D.E.Ü. İ.İ.B.F. Dergisi
Cilt: 10, Sayı: II, 1995, ss.187-199

ECONOMİC ANALYSIS OF ALTERNATIVE SYSTEMS FOR CHOOSING OF OPTIMUM DOMESTIC HOT WATER GENERATION (*)

H.Ahmet AKDENİZ (**) Gürbüz ATAGÜNDÜZ (***)

ÖZET

Bu çalışmada; Ege Üniversitesi Güneş Enerjisi Enstitüsü'nce geliştirilerek verim deneyleri yapılan beton ve normal güneş kollektörleri, diğer sıcak su üreten sistemlerle karşılaştırılarak, ekonomik analizi yapılmıştır. Güneş Enerjili sıcak su üreten sistemlerle diğer alternatif sistemleri karşılaştırılabilmek için, Akdeniz (1)'deki ekonomik analiz modeli kullanılmıştır. İki değişik senaryo sonuçları göstermiştir ki, İzmir'de var olan meteorolojik şartlarda en iyi alternatif "Tüpgaz sistemi takviyeli beton güneş kollektörü sistemi"dir.

INTRODUCTION

As known, in Turkey, about 43 % of the total energy consumption is used in buldings and 85 % of it is used for heating purposes. At the year 2000 it is estimated that the energy consumption in Turkey will reach to about 120 millions tons equal petrol (TEP). About 49.5 % of it will be imported. It is further estimated that within the time period of 1987 to 2000 the yearly energy production increase year about 5.6 % where the energy consumption rate should be about 604 %. Therefore it will be wise to support the research and investions for alternative energy sources and to reduce the imported primary energy sources in order to balance the energy deficit in Turkey.

Going from this stand point of view, in the Solar Energy Institute of the University Ege, Concrete Collectors have been developed and their capability of competitions have been proofed.

The previous works on concrete collectors by Aykut (1), Atagündüz (2) and (3), Ayvaz (4), Erdiş (5) and Gökgöz (6) have evaluted in order to make an economic analysis of concrote collectors. For this purpose first a fall, a program of the Computer Center of the University Ege "MINITAB" has been used in order to check statistically the data of the experiments with concrete collectors and the conventional solar flat plate collectors. Afterwards the economic analysis has been done.

STATISTICAL EVALUATION OF EXPERIMENTAL DATA

It is well known that thermal efficiency cpefficient of a solar flat plate collector, gives the part of the energy of the total solar insolation on to the

(*) Environment and Economy International Symposium, 20-23 Ağustos 1991, BAKÜ'de sunulmuştur
(**) Yard.Doç.Dr., D.E.Ü., İ.İ.B.F. Ekonometri Bölümü
(***) Prof.Dr. Ege Üniversitesi G.E.E.

collector which is absorbed by the collector fluid. Usually it is plotted versus the value which is the ratio of a temperature value is: (collector fluid inlet temperatur+collector fluid outlet temperatur)/2 - surrounding temperature.

The experimental data given by Atagündüz (2) and (3) has been statistically proofed using the computer program "MINITAB".

This program gives a certain relation for the thermal efficiency coefficient and the error matrix fir the corresponding data for each measurment the Experimental data given by Gökgöz (6) for the time october 1989 yields thriugh the program MINITAB to the following relation:

C1 = 0.416 - 11.OC2. In some way the data Karakaş (10) to;

C3 =0.623 - 8.06C4 for the time October 1987, the data Erdiş (5) to;

C5 =0.428 - 16.4C6 for the time July 1984 and the data Karakaş(7) to;

C7 =0.459 + 1.89C8 for the time July 1987. Here C1, C3, C5 and C7 stand for the thermal efficiency coeffiicient and C2, C4, C6 and C8 for the expression x. These expressions have been tested on reliability according to Akdeniz (8). Reliability test told us that only the experiments from Gökgöz (6) October 1989 and Karakaş (7) October 1987 can be taken for economic analysis. The other ones may not be used for further calculations, Fig.1 to Fig. 4.

