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Developing a cheaper and more efficient solar heating swimming pool project: A case study

Hamit Topuz ,Tugba Altundas and Melih Pacaci,Industrial
Engineering Department,Maltepe University,Maltepe,İstanbul, Turkey
Corresponding Author : Hamit Topuz

ABSTRACT: *The widespraed use of renewable energy systems requires the use of data processing both for monitoring system operation and the control of its actual operation. In this paper a solar heating system design for the Swimming pool in the Marmara Eğitim Village Campus Sport Center primarily dedicated to the School Pupils as part of their education. Currently, grid system is often exceedingly expensive, as it consumes excessive natural gas as fuel. Electricity, its running cost is pretty expensive than any other renewable energies namely solar and wind energies in this case solar energy is most versatile option to select. The pool is heated especially in winter by central heating system run by natural gas firing like in many other applications. Because of the high cost of natural gas drastically increasing pool expenses which brings a heavy financial burden to the management. Therefore, we decided to develop a cheaper and more efficient solar power heating system to be suitably installed in the swimming pool rooftop may be used all around the year. In addition, so using solar heating system running cost is much cheaper, more safer and environmently friendly above all inexpensive than any other sources.*

KEY WORDS *: solar heating, natural gas ,swimming pool,financial expenses,*

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I. INTRODUCTION

Today, technological developments and rapidly increasing population, which started with industrial revolution and spread out to all areas of life, caused high energy production especially in developing countries. The need for increased electricity energy has been tried to be achieved by using fossil fuels such as coal, oil and natural gas. The problems experienced in the supply of oil, which is widely used in many areas, mainly due to political developments, caused the rapid rise in energy unit prices and thus global economic crises by showing its effect in the energy market very quickly. [1]

Therefore, the issue of the production, transmission and consumption of the electrical energy, which is required to be used in daily life and industry in the way that will cause the least damage to the environment, has become one of the most important problems to be solved. Perhaps one of the most noticeable among renewable and clean energy technologies is photovoltaic technology, which enables the generation of electrical energy from the sun.

The most important source of energy in the world is the sun. The radiation energy of the sun is the main energy source affecting the physical formations in the ground and atmosphere system. The solar and energy flows in the world are possible thanks to solar energy. Solar energy, which is the origin of many of the natural energy sources, is used directly for purposes such as heating and electricity. Energy is one of the cornerstones of the civilization we have today. It is an indicator of development. With its potential and ease of use, solar energy has the opportunity to expand more easily than other renewable energy sources. Although the potential is owned solar generation in Turkey it is currently not sufficiently effective and widely used. [2]

Energy, which is the main agenda item of the world and will remain on the agenda for many years, is a very important problem for our country as well as for the world. Our country imports energy by spending billions of dollars every year in dependence on foreign energy. Turkey has a high potential for solar energy that has advantageous geographical location due. Period 1966-1982 Turkish State Meteorological Service (DMI), according to data measured by Electrical Power Resources Survey and Development Administration (EIE), Turkey's first solar energy has the potential to create atlases. [3]

II. PROJECT DEFINITION

There are many indoor pools in our country. In indoor swimming pools, it is necessary to provide the thermal comfort conditions of both the pool water of 26 ° C and the interior of the pool. Therefore, the fuel used in the pool heating systems is important. At the same time, considerable amounts of energy are consumed in the heating of these pools. Pools are used every month during the year. For this reason, continuous heating and energy consumption is high. In addition to other fuels, solar energy should be used for heating the pool water in order to reduce the cost for this energy consumption and to minimize the environmental impact.

In this study, it was aimed to design a solar heating system for the swimming pool as part of the training, especially for the students of education, at the Village Campus Sports Center. As mentioned above, the network system is generally extremely expensive, as it consumes excessive natural gas as fuel. Electricity, its running cost is pretty expensive than any other renewable energies namely solar and wind energies in this case solar energy is most versatile option to select. The pool is heated especially in winter by central heating system run by natural gas firing like in many other applications. Because of the high cost of natural gas drastically increasing pool expenses which brings a heavy financial burden to the management.

Therefore, we decided to develop a renewable energy system . In this study, the use of solar energy which is preferred among renewable energy sources of our country for the heating of closed olympic swimming pools has been investigated.

Thus, we aim to make the solar pool available for around the year by designing the solar energy heating system that can be installed properly. As a result of the study, it is aimed to draw attention to the integration of clean and renewable energy use to the existing system and the importance of renewable energy usage in order to meet the hot water demand of Village Campus Sport Center with solar energy.

- **Methodology Used**

In the analysis of the project in order to obtain the hot water needed in the sports center by using solar energy, PV-SOL, Google Earth, AutoCAD, 3d-Max programs are used during the this study. Rooftops surface area that can be used for solar panels placement these programs will be modeled with a realistic and applicable results. They are namely, PV-SOL,3d-MAX and AutoCAD

- **Project Development:**
- Pool measurements and technical data and the availability of the building rooftops area are examined.
- It is imperative that the indoor olympic swimming pools, which is concidered as an expensive investment element of the project therefore, must be used around the year . For this purpose, heat transfer amounts of pools should be calculated carefully.
- Pre-feasibility studies is made considering the technical details of the pool and building rooftops. In all these process, the above mentioned programs are utilized.
- As a result of these calculations, usage of solar energy, efficiency, heat consumption ratio and cost analysis are accordinly is simulated.

- **Background Study**

An appropriate definition of the “Photovoltaic effect “ is the direct conversion of light into electricity,like as a voltage drop or a flow of electrical current.The term “photovoltaic cell” is used to describe a device which converts the energy of light into electrical energy for the purpose of doing work. It is basically synonymous with the term called “solar cells”, are electronic devices that convert sunlight directly into electricity. Other devices ,known as photodetectors or photodiodes sense the light but this light is not converted into energy that can do work. Photovoltaic power were first discovered by a French experimental physicist , Edmond Becquerel in 1839. In 1870’s English scientists ,W.G. Adams and R.E. Day observed an electrical current in selenium using candlelight. Later , in 1882 the first working selenium based solar cell was successfully developed by Charles Fritts.The use of solar panels for generating electricity and heat seems relatively like new development, it has actually been widely used to generate power since early 1900’s.

Further, research increased the efficiency to 15 % and soon limited markets for silicon solar cells were discovered . In 1954 , Calvin Fuller and Gerald Pearson of Bell laboratory produced the first crystal silicon solar cell. The Bell PV converted 4% of the sun’s energy into electricity a rate that was considered the cutting edge in energy technology. The scientists named Daryl M. Chapin et al. made a silicon-based solar cell with an efficiency of about 6% reported. Scientists continued to reinvent and enhanced on the design of the original solar cell and were able to produce a solar cell that was capable of putting 20% return electricity rate. At this point, no commercially viable applications could be found for silicon solar cells on earth—but they were soon found above the earth, in space technology. Then, space race began in the late 1950’s. Because of these advantages space research programs created the now viable silicon solar cell industry on Global base. Most of this history was obtained from reference [1].

In the late 1900’ as awareness grew in the science community about the effects of global warming and the need for renewable energy sources, scientists continued to refine the silicon PV and by early 2000 they were able to make a solar cell with 24% electricity return. In just seven years scientists were again able to increase the electricity return of silicon solar cell using space age materials. By 2007, modern silicon PV Solar cells were operating with 28% electricity return. There are a wide range of PV cell technologies on the market today and more of applications.The global photovoltaic production has gone from 100 mW to over 200 MW in 1999.

