,37	9,55%
	15%	14.933.262,32	7,66%	41.036.718,60	8,38%	77.172.350,00	9,10%
	20%	11.727.235,61	7,27%	34.998.089,99	7,97%	68.641.900,62	8,67%
O&M Cost	-20%	29.533.488,67	9,58%	68.600.612,23	10,32%	116.238.725,67	11,08%
	-15%	28.287.952,12	9,44%	66.238.610,27	10,19%	112.869.968,78	10,95%
	-10%	27.042.415,57	9,30%	63.876.608,31	10,05%	109.501.211,89	10,82%
	-5%	25.796.879,02	9,16%	61.514.606,36	9,92%	106.132.455,00	10,68%
	0%	24.551.342,46	9,02%	59.152.604,40	9,78%	102.763.698,11	10,55%
	5%	23.305.805,91	8,88%	56.790.602,44	9,65%	99.394.941,22	10,42%
	10%	22.060.269,36	8,74%	54.428.600,49	9,51%	96.026.184,33	10,29%
	15%	20.814.732,81	8,59%	52.066.598,53	9,37%	92.657.427,44	10,15%
	20%	19.569.196,26	8,45%	49.704.596,57	9,23%	89.288.670,55	10,01%

Price and Revenue: Revenue is the only positive component of the cash flow. It is largely determined by selling price, but the change in production will also have a parallel effect.



	-20%	-15%	-10%	-5%	0%	5%	10%	15%	20%
Price (G)	-11.150	-5.470.	208.177	5.887.3	11.566.	17.245.	22.924.	28.603.	34.282.
Capital Cost (G)	26.987.	23.132.	19.276.	15.421.	11.566.	7.711.1	3.855.8	622	-3.854.
O&M Cost (G)	16.548.	15.303.	14.057.	12.811.	11.566.	10.320.	9.075.3	7.829.8	6.584.2
Price (P)	1.834.8	7.513.9	13.193.	18.872.	24.551.	30.230.	35.909.	41.588.	47.267.
Capital Cost (P)	37.375.	34.169.	30.963.	27.757.	24.551.	21.345.	18.139.	14.933.	11.727.
O&M Cost (P)	29.533.	28.287.	27.042.	25.796.	24.551.	23.305.	22.060.	20.814.	19.569.

Figure 6.11. Sensitivity graph for 20 MW power plant (NPV)

Operating Costs: The cash flow is a direct function of the margin between revenue and operating costs, so operating costs produce a strong impact on the cash flow and the return.

Capital: Capital is the input at the very beginning of a project and has a high negative influence on the discounted cash flow as the following positive cash flows are increasingly discounted the further away they are in time.