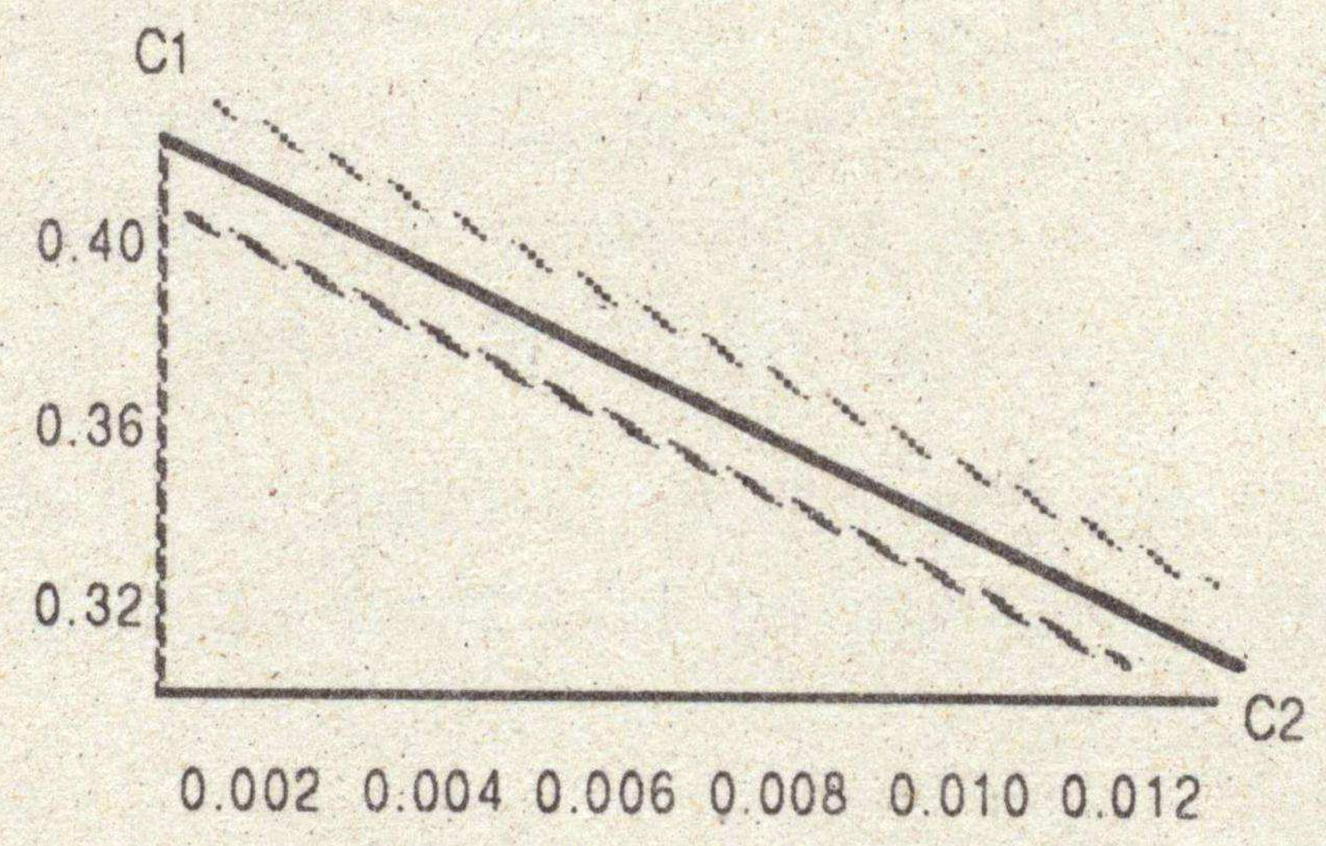

Fig.1 Gökgöz (6) - Experiments October 1984.