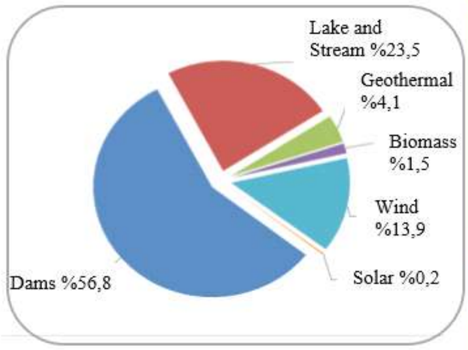
III. OVERVIEW OF RENEWABLE ENERGY RESOURCES

The energy we need to carry out various activities that we cannot give up in our daily lives and in various business sectors has become a concept that will become more important today and also determine the economic and political future of the countries. Today, parallel to the increase in population growth and technology, the need for energy is continuously increasing, and the limited and exhausted energy resources in the world, especially fossil based, lead researchers to find and develop new energy sources. In addition to this, in recent years, global warming has become a threat to the vital activities in the world with the effect of fossil fuel based fuels, and this has caused much more interest in the production, transmission and consumption of the energy in the least damage to the environment.

3.1 RENEWABLE ENERGY SITUATION IN TURKEY

Turkey has a fairly good geographical position in terms of renewable energy potential. However, the level of renewable energy generation is low. There are many factors such as costs and shortcomings in legal regulations. The country's dependence on foreign energy imports to gain use of the existing potential for renewable energy to be taken into consideration if the long-term status is very important for Turkey.

Significant developments in renewable energy in Turkey, especially after 2009 appears to be highly substantial. The total installed capacity of renewable energy production in Turkey was 15.5 GW in 2009, bringing the figure to 31.7 GW level by the year 2015 there has been a noticeable progress in this area. [7] By the end of 2016 the total installed capacity of renewable energy in Turkey is recorded as 34.2 GW. [8]



	GWh	Percent
Biomass *	1.241,1	1,48
Wind	11.652,5	13,93
Solar	194,1	0,23
Dams	47.514,1	56,80
Lake and Stream	19.631,8	23,47
Geothermal	3.424,5	4,09
TOTAL	83.657,9	100,00

	GWh	Percent
Renewable Total	83.657,9	31,9
The Total Turkey	261.783,3	100

* Except Industrial Waste

FIGURE 2.4: In 2015 Breakdown of Turkey Renewable Energy Sources

In Turkey investments made in the field of renewable energy drastically increased by 46 percent as compared to the previous year's investment in renewable energy rose to $ 1.9 billion in 2015. With this investment in renewable energy in Turkey and England exceeding $ 1 billion threshold limit with France and the Netherlands has been one of the four European countries. As of 2015, Turkey's total energy resources constitute approximately 32 percent of renewable sources shown in Figure 2.4

The majority of this ratio is composed of hydroelectric energy sources while the lowest share belongs to solar energy. In line with the targets set by the government and the private sector, renewable energy potentials are relentlessly evaluated and investments are therefore were made and are being made [9].

Renewable energy policies and strategies for the next decade in Turkey listed below:

- To promote renewable energy production and consumption to reduce dependence on fossil fuels and related risks.
- To keep the share of renewable energy sources (including hydroelectricity) and electricity production at least 30 percent.
- To increase the use of biofuels energy by making more use of the agricultural sector potentials

- Updating current strategies and Governmental Policies in line with the demands of both state run institutions as well as private sector.

3.3.1 SOLAR ENERGY IN TURKEY

Due to the geographical location of Turkey in terms of solar energy no doubt has a high potential. Although due some yearly changes in climate in Turkey , the annual sunshine duration of about 2 thousand 738 hours as in Figure 2.5. Average daily sunshine duration 7.5 hours in Turkey whereas compared with Germany ,Turkey is much better position having 60 percent more sunlight over Germany

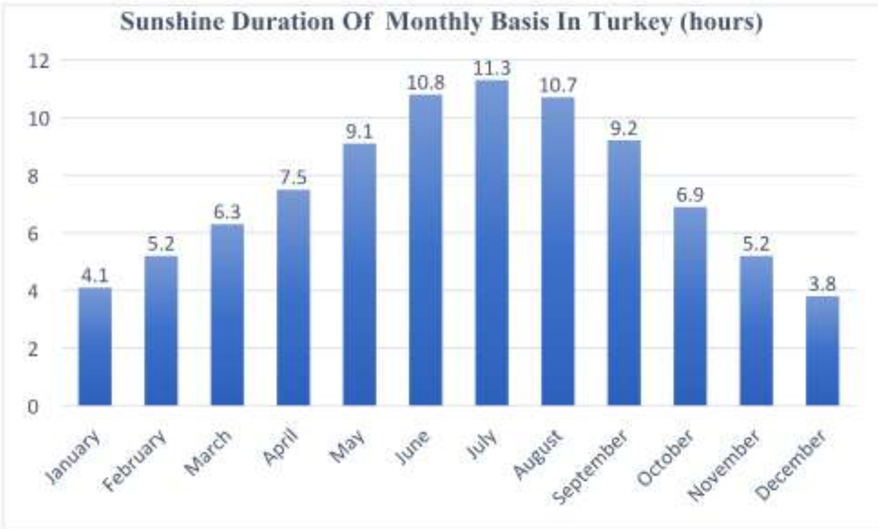


FIGURE 2.5: The Graph of Sunshine Duration of Monthly Basis in Turkey

Turkey, according to calculations made in electricity production from solar potential is estimated to be at least 500 thousand MW. [11] Compared with other renewable energy sources, solar energy source with the most potential in Turkey. Considering that the total installed power of electricity is approximately 79 thousand MW as of the end of 2016, the importance of converting the potential of solar energy into production is once again much of understood.

The technical potential of solar energy in electricity generation is about 189 GWh / year in Turkey, this area itself has the closest countries to the potential of more than 30 percent from Spain and France. See Figure 2.6

Turkey's installed capacity of about 40 MW in 2014, an increase of 519 percent in 2015 increased to 249 MW in 2016 and reached the level of 830 MW. [13] The share of solar energy in the total installed capacity is approximately sligtly over 1 percent. Solar energy until the year 2010 in Turkey generally used for the purpose of heating water under the name of thermal solar systems on the roofs of buildings, from 2010 in the solar system observed a growth trend and the production of electricity from solar energy has gained substantial speed.

Within the framework of the National Renewable Energy Action Plan, solar energy should be used in a more efficient, technological and innovative way for the purpose of providing at least 15 percent of the heating and cooling needs from renewable energy sources for 2023. In this respect, the best way to use the advantages of geographical location, Turkey must promote the use of solar energy as soon as possible.

Turkey's total electricity in order to meet the current demands will be spread over an area of 790 km long solar panels are needed. [14] Under forecasts of 500 thousand MW of gross electricity demand in 2023 would be provided Turkey to use all the potential of the entire solar electricity demand can be met by the year 2023, when only solar energy is focused. However, it is clear that the existing facilities and costs will not allow this prediction to be realized.

The forecasts made by the Ministry of Energy and Natural Resources (MENR) are for the year 2019 and further to produce 3 thousand MW of electricity in solar energy and to increase this figure to 5 thousand MW by 2023 objective.