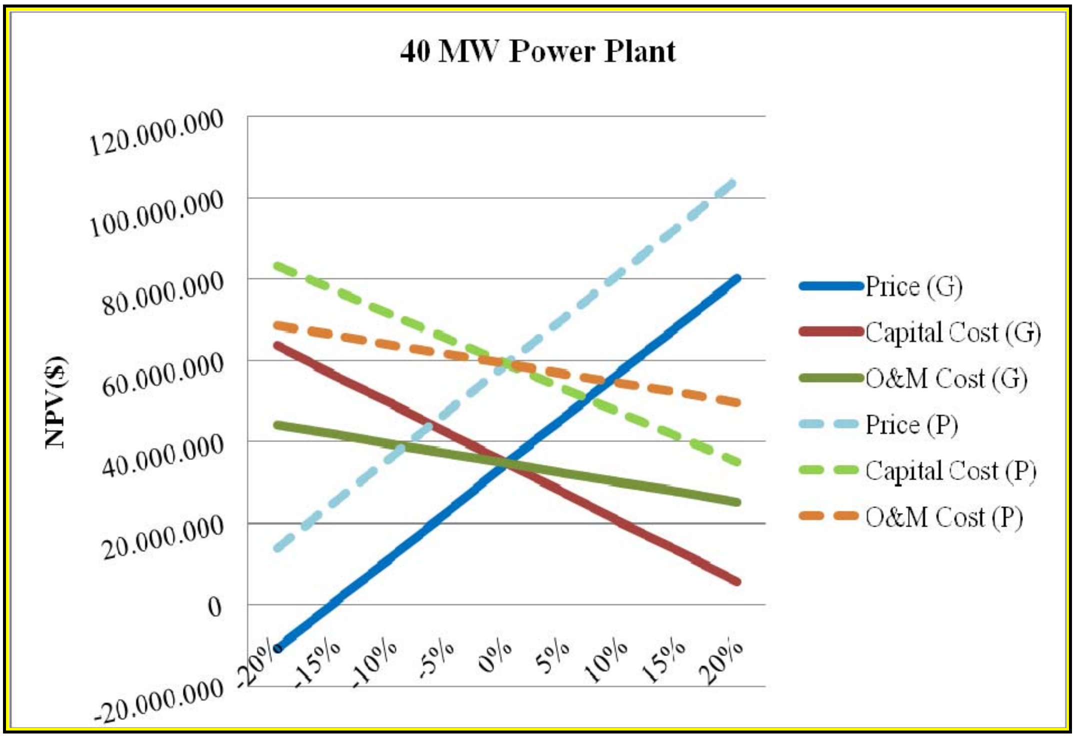


Figure 6.12. Sensitivity graph for 40 MW power plant. (NPV)