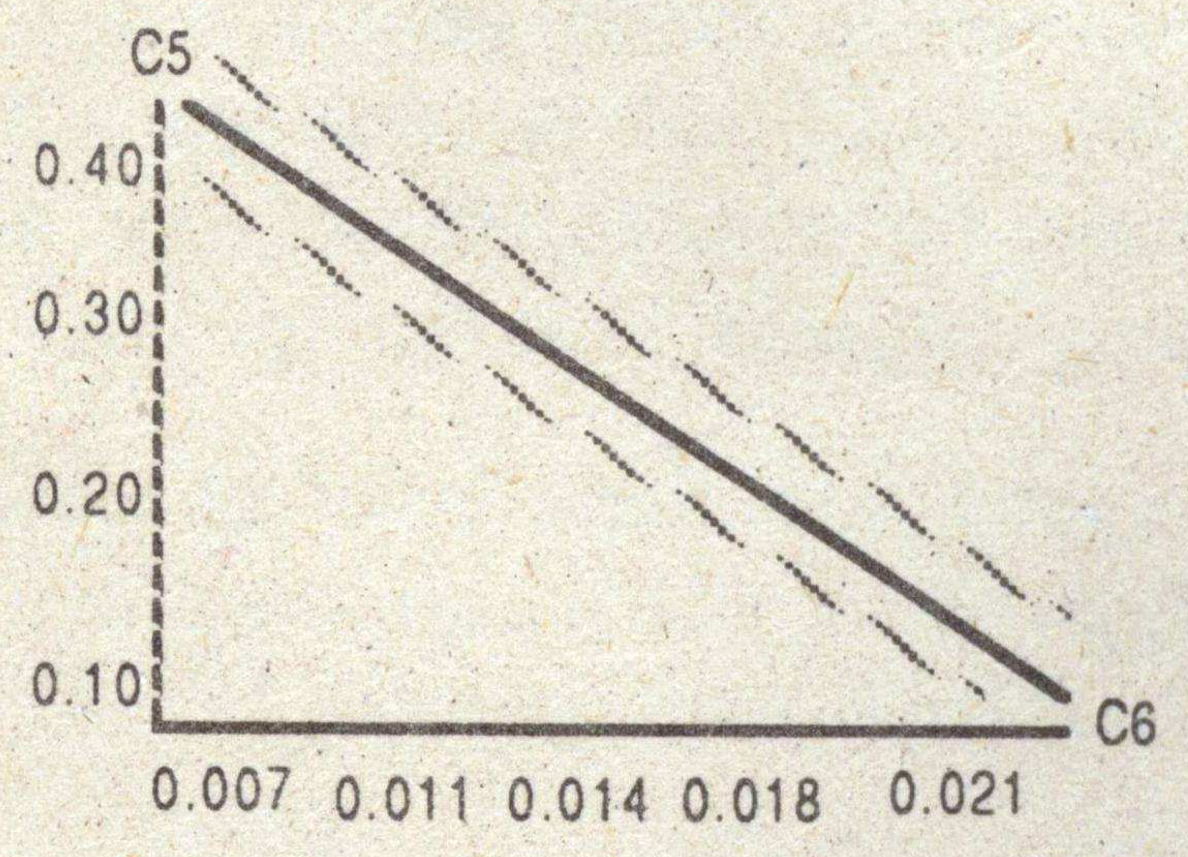

Fig. 2 Karakaş (7) - Experiments,October-1987.