Southeastern Anatolia Region in terms of solar energy potential in Turkey and the Mediterranean are predominant regions. On the other hand, the least solar regions of the country are the Marmara region and the Eastern Black Sea region. Although Turkey in terms of solar potential in an extremely convenient location at the point of utilization of solar energy is faced with certain difficulties. Below ,Turkey’s Global radiation profile in Figure.2.8

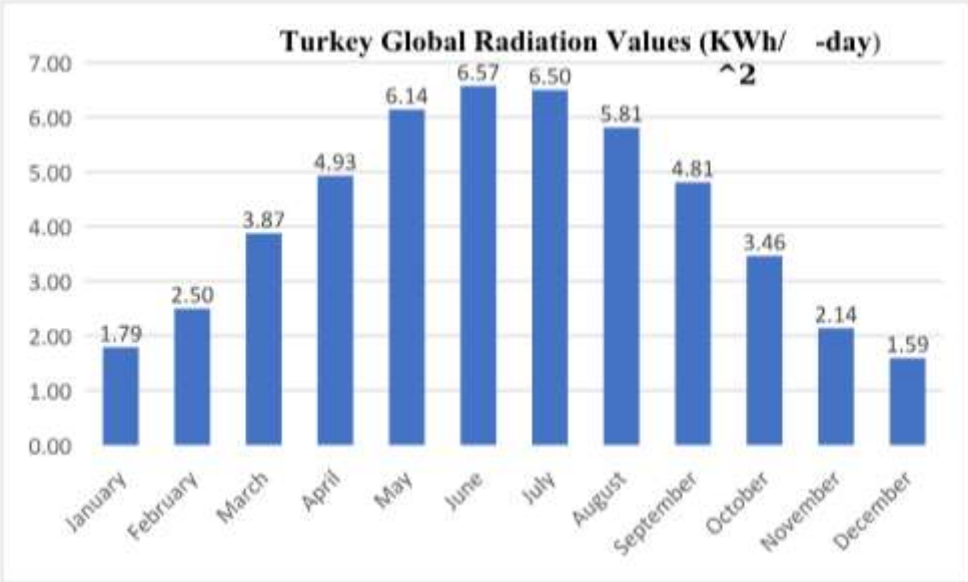


FIGURE 2.8: The graph of Turkey Global Radiation Values

IV. SOLAR VALUES IN THE STUDY

The Campus Sport Center Swimming Pool to be discussed in the study is located 40.957661 north latitude and 29.181507 east longitude. In Figure .8.1below, the satellite image was taken by using the google earth application data of the swimming pool building.

FIGURE 4.1: Location of Campus Sport Center

Although Turkey also has high solar radiation intensity values, like other countries, is in an advantageous position compared to many other countries due to its geographical position has a higher solar energy potential. See FIGURE 8.2

The potential atlas of our country's solar energy generated by using the solar measured values measured between the yearss from 1985 to the year of 2006 as indicated in the General Directorate of State Meteorology Forecasting Affairs (DMI) is presented in Figure 8.2 and the monthly potential distribution is shown in Figure 8.3. As can be seen, the regions with the highest solar energy potential are the Southeast Anatolia Region and the Mediterranean Region.

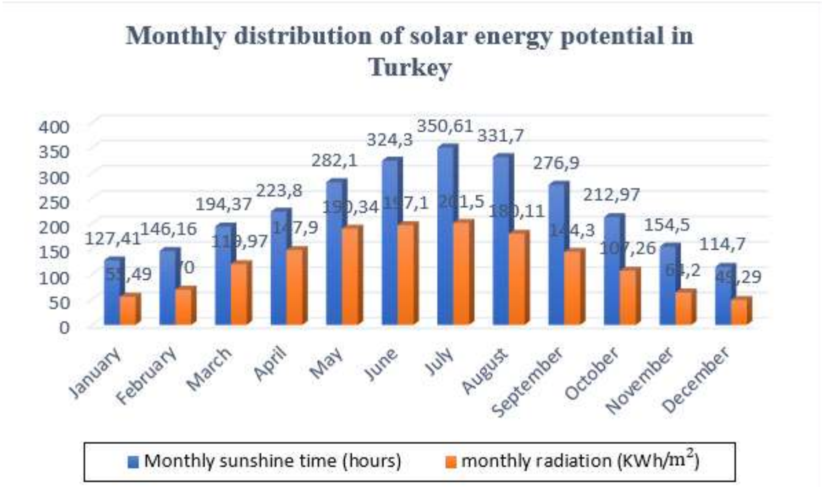


FIGURE 8.2: Monthly distribution of solar energy potential in Turkey [19]

In Istanbul province for solar radiation measurement data Figure 8.4 and Figure 8.5.

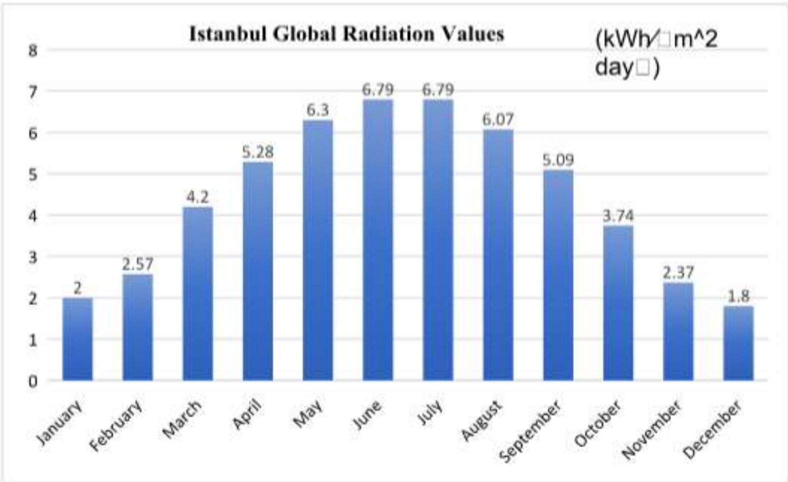


FIGURE 8.4 : Istanbul monthly solar radiation values (KWh/ [19]

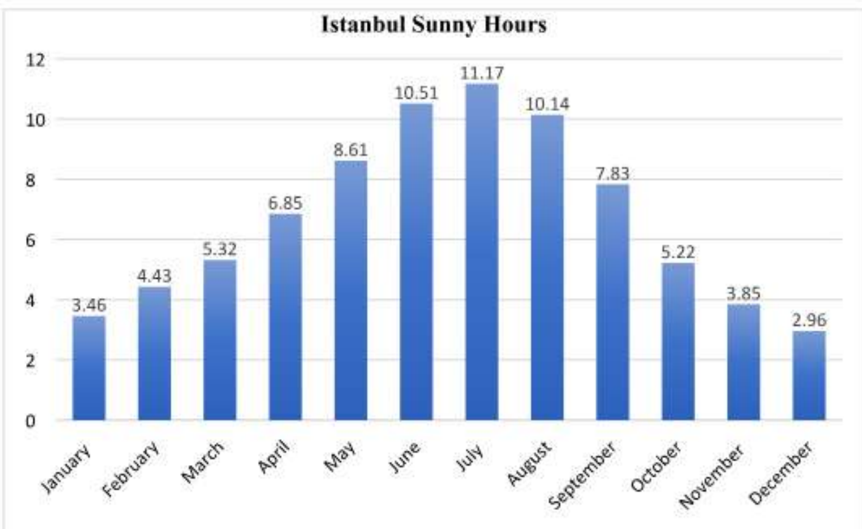


FIGURE 8.5 : Istanbul Monthly Sunshine Time (hours) [19]

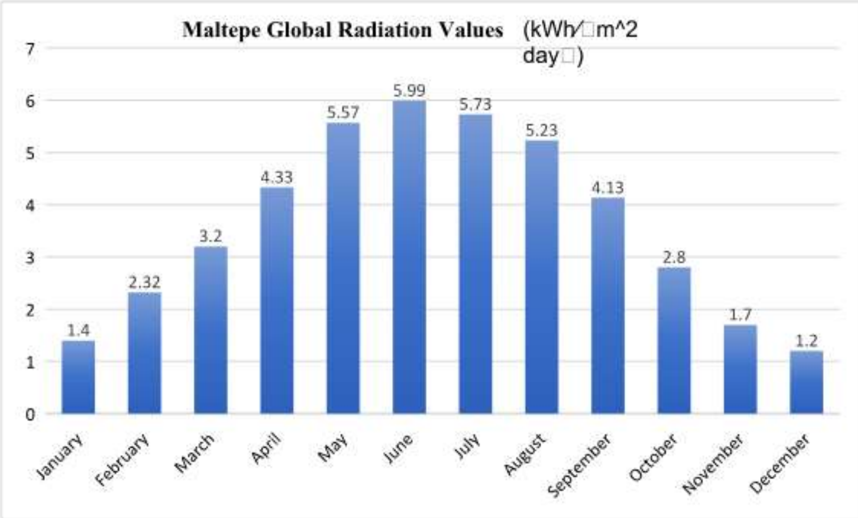


FIGURE 8.6 : Maltepe monthly solar radiation values (KWh / [19]