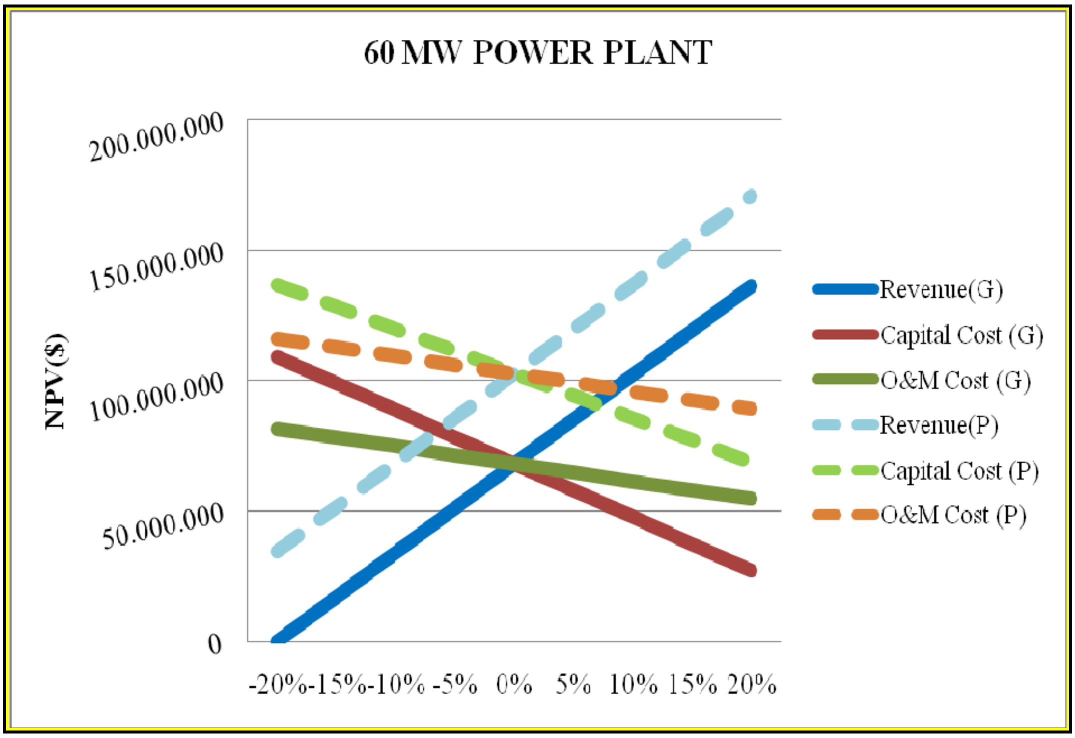
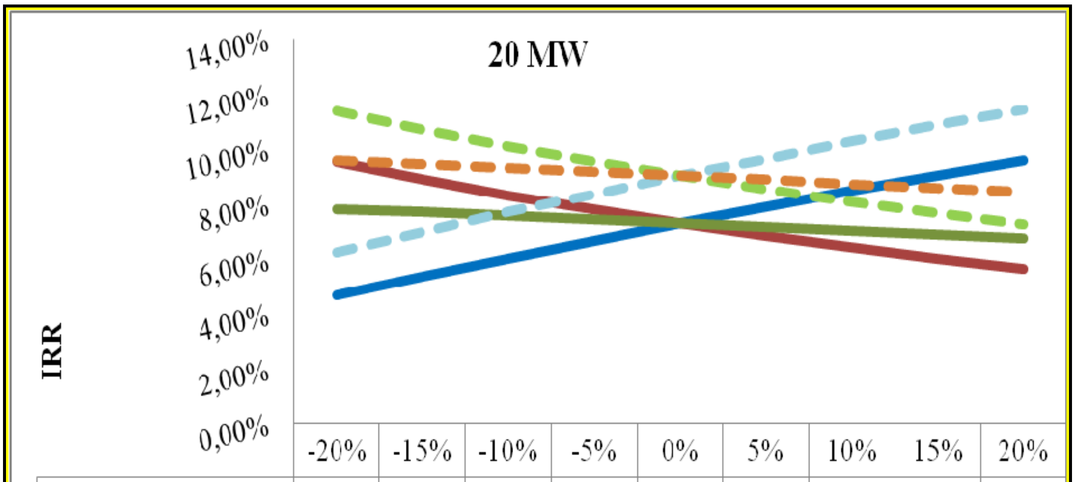
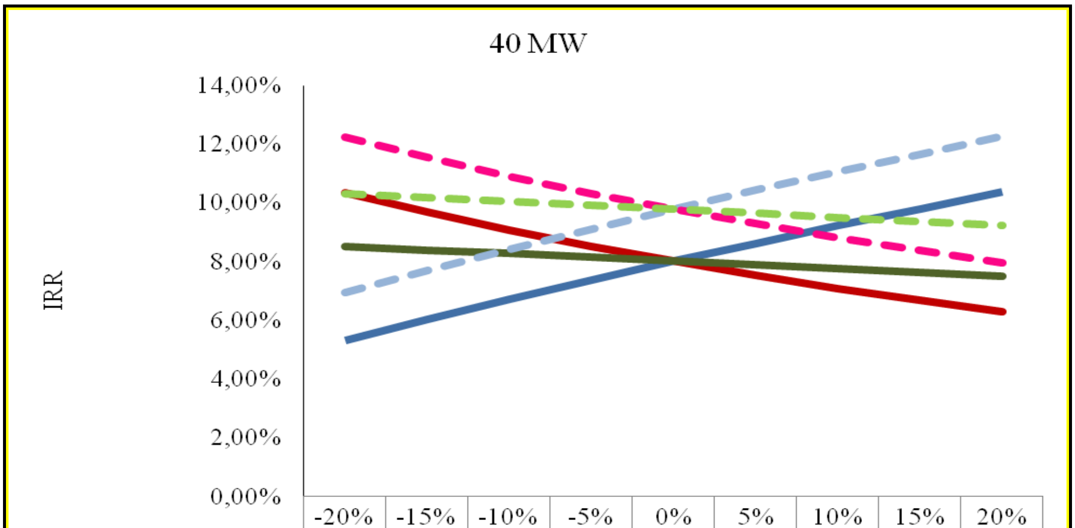