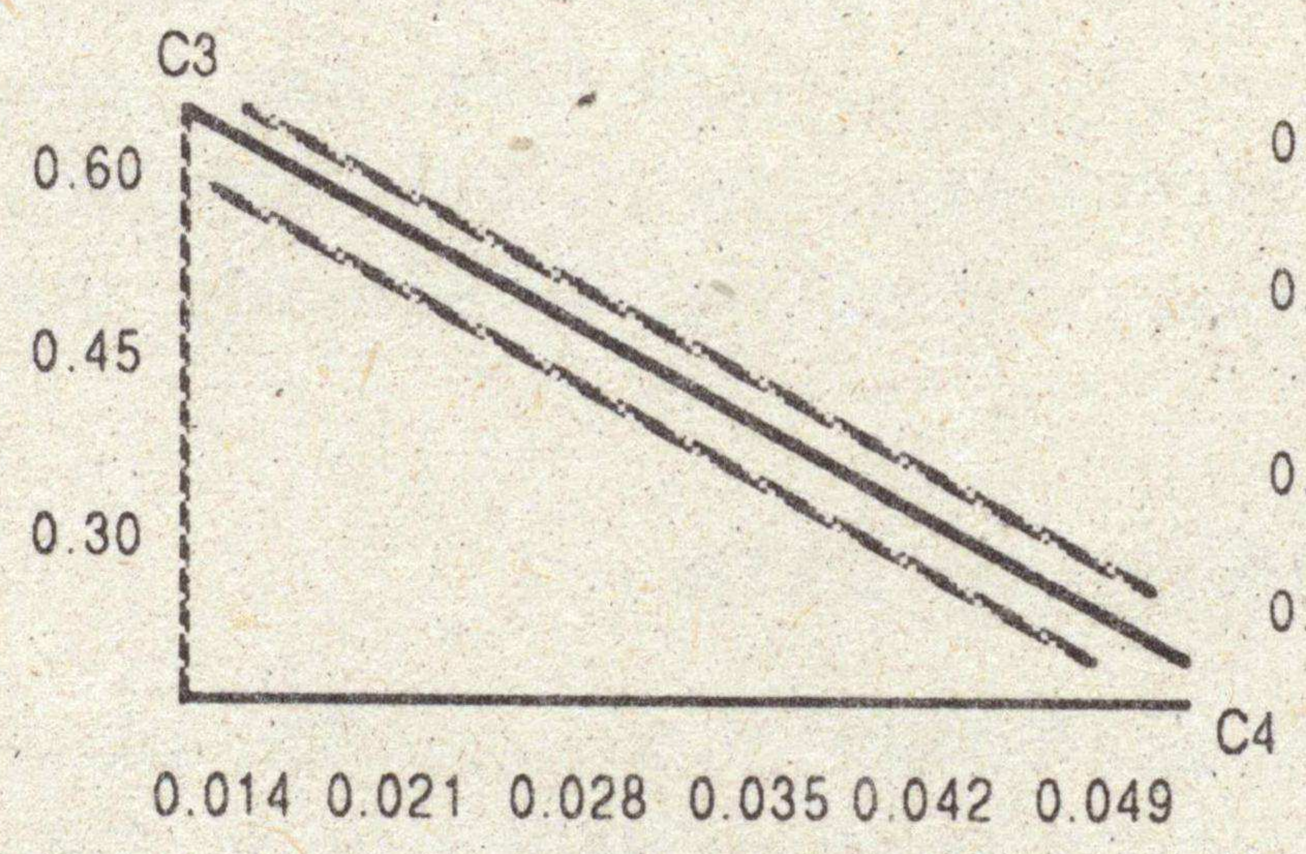

Fig. 3 Erdiş (5)-Experiments, July 1984.