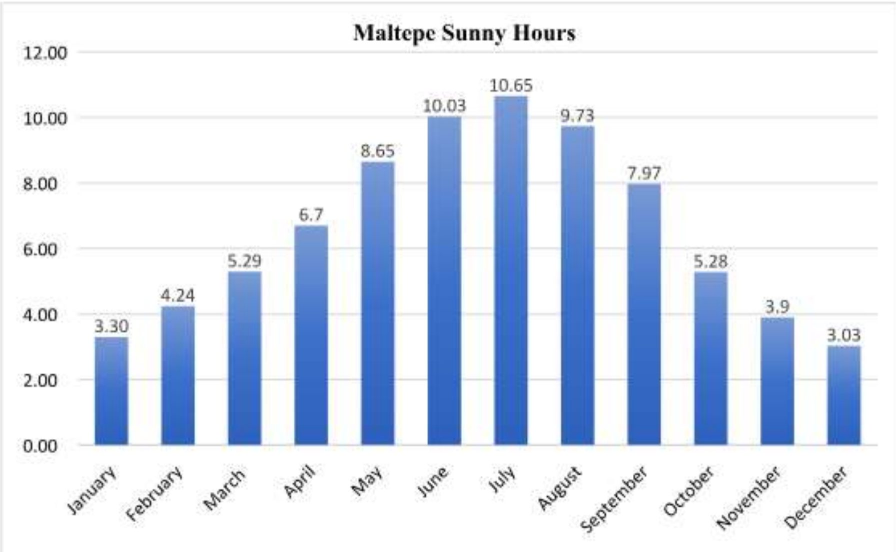


FIGURE 8.7 : Maltepe Monthly Sunshine Time (hours) [19]

V. PROJECT CALCULATION DETAILS

5.1. DATA COLLECTION

5.1.1. SWIMMING POOL DATA

The technical drawing of the Olympic swimming pool and sports complex building we work on is modeled below with AutoCAD and 3D-MAX applications.

The pool data is as shown on the Figure.9.1 and Figure.9.2

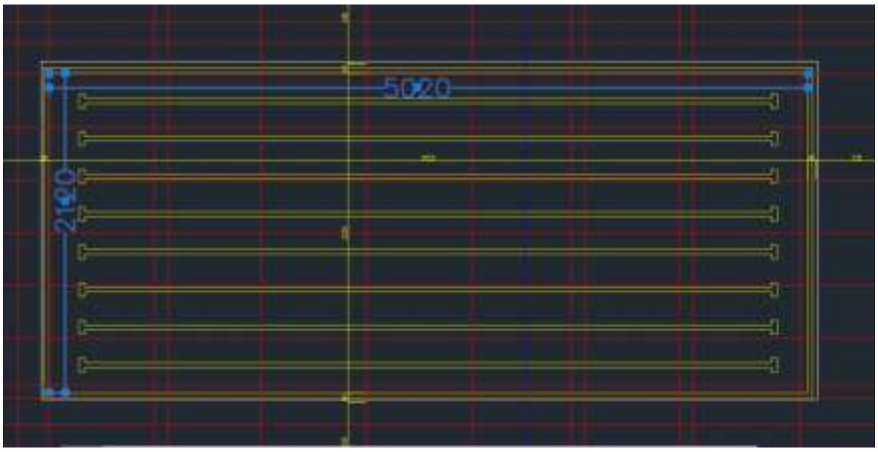


FIGURE 5.1: Technical Drawing of The Pool With AutoCAD Program

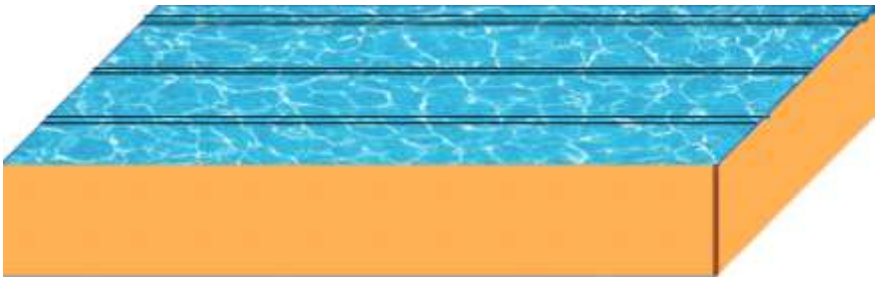


FIGURE 5.2 : 3D Modeling of The Swimming Pool With Photoshop Program

5.1.2 POOL BUILDING AND ROOFTOPS DATA

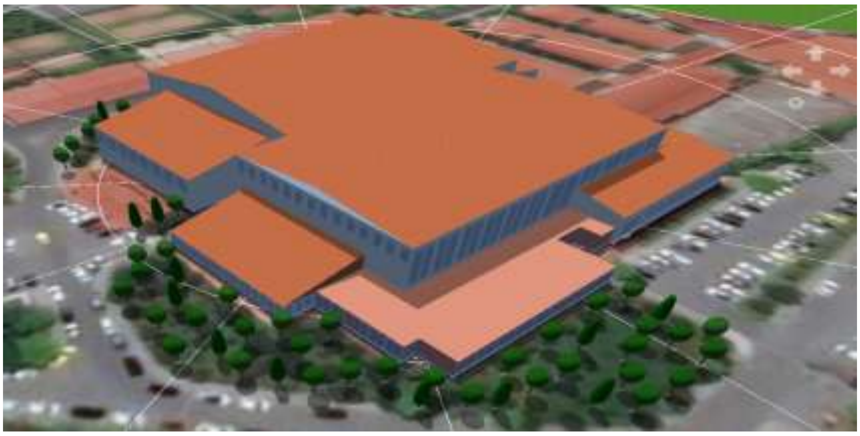


FIGURE 5.3 : Typical 3D Illustration of Sport Center Building and Pool Building

Calculated rooftops surfaces area:

- Surface Area of Sport Center Building A consisted of 3 different roofs is 3964
- Surface Area of Pool Building B consisting of 5 different roofs is 4705

FIGURE 5.4: The Front View of The Building

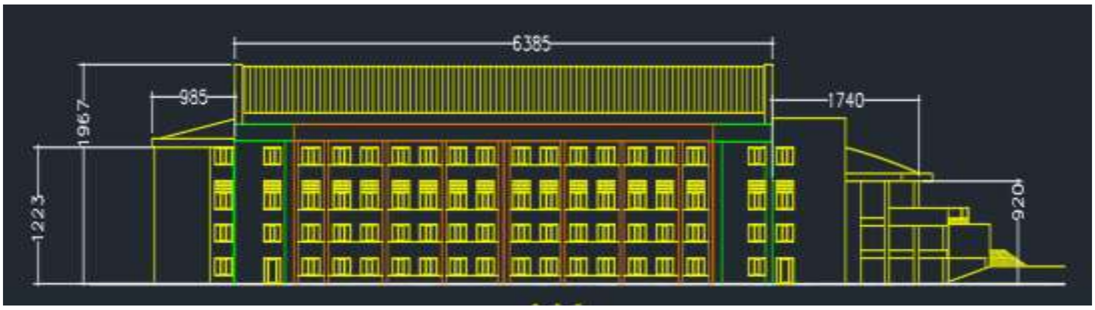


FIGURE 5.5 : Cross Section Building A

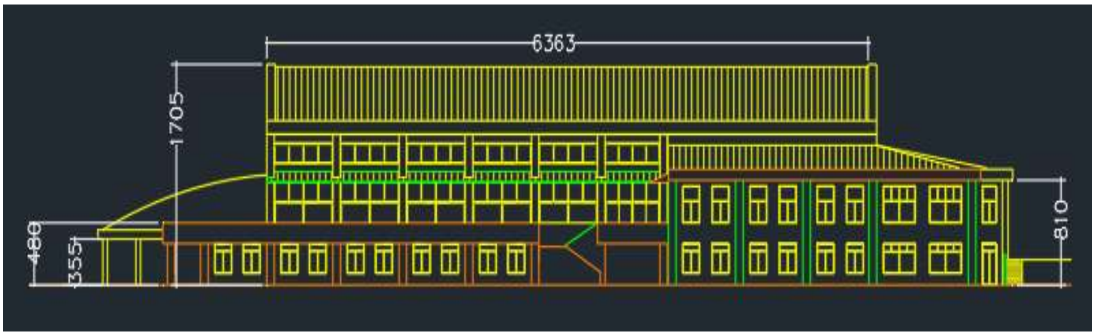


FIGURE 5.6 : Cross Section Building B

5.2. HEAT LOSS AND HEAT GAIN CALCULATIONS

Calculating the heat loss in the Olympic Pools, we can find the energy required to heat the pool. The heat loss in Indoor Olympic Swimming Pools occur essentially occurs in four ways:

- Convection heat loss ,
- Hidden heat losses due to evaporation from the water surface,
- Net radiation heat loss occuring between the surface of the pool and its surroundings,
- Heat losses from the bottom of the pool to the ground with the side walls of the pool.

We have calculated the required heat energy with the formulations used in the Table of 9.1.
There are two kinds of energy we need to calculated;

- Pool commissioning heat load requirement
- Additional heat power requirements

We calculated the heat loss using the heat loss constant as in the table.
This constant value varies for indoor and outdoor swimming pools. [23]

TABLE 5.1: Pool Heating Calculation [24]

	POOL HEATING CALCULATION		
	Pool Dimensions		**Units**
	Depth	2,30	m
	Width	21,20	m
	Length	50,20	m
V	Pool Volume	2.447,75	m^3
A	Pool Area	2.456,92	m^2
t_i	Initial Heating Time	60,00	$hour$
t_2	Desired Pool Water Temperature	28,00	°C
t_1	First Temperature of Pool Water	15,00	°C
c_p	Specific Heat Capacity of Water	1.000,00	$kcal/kg\ K$
Q_i	Pool Commissioning Heat Load Requirement	530.346,27	$kcal/h$
f	Structural Heat Loss Constant	103,20	$kcal/m^2$
Q_{add}	Additional Heat Power Requirements	253.554,14	$kcal/h$
Q_t	Heat Power Requirement In Continuous Operation	783.900,41	$kcal/h$
		911,51	kw
	Structural Heat Loss Constant for Indoor Pool	W/m^2	$kcal/m^2$
		120,00	103,20

5.3. HEATING EXPENCES (NATURAL GAS CONSUMPTIONS)
Below listing shows where the heating compounds in the willage campus.

- Marma Hotel Istanbul Asia,Marmara Private College (classrooms, ofices, pools ...)
- Student House,Faculties,Cultural Center,Staff Accomodotions
- Others (mosque, fitness center, studies center, shower bath etc.)

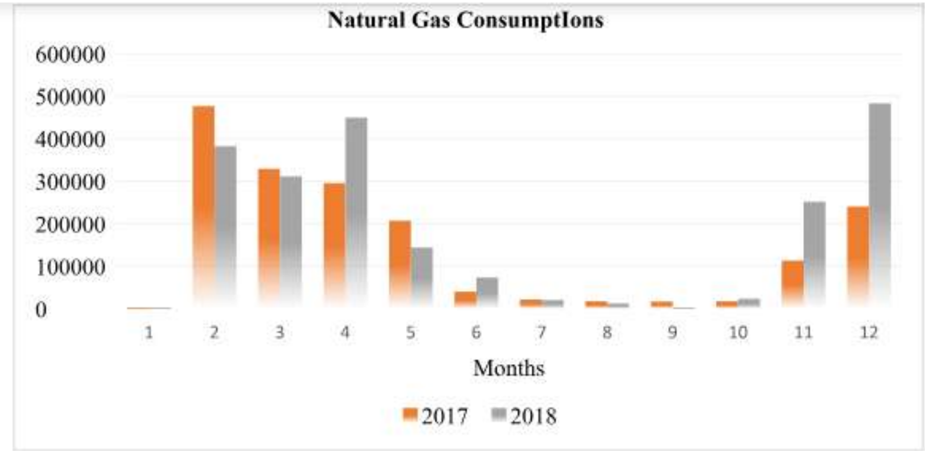


FIGURE 5.7: Natural Gas Consumptions of Values In 2017&2018 Years

5.4. DESIGN OF SOLAR HEATING SYSTEM INSTALLATION
As a result of the calculations made on the previous page, we calculated the energy required to heating the Olympic swimming pool. The total required heat energy is At this stage, we will build the solar heating system on top of the building to meet the heat energy. For this installation, the dimensions of the building and the roof are required. We used the PV-SOL Software Program. Examining the building where the pool is located and the adjacent sports hall, we decided whether it is suitable for the installation. We thought of different options to meet the required energy. We have evaluated the installation in the three options below and reached the data generated as a result of the installation:

- The power that generated if we use the total roof area of two buildings.
- The power generated when we use the total roof area of the building where the pool is located.
- The power that generated if we use the main roof of two buildings.

The reason we use of the PV-SOL Software;
The user-friendly 3D menu navigation is divided into the six sections of terrain view, object view, module coverage, module mounting, module configuration and cable plan. Simply we select possible shading objects and position them on the terrain or the building. PV-SOL Software then calculates how often on average the modules are shaded by the objects and displays the result in graphical form.

Our benefit, the visualization in 3D mode provides you with detailed information on shadows cast at various times of the day and year, and consequently likely reductions will be obtained. Through the detailed analysis of the shading of individual modules, the effect of power optimization on the system yield can also be precisely visualized in PV-SOL Software.

5.4.1. FIRST CASE OPTION-1 (ACCEPTABLE OPTION)
In this option, we made an installation by taking the roof of the building where the pool is located as in Figure 9.3. We placed the panels by selecting the appropriate regions where we can make the panel layout.
The panel features of used and the total power we obtain are available in the following tables.

TABLE 5.2: Used PV Module Characteristics in option-1
TABLE 5.3: Result of Polycrystalline Solar Panel Installation

Polycrystalline Solar Panel Installation		PV Module Characteristics			
Application Type	Roof Mounted	PV Module	TMP672320	good opt	
Used Panel	Tamesol 320W	Producer	Tamesol Desa S.L.		
Number of Panels	1555	Cell Type	Polycrystalline		
Zone Radiation	1,344.40 kWh/m²	Cell Number	72		[illegible]
Installed Power	515.702 [kWh]/year	Width	992 mm		
Investment Cost	746,400.00 ?	Height	1956 mm		
		Depth	40 mm		
Zone Radiation	1,344.40 kWh/m²	Weight	23 kg		
Installed Power	515.702 [kWh]/year				
Investment Cost	746,400.00 ?				

Polycrystalline Solar Panel Installation		PV Module Characteristics			
Application Type	Roof Mounted	PV Module	TMP672320	1555	1,344.40 kWh/m²
Used Panel	Tamesol 320W	Producer	Tamesol Desa S.L.		
Number of Panels	2100	Cell Type	Polycrystalline	better option	[illegible]
Zone Radiation	1,344.40 kWh/m²	Cell Number	72		
Installed Power	701.213 [kWh]/year	Width	992 mm		
Investment Cost	1,036,800.00 ?	Height	1956 mm		
		Depth	40 mm		
		Weight	23 kg		

Polycrystalline Solar Panel Installation		PV Module Characteristics			
Application Type	Roof Mounted	PV Module	TMP672320		
Used Panel	Tamesol 320W	Producer	Tamesol Desa S.L.		
Number of Panels	2852	Cell Type	Polycrystalline	best option	[illegible]
Zone Radiation	1,344.40 kWh/m²	Cell Number	72		
Installed Power	955.529 [kWh]/year	Width	992 mm		
Investment Cost	1,368,960.00 ?	Height	1956 mm		
		Depth	40 mm		
Installed Power	955.529 [kWh]/year	Weight	23 kg		
Investment Cost	1,368,960.00 ?				