Figure 6.13. Sensitivity graph for 60 MW power plant(NPV)



	-20%	-15%	-10%	-5%	0%	5%	10%	15%	20%
Price (G)	4,66%	5,35%	6,02%	6,67%	7,29%	7,89%	8,47%	9,04%	9,59%
Capital Cost (G)	9,54%	8,90%	8,32%	7,78%	7,29%	6,83%	6,40%	6,00%	5,62%
O&M Cost (G)	7,82%	7,68%	7,55%	7,42%	7,29%	7,15%	7,02%	6,88%	6,74%
Price (P)	6,25%	6,98%	7,69%	8,37%	9,02%	9,65%	10,27%	10,86%	11,44%
Capital Cost (P)	11,38%	10,72%	10,11%	9,54%	9,02%	8,54%	8,09%	7,66%	7,27%
O&M Cost (P)	9,58%	9,44%	9,30%	9,16%	9,02%	8,88%	8,74%	8,59%	8,45%

Figure 6.14. Sensitivity graph for 20 MW power plant (IRR)



	-20%	-15%	-10%	-5%	0%	5%	10%	15%	20%
Price (G)	5,33%	6,04%	6,72%	7,38%	8,01%	8,62%	9,22%	9,80%	10,37%
Capital Cost (G)	10,35%	9,68%	9,08%	8,52%	8,01%	7,53%	7,09%	6,68%	6,29%
O&M Cost (G)	8,52%	8,40%	8,27%	8,14%	8,01%	7,88%	7,75%	7,62%	7,48%
Price (P)	6,96%	7,71%	8,42%	9,11%	9,78%	10,43%	11,05%	11,66%	12,25%
Capital Cost (P)	12,23%	11,54%	10,91%	10,32%	9,78%	9,28%	8,81%	8,38%	7,97%
O&M Cost (P)	10,32%	10,19%	10,05%	9,92%	9,78%	9,65%	9,51%	9,37%	9,23%

Figure 6.15. Sensitivity graph for 40 MW power plant (IRR)

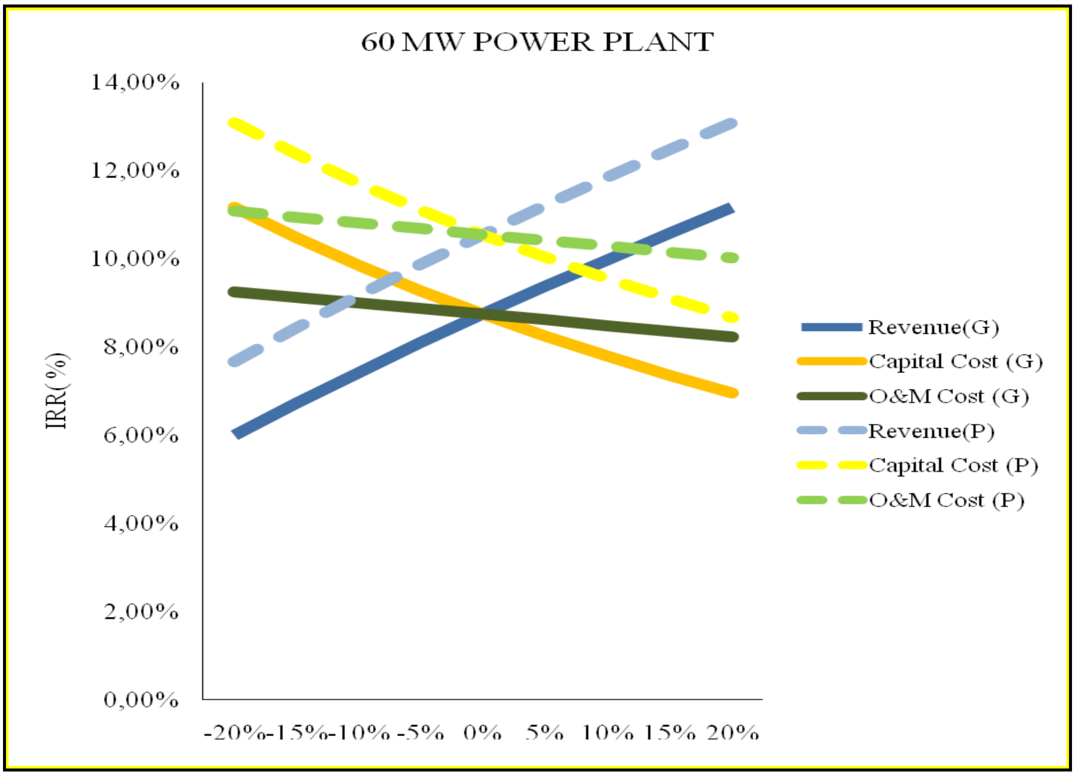


Figure 6.16. Sensitivity graph for 60 MW power plant (IRR)

Discount rate is a key factor in project evaluation. The selection of the discount rate has announced in the previous chapters. Between NPV and IRR values is a simple mathematical relationship, but in both methods to establish investment criteria requires the definition of an appropriate discount rate. Fig.6.17., Fig.6.18., and Fig 6.19. show the changes NPV when discount rate changes.