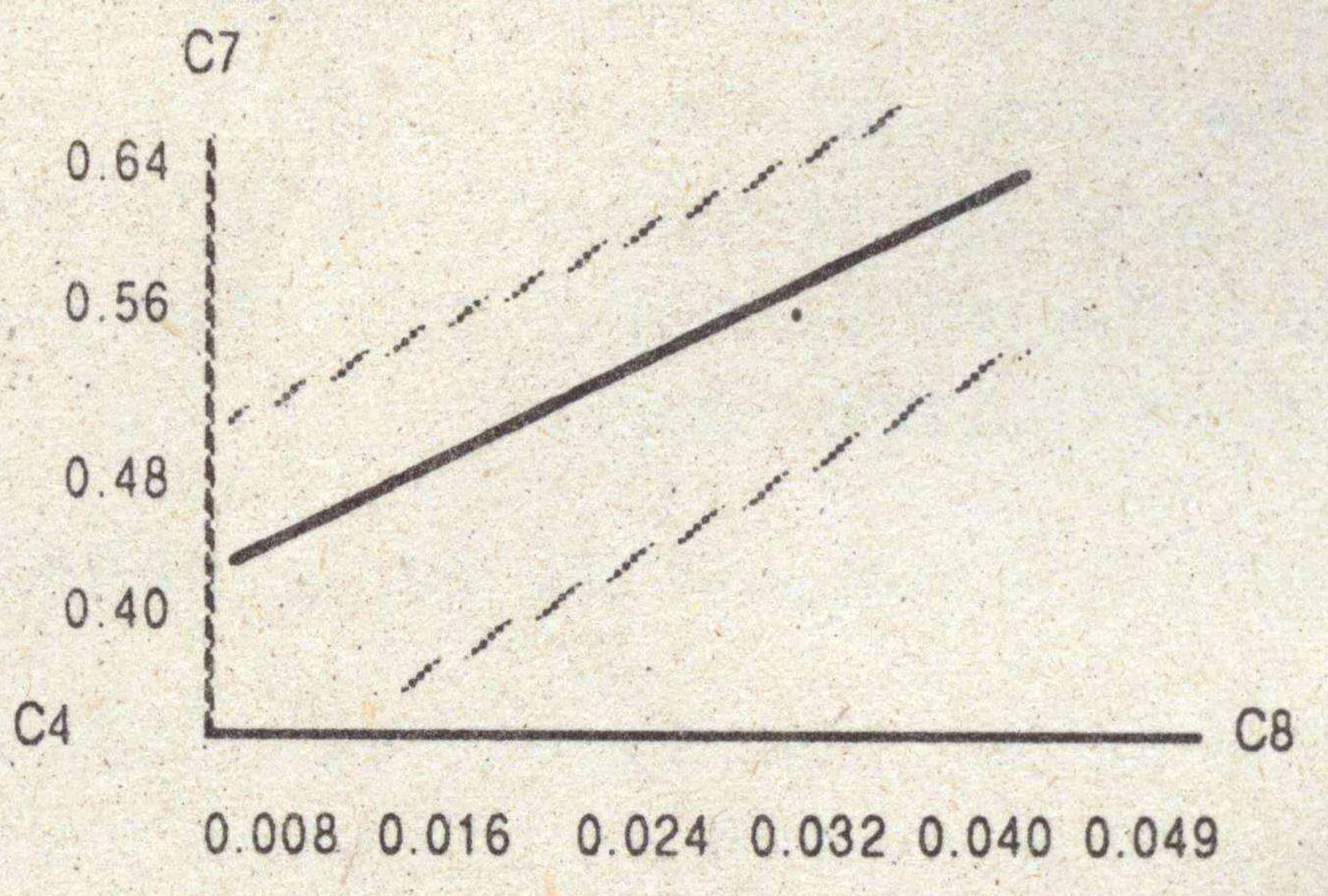

Fig.4 Karakaş (7)-Experiments,July 1987.

Legend for the Figures 1 to 4: ----- approximated line
...... reliability boundaries

The reliability band width with 95 % probability, determination coefficient in precent and the degree of freedom for the thermal efficiency coefficients given in Figures 4 are given in Table1. From Table 1 it is obvious that,only the date it the experiments from Gökgöz (6) October 1989 and Karakaş (78) October 1987 can be taken as a basis for economic analysis.

Table 1. Statistical evaluation of experimental data from Gökgöz (6), Karakaş (7) and Erdiş (5).

Figure number	Reliability Band Width	Determination Coefficient %	Degree of Freedom
1	0.405-0.428	56.1	12
2	0.614-0.626	76.3	39
3	0.230-0.626	90.5	2
4	0.423-0.495	14.4	52

ECONOMIC ANALYSIS OF SOLAR HOT WATER GENERATION

Life-cycle cost concept and net present value method according to Lawrance (9) and the modified form of it as "life-cycle cost concept with net present cost method" after Akdeniz (10) have been applied here in order to determine the hot water supply system with minimum costs as an optimum alternative. For this purpose, first of all it is necessary to determine the alternative hot water supply system. The following system have been choosen as alternative system.

1- Fuel-oil-fired boiler system,

2-Lignite-fired boiler-system,

3-Electrically heated boiler system,

4-LPG-fired boiler-system.

Thus, concrete and conventional solar collector system with an auxillary heating using electrical energy or LPG, there are eight hot water supply system to be considered.

This eight alternatives will be compared and the system with the minimum net present costs will be choosen as the optimum hot water supply system. For the economic analysis the following assumptions have been made.

- The economic life of the concrete collector should be 16 years.

- The changes of the price indicies of the fuels have been taken from the "İstanbul Ticaret Odası Verileri (Data of the Chamber of Commerce Istanbul)".

According to this assumptions two different scenarios have been developed:

a- Scenario I

Fuel price indicies between the years 1968-1989 have been taken in order to determine the change in fuel prices after 1989 within 16 years (1990-2005) through a regression analysis (10).

b- Scenario II

General price indicies between the years (1968-1989) have been taken in order to determine the change in fuel prices after 1989 within 16 years (1990-2005) through a regression analysis (10).

In the both scenarios, the calculations have been made with the following assumptions:

- The change ratios of the all other running costs should be equal to the change ratio of the fuel price

- The mean value of the calculated operating and maintenance costs for two years should be constant during the time period of the years,

- For the alternatives with 10 years of economic life, after years, the replacement costs should be equal to the half of the initial investment costs,

- Net present costs have been calculated with a interest rate of 35 % as the aritmetic mean value of the interst rates from 1970 tall 1989 given by the "Türkiye İş Bankası (Türkish Work Bank)".

And for each two years periods a 2 % that interst rate of 35 % a risk capital ratio has been whole economic life added during the

- Salvage value has been taken as zero.

Calculation of Initial Investment Costs

1- Fuel oil-fired boiler system:

In the table 2 the first investment costs for 2500 kg hot water per day (tenunit apartment building) have been given. Afterwards the costs for one family (one-unit) can be calculated from Table 2.

Table 2. Fuel oil-fired boiler system.

Item number	Item	Amount	Unit Price (TL)	Costs (TL)
-	Bolier(40000 kcal/h)	1 piece	2.760.000	2.760.000
-	Oil burner and preheater	1 piece	3.300.000	3.300.000
-	Hot water tank	1 piece	2.250.000	2.250.000
-	Coil	1 piece	1.700.000	1.700.000
				10.010.000
			10% Taxes	1.001.000
				TOTAL:11.011.000

Costs for one-unit: 11.011.000/10=1.101.100 TL.