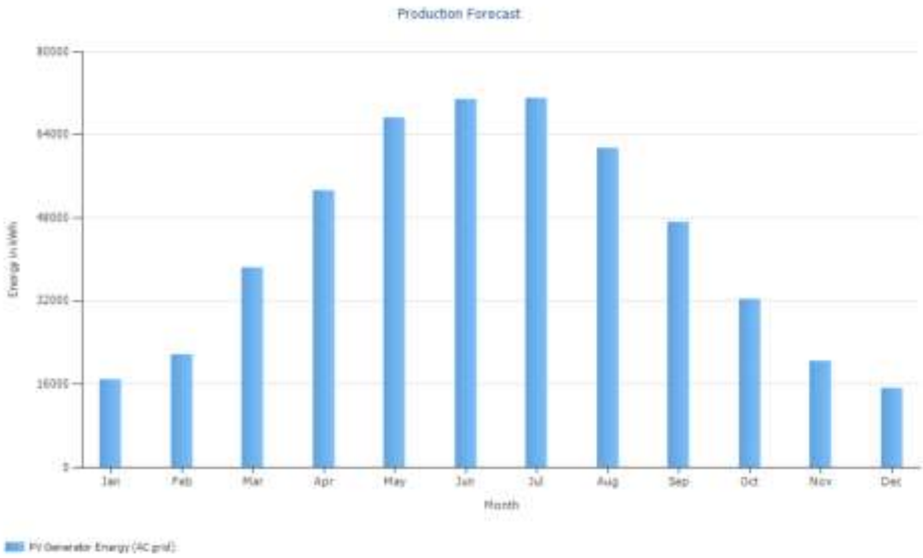


FIGURE 5.8: Production Forecast of The First Case

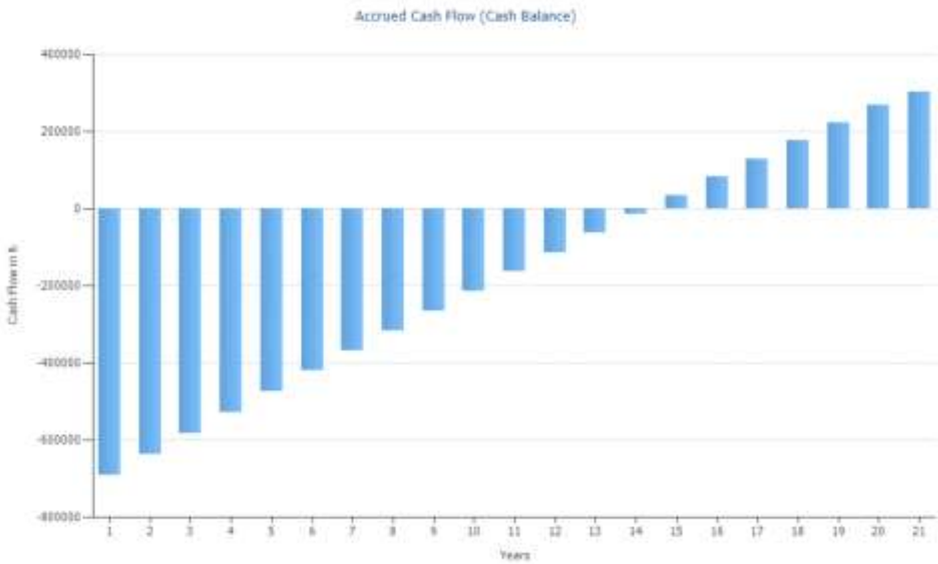


FIGURE 5.9: Accrued Cash Flow of The First Case

5.4.2. SECOND CASE : OPTION-2 (SECOND BEST OPTION)

In this option, we have installed the rooftops of the building where the pool is located and the sports hall as in Figure 9.12 .The panels are selected and installed in appropriate areas accordingly.
The panel features used and the total power available indicated in the following tables.

TABLE 5.4: Used PV Module Characteristics in option-2

Polycrystalline Solar Panel Installation		PV Module Characteristics			
Application Type	Roof Mounted	PV Module	TM-P672320	good opt	
Used Panel	Tamesol 320W	Producer	Tamesol Desa S,L		
Number of Panel	1555	Cell Type	Polycrystalline		
Zone Radiation	1.344,40 kWh/m²	Cell Number	72		altmışlık
Installed Power	515.742[kWh]/year	Width	992 mm		
Investment Cost	746,400.00 ?	Height	1956 mm		
		Depth	40 mm		
Zone Radiation	1.344,40 kWh/m²	Weight	23 kg		
Installed Power	515.742[kWh]/year				
Investment Cost	746,400.00 ?				

Polycrystalline Solar Panel Installation		PV Module Characteristics			
Application Type	Roof Mounted	PV Module	TM-P672320	1555	1.344,40 kWh/m²
Used Panel	Tamesol 320W	Producer	Tamesol Desa S,L		
Number of Panel	2160	Cell Type	Polycrystalline	better option	seksenlik
Zone Radiation	1.344,40 kWh/m²	Cell Number	72		
Installed Power	771.213[kWh]/year	Width	992 mm		
Investment Cost	1,036,800.00 ?	Height	1956 mm		
		Depth	40 mm		
		Weight	23 kg		

Polycrystalline Solar Panel Installation		PV Module Characteristics			
Application Type	Roof Mounted	PV Module	TM-P672320		
Used Panel	Tamesol 320W	Producer	Tamesol Desa S,L		
Number of Panel	2852	Cell Type	Polycrystalline	best option	yüzlük
Zone Radiation	1.344,40 kWh/m²	Cell Number	72		
Installed Power	955.529[kWh]/year	Width	992 mm		
Investment Cost	1,368,960.00 ?	Height	1956 mm		
		Depth	40 mm		
Installed Power	955.529[kWh]/year	Weight	23 kg		
Investment Cost	1,368,960.00 ?				

TABLE 5.5: Result of Polycrystalline Solar Panel Installation

Polycrystalline Solar Panel Installation		PV Module Characteristics			
Application Type	Roof Mounted	PV Module	TM-P672320	good opt	
Used Panel	Tamesol 320W	Producer	Tamesol Desa S.L.		
Number of Panel	1555	Cell Type	Polycrystalline		
Zone Radiation	1,344,40 kWh/m²	Cell Number	72		[illegible]
Installed Power	515,740 [kWh]/year	Width	992 mm		
Investment Cost	746,400.00 ?	Height	1956 mm		
		Depth	40 mm		
Zone Radiation	1,344,40 kWh/m²	Weight	23 kg		
Installed Power	515,740 [kWh]/year				
Investment Cost	746,400.00 ?				

Polycrystalline Solar Panel Installation		PV Module Characteristics			
Application Type	Roof Mounted	PV Module	TM-P672320	1555	1,344,40 kWh/m²
Used Panel	Tamesol 320W	Producer	Tamesol Desa S.L.		
Number of Panel	2100	Cell Type	Polycrystalline	better option	[illegible]
Zone Radiation	1,344,40 kWh/m²	Cell Number	72		
Installed Power	771,213 [kWh]/year	Width	992 mm		
Investment Cost	1,036,800.00 ?	Height	1956 mm		
		Depth	40 mm		
		Weight	23 kg		

Polycrystalline Solar Panel Installation		PV Module Characteristics			
Application Type	Roof Mounted	PV Module	TM-P672320		
Used Panel	Tamesol 320W	Producer	Tamesol Desa S.L.		
Number of Panel	2852	Cell Type	Polycrystalline	best option	[illegible]
Zone Radiation	1,344,40 kWh/m²	Cell Number	72		
Installed Power	955,529 [kWh]/year	Width	992 mm		
Investment Cost	1,368,960.00 ?	Height	1956 mm		
		Depth	40 mm		
Installed Power	955,529 [kWh]/year	Weight	23 kg		
Investment Cost	1,368,960.00 ?				