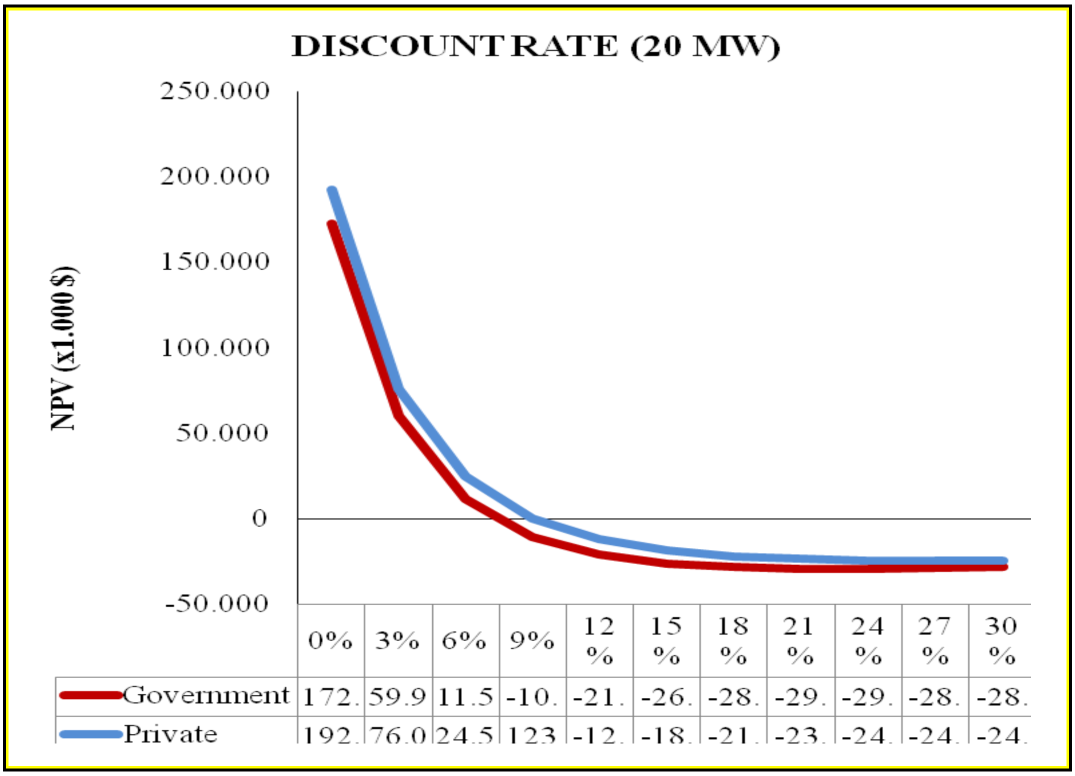


Figure 6.17. NPV versus discount rate for 20 MW power plant

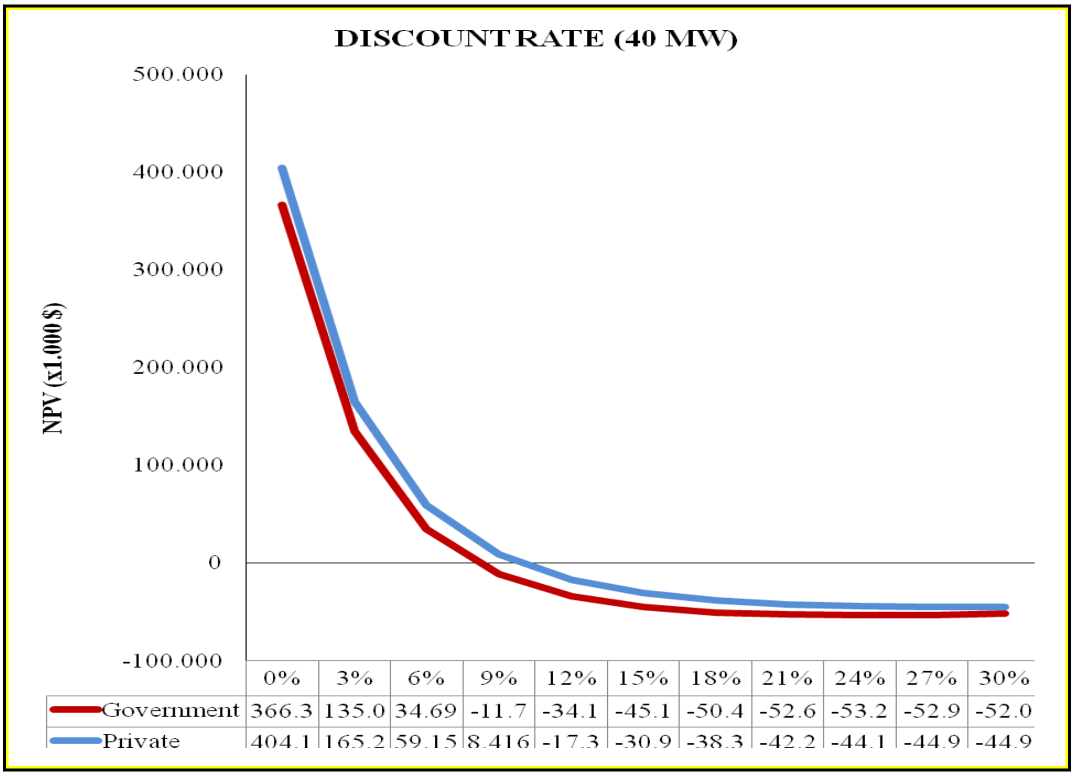


Figure 6.18. NPV versus discount rate for 40 MW power plant

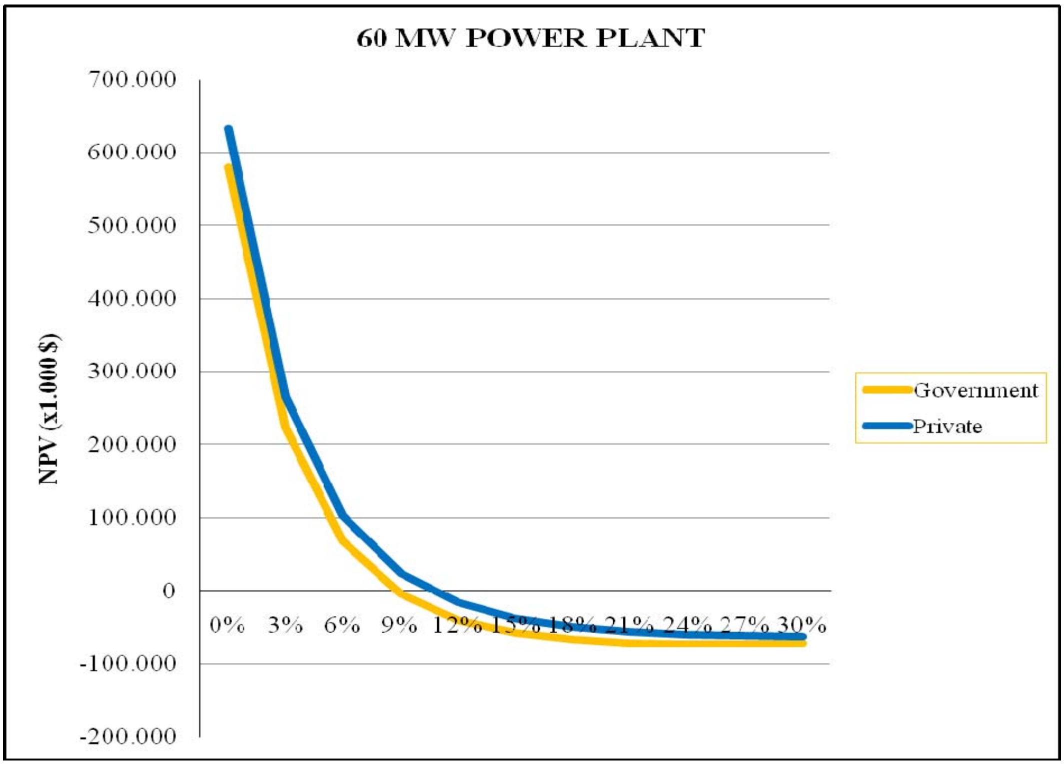


Figure 6.19. NPV versus discount rate for 60 MW power plant

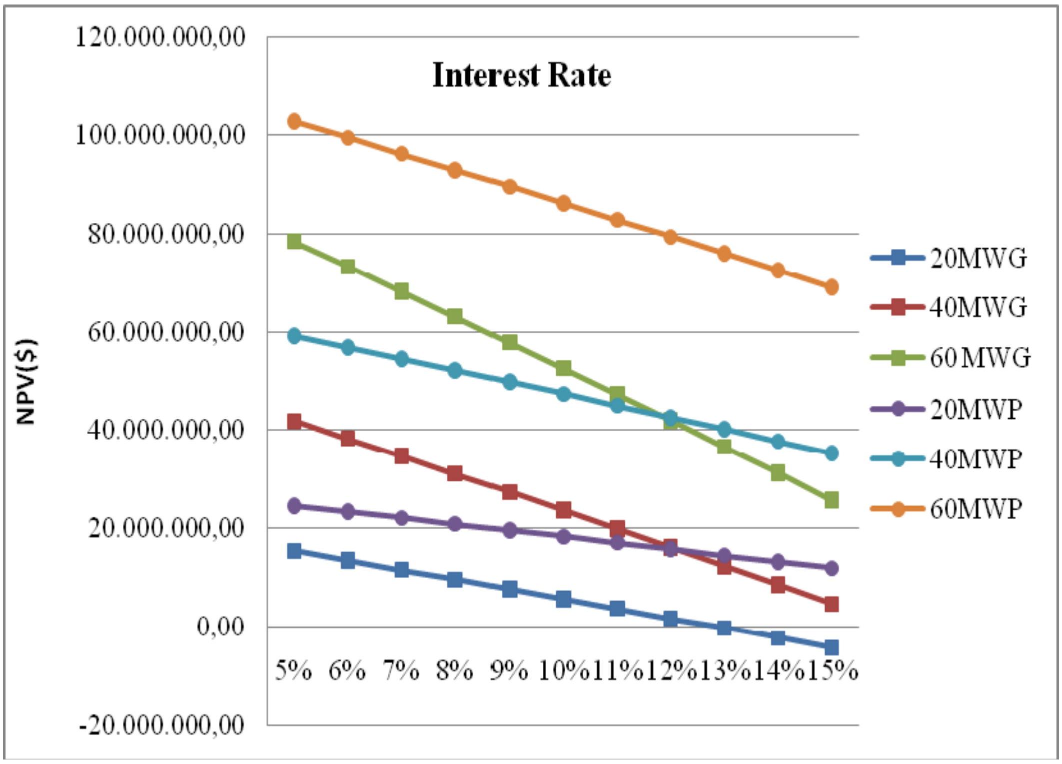


Figure 6.20. NPV via debt interest rate

Basically, interest rates consist of the average cost of borrowing money (e.g. LIBOR) to which the lender adds a compensation for the risk associated with its use. Figure 6.20. shows the influence of interest rate to economic parameters like NPV when electric sales price 8,8 cent per kWh and discount rate is 6%.Interest rate have high effect on NPV.