2- Lignite-fired boiler system:

In Table 3 the costs for ten-unit apartment building have been given. Afterwards the costs for one-unit will be calculated from Table 3.

Table 3. Lignite-fired boiler system.

Item Number	Item	About	Unit Price (TL)	Costs (TL)
-	Boiler (60.000 kcal/h)	1 piece	4.650.000	4.650.000
-	Hot water tank	1 piece	2.250.000	2.250.000
-	Coil	1 piece	1.700.000	1.700.000
				8.610.000
			10% Taxes	860.000
			Total:	9.450.000.-TL

Costs for one-unit= 9.460.000.-TL/10=946.000.-TL

3- Electrically heated boiler:

Total cost = 548.000.-TL

4- LPG-Heated boiler:

Total cost = 781.000.-TL

5- Concrete solar collector with electrical auxiliary heater:

According to Akagündüz (2) the cost of concrete collectorper square meter is 114.076.-TL 250 kg hot water consumption per day per family

If the that water demand per day and per family is taken as 250 kg and assuming a temperature differenz of 23^{o} C these is aneed of 3.08 m^{2} concrete collector. It costs 351.354.-TL A 5 kw auxiliary heater costs 300.000.-Tl. Thus the total initial investment cost will be:

Concrete collector		351.354.-
Electrical heater		300.000.-
Total	:	651.354.-TL

6- Conventional flat-plate solar collector with electrical auxiliary heater:

According to Atagündüz (3) the cost of a conventional Flat-plate solar-collector per square meter is 247.719.-TL. For the same conditions at the concrete collector (250 kg hot water per day per family, t= 23^{o} C the total initial investment cost will be:

Conventional collector	:	463.235.-
Electical heater	:	300.000.-
Total	:	763.235.-TL.

7- Conventional flat-plate solar-collector with LPG-auxiliary heating system:

The initial investment costs will be:

Conventional collector	:	463.235.-
LPG-heating system	:	781.000.-
Total	:	1.244.235. TL.-

8- Concrete Solar-collector with LPG-auxiliary heating system:

The initial investment costs will be:

Concrete solar-collector	:	351.354.-
LPG-heating system	:	781.000.-
Total	:	1.132.300.-TL

Calculation of Annual Costs

In order to be able to calculate the annual costs the fuel price developing in coming years should be known. First of all the fuel prices for the years 1990 are given in Table 4.

Table 4. Fuel prices at 1990

Item Number	Item	Unit Price at 1990 (TL)
-	Electric	
	0-120 kwh	122.-TL/kwh
	after 120 kwh	232.-TL/kwh
-	Soma-Lignite	150.-TL/kg
-	LPG	950.-TL/kg
-	Fuel-oil	664.-TL/kg

The change in fuel prices during the economic life will be calculated according to Akdeniz (1).

For the scenario I and Scenario II will be:

Scenario I

LYFI = 1.46 + 0.142C4

Scenario II

LGFI = 1.56 + 0.132C4

Here C4 gives the years. LYFI is the logorithmic fuel price index and LGFI gives the logorithmic general price index. Using the above given relations the fuel-price change ratio for scenario I and II will be: 39% for scenario I and 36% for scnario II.

Annual Costs

Taking 250 kg domestic hot eater per day per family as a basis, the annual fuel demand, fuel costs and the annual operating and maintenance costs of the eight alternatives can be calculated,Table 5.

In table 5 the annual costs for scenario I and scenario are given for the year 1990.

Table 5. Annual Costs for scenario I and scenario II for the year 1990

Hot Water Generation alternatives	Yearly Fuel demand	Efficiency Coefficient for burning process (-)	Annual Fuel Cost (TL)	Annual Operating and maintenance cost (TL)	Total Cost (TL)
1-Fuel-oil-fired boiler system	294.70 liter	0.75	195681	355000	550681
2-Lignite-fired boiler system	874.50 kg	0.60	131175	355000	486175
3-Electrical heated boiler system	2871.58 kwh	0.85	507807	50781	558588
4-LPG-Boilersy stem	262.34 kg	0.80 kg	249223	24922	274145
5-Concrete solar-collector with electrical heater	944.13 kwh	0.85	166238	16624	182862
6-Conventional solar-collector with electrical heater	944.13 kwh	0.85	166238	16624	182862
7-Conventional solar-collector with LPG-heater	86.25 kg	0.80	81938	8194	90132
8-Concrete solar collectorwith LPG-heater	86.25 kg	0.80	81938	8194	90132

In Table 6 the calculated interest rate ratios over the years are given The calculations have been made taking into account the assumption made before.