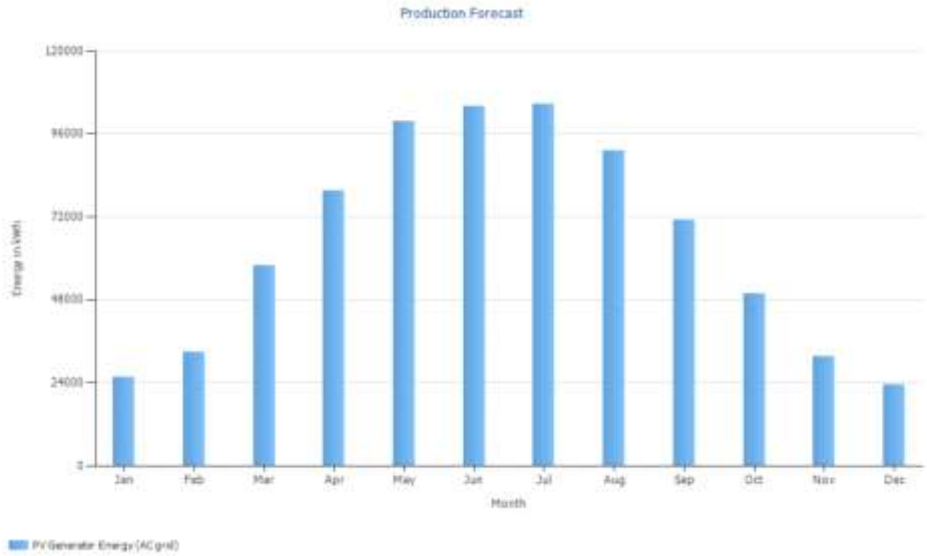


FIGURE 5.10: Production Forecast of The Second Case

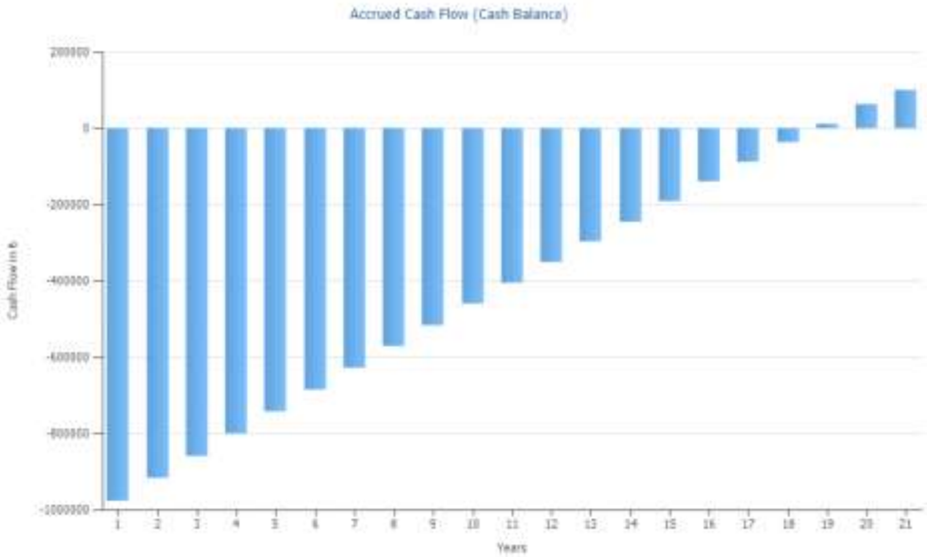


FIGURE 5.11: Accrued Cash Flow of The Second Case

5.4.3. THIRD CASE : OPTION -3 (WORKABLE OPTION)

In this option, we have installed the panels at the rooftops of buildings where the pool and the sports center are located as in the Figure 9.3. We have installed panels by selecting the appropriate areas in accordance with the panel layouts.

The panel features and the total power we have are available indicated in the following tables.

TABLE 5.6: Used PV Module Characteristics in option-3

Polycrystalline Solar Panel Installation		PV Module Characteristics			
Application Type	Roof Mounted	PV Module	TM-P672320	good opt	
Used Panel	Tenesol 320W	Producer	Emesol Desa S.L.		
Number of Panel	1555	Cell Type	Polycrystalline		
Zone Radiation	1,344.40 kWh/m²	Cell Number	72		[illegible]
Installed Power	515.742[kWh]/year	Width	992 mm		
Investment Cost	746,400.00 ?	Height	1956 mm		
		Depth	40 mm		
Zone Radiation	1,344.40 kWh/m²	Weight	23 kg		
Installed Power	515.742[kWh]/year				
Investment Cost	746,400.00 ?				

Polycrystalline Solar Panel Installation		PV Module Characteristics			
Application Type	Roof Mounted	PV Module	TM-P672320	1555 1,344.40 kWh/m²	
Used Panel	Tenesol 320W	Producer	Emesol Desa S.L.		
Number of Panel	2160	Cell Type	Polycrystalline	better option	[illegible]
Zone Radiation	1,344.40 kWh/m²	Cell Number	72		
Installed Power	771.213[kWh]/year	Width	992 mm		
Investment Cost	1,036,800.00 ?	Height	1956 mm		
		Depth	40 mm		
		Weight	23 kg		

Polycrystalline Solar Panel Installation		PV Module Characteristics			
Application Type	Roof Mounted	PV Module	TM-P672320		
Used Panel	Tenesol 320W	Producer	Emesol Desa S.L.		
Number of Panel	2652	Cell Type	Polycrystalline	best option	[illegible]
Zone Radiation	1,344.40 kWh/m²	Cell Number	72		
Installed Power	955.529[kWh]/year	Width	992 mm		
Investment Cost	1,348,960.00 ?	Height	1956 mm		
		Depth	40 mm		
Installed Power	955.529[kWh]/year	Weight	23 kg		
Investment Cost	1,348,960.00 ?				

TABLE 5.7: Result of Polycrystalline Solar Panel Installation

Polycrystalline Solar Panel Installation		PV Module Characteristics			
Application Type	Roof Mounted	PV Module	TM-P672320	good opt	
Used Panel	Tamesol 320W	Producer	Tamesol Desa S.L		
Number of Panel	1555	Cell Type	Polycrystalline		
Zone Radiation	1,344.40 kWh/m²	Cell Number	72		alt weight
Installed Power	515.742[kWh]/yea	Width	992 mm		
Investment Cost	746,400.00 ?	Height	1956 mm		
		Depth	40 mm		
Zone Radiation	1,344.40 kWh/m²	Weight	23 kg		
Installed Power	515.742[kWh]/yea				
Investment Cost	746,400.00 ?				

Polycrystalline Solar Panel Installation		PV Module Characteristics			
Application Type	Roof Mounted	PV Module	TM-P672320	1555	1,344.40 kWh/m²
Used Panel	Tamesol 320W	Producer	Tamesol Desa S.L		
Number of Panel	2160	Cell Type	Polycrystalline	better option	selsoalt
Zone Radiation	1,344.40 kWh/m²	Cell Number	72		
Installed Power	771.213[kWh]/yea	Width	992 mm		
Investment Cost	1,036,800.00 ?	Height	1956 mm		
		Depth	40 mm		
		Weight	23 kg		

Polycrystalline Solar Panel Installation		PV Module Characteristics			
Application Type	Roof Mounted	PV Module	TM-P672320		
Used Panel	Tamesol 320W	Producer	Tamesol Desa S.L		
Number of Panel	2852	Cell Type	Polycrystalline	best option	yield alt
Zone Radiation	1,344.40 kWh/m²	Cell Number	72		
Installed Power	955.529[kWh]/yea	Width	992 mm		
Investment Cost	1,368,960.00 ?	Height	1956 mm		
		Depth	40 mm		
Installed Power	955.529[kWh]/yea	Weight	23 kg		
Investment Cost	1,368,960.00 ?				