Table.6.8. Summary of all alternatives

	Government Project			Private Project		
	20 MW	40 MW	60 MW	20 MW	40 MW	60 MW
Total revenue($)	151.771.048	283.956.519	425.934.779	151.771.048	283.956.519	425.934.779
Total cost ($)	73.591.582	139.011.615	197.176.373	58.185.149	109.993.226	156.183.639
Simple payback period(years)	9	8	8	9	8	8
Discounted payback period(years)	10	9	9	10	9	9
Benefit-cost ratio	2,06	2,04	2,16	2,60	2,58	2,73
Unit energy cost (cent/kWh)	4,33	4,10	3,88	3,80	3,59	3,40

Unit energy cost is the most important criteria to choose between power plant alternatives. The effect of all technical and economical parameters are evaluated considering this cost. The factors that effect unit energy production are as follows: thermic productivity, fuel type and price, power of plant, construction period and range of expenses during construction, investment cost, interest, escalation and reduction rates and payback period. Energy production cost can be summarized as investment, operation and maintenance costs. Unit energy production cost is calculated by dividing expences within a period by the produced amount of energy within the same period. Unit energy production values for alternatives are given in summary Table 6.8.

$$g = \frac{\sum_{t=-L}^{n}[c_k(t)+c_f(t)+c_m(t)](1+r)^{-t}}{E\sum_{t=1}^{n}(1+r)^{-t}} \qquad (7.1)$$

Here, Ck(t), Cf(t), and Cm(t) are respectively time dependent annual capital, fuel, and operation and maintenance costs; r is discount rate, n is the life of span and finally L is the construction period.