Table 6. The interest rate ratios for the time period 1990 to 2005.

Years	1990-1991	1992-1993	1994-1995	1996-1997
Interest rate	0.357	0.364	0.371	0.379
Years	**1998-1999**	**2000-2001**	**2002-2003**	**2004-2005**
Interest rate	0.386	0.394	0.402	0.410

In Table 7 for the scenario I and in Table 8 for the scenario II the annual costs for two-years periods have been given.

Table 7. Time Period costs of alternative for Scenario II.

Alternatives Time Period	1	2	3	4	5	6	7	8
1990-91	658064	580979	667513	327604	218520	218520	107708	107708
1992-93	1271445	1122510	1289702	632963	422203	422203	208102	208102
1994-95	2456559	2168801	2491832	1222947	815738	815738	402075	402075
1996-97	4746318	4190341	4814469	2362855	1576087	1576087	776848	776848
1998-99	9170361	8096157	9302034	4565272	3045158	3045158	1500947	1500947
2000-01	17718054	15642586	17972460	8820562	5883549	5883549	2899980	2899980
2002-03	34233051	30223039	34724589	17042207	11367605	11367605	5603066	5603066
2004-05	66141677	57993934	67091378	32927499	21963350	21963350	10825654	10825654

Taking into account the effective interest rate, $i_{eff} = (i-j)/(i+j)$ where is the actual interest rate and j gives the rate of price escalation, the net present cost of the alternatives can be calculated, afterwards, the alternative with minimum net present cost will be choosen as the best alternative.

Table 8. Time period costs of alternatives for scenario II.

Alternatives Time Periode	1	2	3	4	5	6	7	8
1990-91	649804	573687	659134	323491	215777	215777	106356	106356
1992-93	1201877	1061091	1219134	598330	399102	399102	196716	196716
1994-95	2222991	1962593	2254911	1106670	738178	738178	363845	363845
1996-97	4111644	3630012	4170682	2046896	1365334	1365334	672968	672968
1998-99	7604898	6714071	7714093	3785939	2525322	2525322	1244722	1244722
2000-01	14066019	12418345	14267987	7002473	4670836	4670836	2302238	2302238
2002-03	26016508	22968971	26390068	12951774	86391774	86391774	4258219	4258219
2004-05	48120133	42483408	48811070	23955600	15979022	15979022	7876001	7876001

Table 9 for scenario I and Table 10 for scenario II give a sample of the computer output. from these Tables it is obvious that the best alternative for scenario I is the concrete solar collector with LPG-auxiliary heating and for scenario II the same system.

Table 9. Result of the economic analysis according to Scenario I.

1.ALTERNATIVE: FUEL-OIL FIRED BOILER SYSTEM

2.ALTERNATIVE: LIGNITE-FIRED BOLIER SYSTEM

3.ALTERNATIVE: ELECTRICAL HEATED BOILER SYSTEM

4.ALTERNATIVE: LPG-BOILER SYSTEM

5.ALTERNATIVE: CONCRETE SOLAR-COLLECTOR WITH ELECTRICAL HEATER

6.ALTERNATIVE: CONVENTIONAL SOLAR-COLLECTOR WITH ELECTRICAL HEATER

7.ALTERNATIVE: CONVENTIONAL SOLAR-COLLECTOR WITH LPGHEATER

8.ALTERNATIVE: CONCRETE SOLAR COLLECTOR WITH LPG-HEATER

SCENARIO: I

1. Present Cost of Alternative = 1,024366E +07

2. Present Cost of Alternetive =9120658

3. Present Cost of Alternetive =9663970

4. Present Cost of Alternetive =5523613

5. Present Cost of Alternetive =3698887

6. Present Cost of Alternetive =4053942

7. Present Cost of Alternetive =3321869

8. Present Cost of Alternetive =2966816

MINIMUM PRESENT COST = 2966816

* *

TABLE 10. Rresult of economic analysis according to Scenario II.

* *

SCENARIO : II

1. Present Cost of Alternative =1,051366E + 07

2. Present Cost of Alternative =93666776

3. Present Cost of Alternative =9918192

4 .Present Cost of Alternative =5669616

5. Present Cost of Alternative =3787086

6. Present Cost of Alternative =4161240

7. Present Cost of Alternative =3410549

8. Present Cost of Alternative =3036394

MINIMUM PRESENT COST = 3036394

* *

CONCLUSION

The economic analysis of the solar collectors shows that under certain restrictions the best alternative system for domestic hot water generation is the concrete solar collector developed in the solar energy Institute of the University Ege with a LPG-auxiliary heating system.