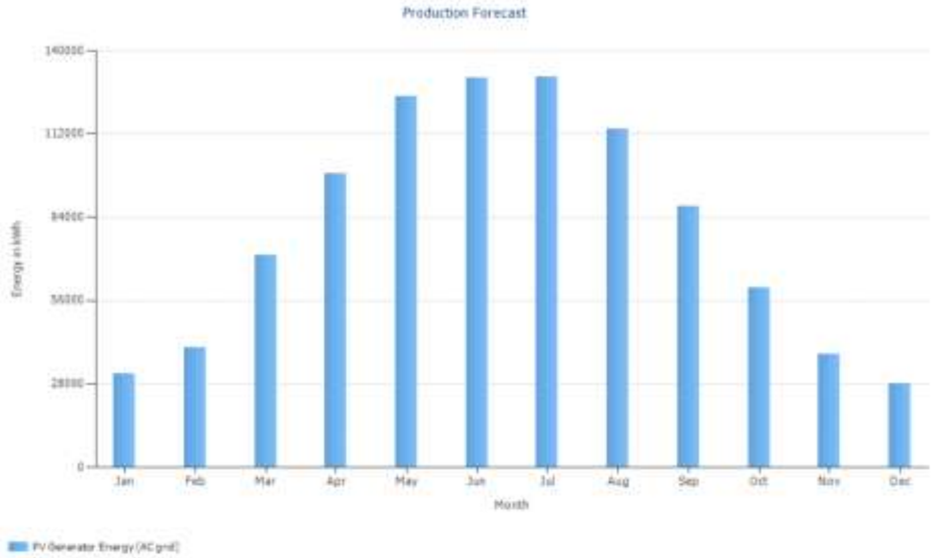


FIGURE 5.12: Production Forecast of The Third Case

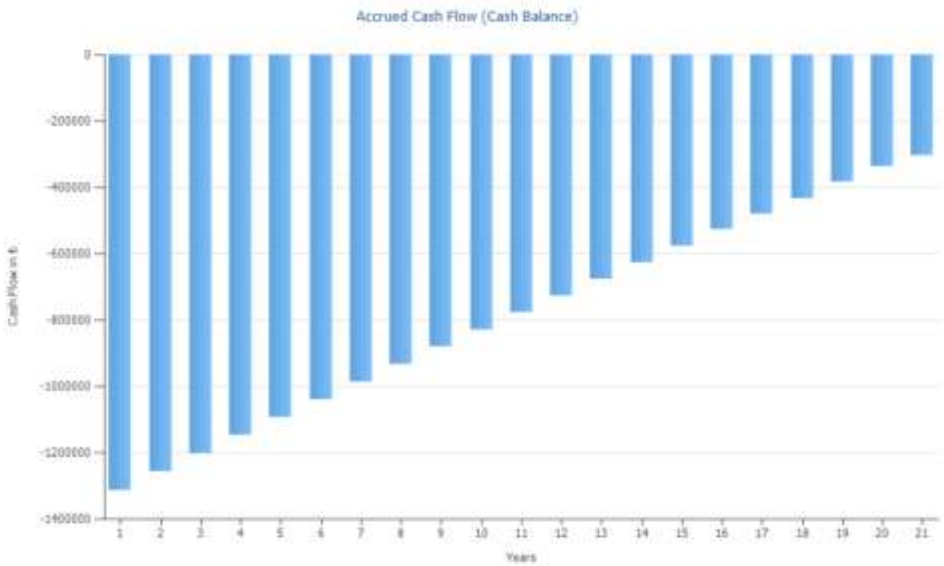


FIGURE 5.13: Accrued Cash Flow of The Third Case

5.4.4. OUTLINES OF THE THREE OPTIONS ARE GIVEN IN THE FOLLOWING TABLES

TABLE 5.8: Outlines of the Three Cases

Polycrystalline Solar Panel Installation		Polycrystalline Solar Panel Installation		Polycrystalline Solar Panel Installation	
Application Type	Roof Mounted	Application Type	Roof Mounted	Application Type	Roof Mounted
Used Panel	Tamesol 320W	Used Panel	Tamesol 320W	Used Panel	Tamesol 320W
Number of Panels	1555	Number of Panels	2160	Number of Panels	2852
Zone Radiation	1.344,40 kWh/m^2	Zone Radiation	1.344,40 kWh/m^2	Zone Radiation	1.344,40 kWh/m^2
Installed Power	515.742 $kWh/year$	Installed Power	771.213 $kWh/year$	Installed Power	955.529 $kWh/year$
Investment Cost	746.400,00 ₺	Investment Cost	1.036.800,00 ₺	Investment Cost	1.368.960,00 ₺

- In the 1st section of the table above in total, we have an area of square meters. We installed panels in this area. As a result of this installation, our annual energy production amount reached to . Thus, it meets of the energy required for the purpose of heating. The investment cost is T.L.
- In the 2nd section of the table above in total, we have an area of square meters. We installed panels in this area. As a result of this installation, our annual energy production amount reached to Thus, this meets of the energy required for the purpose of heating. The expected investment cost would be around T.L.
- In the 3rd section of the table above, in total, we have an area of square meters. We installed panels in this area. As a result of this installation, the annual energy production amount reached to . Thus, this option generates of the energy required for the purposes of heating, and the investment cost will be around T.L.

When we examine the payback periods of these three different options as shown in Figures 9.9, 9.11 and Figure:9.13 in order:

- The payback period for the first option expected to be in the range of 14 years
- The payback period for the second option expected to be in the range of 19 years
- The payback period for the third option expected to be above 20 years

- As a result, when considered these three options, option-1 is advantageous both in terms of payback period and investment cost. It meets not only the whole heat energy but of it. This option is acceptable.
- When compared the option-2 with others, the investment cost and the payback period are favoriable than option-3, but not favoriable option-1.
- As compared, the option-3 seems to be reasonable, but payback period is longer then the first and second case, and the investment cost exceeds the other two options.

VI. CONCLUSIONS

In recent years, energy has become a crucial factor especially for developing countries. Countries that can provide their own energy needs within their own limits are considered to have taken the biggest step towards having strong economies, largely by reducing their dependence on foreign sources.

Increasing the use of clean and renewable energy has become a necessity in order to reduce the use of fossil fuels, which is a major economic expense item in our country, as well as environmental pollution and global warming, which show more impacts day by day.

In this work, it was found that the heating of swimming pool in Marmara College Campus by using solar energy is presented in three alternatives options as given below. The cost of the Project and the Project payback times were determined through PV-SOL simulation program. The results in similar magnitudes derived from this simulation program indicate that the reliability of our findings has substancially been increased.

Case 1: About 56 % and 60 % of the energy requirement of the Project including hot water requirements and consumptions in the compound is met. The payback period of 10-14 years is the most optimal solution.

Case 2: It generates more than 85 % energy we needed according to the first case. However, the payback period is of 19-20 years which is 6 years longer than the first option.

Case 3: It meets 100% energy required for the Project. But, the payback period is over 20 years which is the longest among the three cases.

It is the Management's decision to pick up the one which is more economical and sustainable.

VII. RECOMMENDATION

Solar energy is the most important source of clean and renewable energy resources with the distribution of resources spread all over the world. The buildings constituting a part of 50% are at a critical point for the solution of the energy problems. In other words, the energy consumed in buildings with renewable and clean energy will contribute to the energy shortage in the world.

With this work we have shown the use of solar energy is economical and that of more cleaner enviromentally friendly saves monumental amount of corbondioxide emmissioned into the atmosphere contribute a better impact on global warming too.

All three cases' findings are put before the management to evaluate each of these three options more carefully and willingly .All cases are examined more scientifically and from the point of economical viability as to help the management to decide the best option from the point of economy , applicability and suitability for the campus.

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