If annual energy production is a function of time, in other words if it changes year after year, equivalent unit energy production cost is calculated by the following equation:

$$g = \frac{\sum_{t=-L}^{n} [C_k(t) + C_f(t) + C_m(t)](1+r)^{-t}}{\sum_{t=1}^{n} E(t)(1+r)^{-t}} \tag{7.2}$$

A benefit-cost ratio analysis (BCR), which is useful for evaluation of investment projects in terms of their effectiveness, is a technique. All benefits and costs should be represent in discounted present values. As a result, for every dollar invested in the 60 MW geothermal private project it returned almost 2.73 $ after one year of use.

Simple payback is the amount of time it will take to recover installation costs based on annual energy cost savings. The equation for simple payback is annual energy cost savings per year divided by the initial installation cost. Simple payback won't provide information about a project's profitability; only how long it takes to recoup the investment.

CHAPTER 7

CONCLUSIONS

Evaluation of investment projects is divided into two as economical evaluation and financial evaluation. Financial evaluation, aims at searching whether projects estimated to be profitable will smoothly run or not with their current financial positions. In this type of evaluation, where the financial sources of the project come from and its cash flow are also examined.

In this study, NPV, IRR and discount payback methods have been used. These methods are among investment making decision techniques and they all consider the time value of money. A financial plan has been formed after examining and considering bank loan conditions applied in renewable energy sources in Turkey. In addition, the financial structure of the investment has been used as a means of converting capital cost into unit cost. Time value of money has also been considered while estimating unit energy cost.

The capital cost and O&M costs were calculated with Sanyal's formules that declare the mathematical relation between power plant size and costs in this analysis. As the law suggests, the price of electricity for each year is the average wholesale price of the previous year determined by EPDK. The price for 2010 is 13.32 Ykr/kWh. Therefore electric sales price was assumed 8,8 cent/ kWh in this thesis.

Two scenarios for three different size geothermal plants have been designed. The first scenario has been planned as a government project and unit energy costs have been estimated as 4,33 cent/kWh, 4,10 cent/kWh, and 3,88 cent/kWh for 20MW, 40MW, and 60MW respectively. In the second scenario, which has been designed as a private sector project, the figures have been estimated as 3,80cent/kWh, 3,59 cent/kWh, and 3,40 cent/kWh. It has been concluded that the size of the plant, the structure of the capital, the length of the repayment and interest rate have an effect on unit energy cost.

Positive NPV value was obtained for each of two scenarios. However, if private project and government project compare with each other, ıt was seen that private projects have high NPV values, but they have less unit energy costs than goverment ones. In other words, private projects much more feasible than government projects.

This result can be associated with equity-dept stability of capital. According to the obtained results, of all the alternatives the best result is the 60 MW private project. In this project, when electric sales price is taken as 8,8 cent per kWh, NPV has been calculated as 102.763.698$ and IRR as 10,55 %. Furthermore, discount payback has been obtained as 9 years and the benefit cost ratio as 2,73 for the same project.

The blind side of this thesis is that it does not cover the changing factors such as electric sales price, O&M cost, and renovation cost over time. Whereas with a more detailed study, the forthcoming values of them would be estimated with the help of analysis related to their previous value. Consequently, more exact value could be achieved by taking these factors as a founction of time for the calculation of unit energy cost.

Although geothermal energy by itself is not potentially rich enough to meet the electricity demand of Turkey, it is obvious that it will contribute significantly to the economy of the country. Being an alternative way of existence energy resources is of importance at this point. In addition, geothermal energy has more advantages than other energy resources. In spite of its high investment cost, its operating and maitanence costs are low. Producing energy non-stop apart from their maintanance periods and unless are another advantages of geothermal energy. Besides, they are not effected by changes in fuel prices as in natural gas plants. Having a 100% reliability of installed power is another advantage of this energy type. The last advantage that can be counted for geothermal energy is that a great portion of geothermal plant costs occur during construction period, local economies are positively effected by these investments.

To sum up, there are high expectations that energy requirements of the future will be more regenerative and sustainable. Geothermal energy by itself is not potentially rich enough to meet the electricity demand of Turkey. However, it is obvious that it will contribute significantly to the economy of the country. Unit energy cost calculations are of importance on geothermal projcets. In this thesis study, how unit energy cost changes depending on financial structure and the size of power plant.

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