If the pay back period of this system is calculated one can be that in a relatively short time the even break point will be reached and this time is about 2.3 years which is shorter than are other even break points of the all other seven alternative system.

SUMMARY

A new type concrete collector for has been developed in the solar Energy Institute of the University Ege. Thermal efficiency coefficients of different types of concrete collectois which have been determined by tests according to ASHRE-standards, have compared with the thermal efficiency coefficients of conventional solar flat plate collectors. Fuel-oil and liguite fired boiler system, electrically heated boiler system and LPC-fired boiler system have been compared with solar domestic hot water systems such as: concrete solar collector, conventional solar collector and solar collectors with auxillary heating.

For the economic analysis the life-cycle costing concept has been choosen where the net present cost method has been taken to compare the costs of solar energy and conventional domestic hot water generating systems where fuel-oil fired, lignite-fired boiler systems, electrically and LPG heated systems have been choosen as conventional systems agaist the solar energy systems.

The results of scenarlos have showed that the concrete solar collector with LPG-auxillary heating system as the best alternative at the existing meteorological conditions in İzmir/TÜRKİYE.

KAYNAKÇA

AKYURT, M.: "Güneşli Su Isıtıcısı (Solar-Water Heater)", **O.D.T.Ü.Isı Tek 3 No.lu Araştirma**, Ekim 1974, Ankara.

ATAGÜNDÜZ, G.: "E.Ü. Güneş Enerjisi Enstitüsü Beton Kollektörleri ve Testleri (Test of Cocrete Collectors of the Solar Energy Institute of the University Ege)", **5. Enerji Kongresi**, 22.Ekim.1990, Ankara.

ATAGÜNDÜZ, G.: "E.Ü. Güneş Enerjisi Enstitüsü Beton Kollektörlerinin Normal Kollektörlerle Karşılaştırılması ve Maliyet Analizi (Comparison of the Cocrete Collectors of the Solar Energy Institute of the Universty Ege with the Conventional solar-Collectors and their Cost Analysis)", **5. Enerji Kongresi**, 22-25. Ekim. 1990, Ankara.

AYVAZ, H.: **"Beton KollektÖrlerde Değişik Boru Malzemelerinin Isı Transferi Yönünden Teorik ve Deneysel İncelenmesi (Theorical and Experimental Investigations on Pipe Materials in Concrete Solar-Collectors and their influence on Heat Transfer)"** E.Ü. Güneş Enerjisi Enstitüsü Yüksek Lisans Tezi (MS-Thesis, Solar Energy Institute), 1984.

ERDIŞ, F.: **"Beton Kollektörlerde Seçici Yüzeylerin kollektör verimine Etkisinin Deneysel Olarak İncelenmesi (Experimental Investigations on the İnfluence of the Selective Surfaces on the Collector Thermal Efficiency Coefficients)"** E.Ü. Güneş Enerjisi Enstitüsü, Yüksek Lisans Tezi (TS-Thesis , Solar Energy Institute),1984.

GÖKGÖZ, Ş.: **"Beton Kollektör Test Standı (Concrete Solar-Collector Test Standı)"** E.Ü.Güneş Enerjisi Enstitüsü Yüksek Lisans Tezi (MS-Thesis, Solar-Energy Institute),1990.

KARAKAŞ,T,: **"Düzlemsel Toplayıcıların Verim Testlerine Kireçtaşı Birikimi ve Korozyonu Önleyebilen,Yavaş Çözülen Polifosfatların (Siliphos) Enerji Kazancı Yönünden Etkisinin Mukayeseli İncelenmesi (Experimental Investigations on the Influence of Polyphosphates on the Scaling and Consonon in Flat-Plate Solar-Collector)"**, E.Ü. Güneş Enerjisi Enstitüsü, Doktora Tezi (ph-D.-Thesís Solar energy Institute), 1988.

AKDENİZ, F.: **Olasılık ve İstatistik** (Probability and Statistic), Ankara Üniversitesi, Fen Fakültesi,Yayın No:138, Ankara.

LAWRENCE, K.; MCRAE,A.; ALLEY,S.; WATSON,T.: **"Energy Conservation"**,Aspen Systems corporation Rockville, Maryland, 1980.

AKDENİZ, H.A.: **"Optimum Bina Isıtma Sisteminin Seçiminde Alternatif Kararların Ekonomik Analizi** (Economic Analysis of Alternative Decisions during the Selection of the Optimum Building Heating system)" E.Ü.Güneş Enerjisi Enstitüsü ph. D. Thesis, 1989.