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AN ECONOMIC ANALYSIS OF RESIDENTIAL PV SYSTEM FOR ADIYAMAN, TURKEY

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Abstract: Solar energy constitutes the main source of all energy sources and it is one of the most important renewable energy sources in terms of huge potential. As others, energy sources not just in certain places in the world, everywhere have the potential where the sun rises and set. Turkey is located on the sunny area and solar energy generation is quite rich in potential. Together with the substantial increase in the efficiency of photovoltaic cells, generating electricity from solar energy is becoming increasingly common. Especially in places where no grid connection, photovoltaic cells is very useful in supplying the energy needs. In this study, Turkey's solar energy potential was analyzed, and PV systems to meet the electricity needs of a home were analyzed economically. Consequently, in order to meet the electricity needs of a house in Adiyaman conditions that require a surface area of 24 m^2 with a PV system, and this system was determined to be able to amortize itself in 10 years.

Keywords: Solar Energy, PV System, Economic Analysis

Türkiye Adıyaman Koşullarında PV Sistemlerinin Ekonomik Analizi

Özet: Güneş enerjisi bütün enerjilerin kaynağı olup potansiyel bakımından yenilenebilir enerji kaynakları arasında en önemlilerindendir. Türkiye güneş kuşağı üzerinde bulunmaktadır ve güneş enerjisi potansiyeli olarak oldukça zengindir. Fotovoltaik pillerin verimlerinde sağlanan ciddi artış ile birlikte fotovoltaik piller ile güneş enerjisinden elektrik üretilmesi giderek yaygınlaşmaktadır. Özellikle şebeke elektriğinin bulunmadığı yerlerde ihtiyaç olan enerjinin karşılanmasında fotovoltaik piller oldukça kullanışlıdır. Bu çalışmada, Türkiye'nin güneş enerjisi potansiyeli ortaya konulmuş, PV sistemler kullanılarak bir evin elektrik ihtiyacının karşılanması ekonomik olarak analiz edilmiştir. Sonuç olarak, Adıyaman koşullarında bir evin elektrik ihtiyacını karşılamak için 24 m^2 yüzey alanına sahip PV sisteminin gerekli olduğu ve bu sistemin kendini 10 yıl içinde amorti edebileceği belirlenmiştir.

Anahtar Kelimeler: Güneş enerjisi, PV Sistem, Ekonomik Analiz

1. INTRODUCTION

Turkey is an energy importing country and 70 % of total energy consumption is supplied by imported energy. Furthermore, there is an estimated yearly renewable energy potential of around 560 TWh from commercially utilizable sources such as hydropower, wind, biomass, geothermal and solar energy, in Turkey (Kotcioglu, 2011). The greatest advantage of solar energy as compared with other forms of renewable energy is that its potential is greater than others. Solar

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energy is used to heat and cool buildings, heat water for domestic and industrial uses, generate electricity, and many more operations (Kalogirou, 2009).

In recent years, the payback times are reduced with the improvements in the efficiency of PV and manufacturing methods. Therefore, it is becoming increasingly common to produce electricity with photovoltaic. Ozturk et. al. (2012) studied the life cycle cost analysis of photovoltaic energy systems. The parametric studies show that, life cycle cost assessment of photovoltaic systems which are connected and non-connected with the grid are calculated 0.40 and 0.67 \$/kWh, respectively. Paudel and Sarper (2013) investigated an economic analysis of a 1.2 MW capacity grid-connected photovoltaic (PV) power plant installed at the Colorado State University-Pueblo. It was hypothesized that a well-designed PV system is now affordable not only to environmentally conscious customers but also to ordinary citizens with some incentives to supplement the utility supply. Spertino et. al. (2013) studied a technical-economic analysis of investments in PV systems installed on the roof top, considering incentive policies, and applies it to some significant case studies in the Countries, in which PV market is the most prosperous. Khalid and Junaidi (2013) studied the feasibility of photovoltaic based power plant. It was determined by comparing monthly average daily global solar radiation data of eight Pakistani cities and Quetta city is chosen for the 10 MW plant. This analysis shows that presently the proposed PV power plant is not feasible if only economic factors are considered. Pillai et. al. (2014) studied a comparative assessment of the near-term economic benefits of grid-connected residential PV systems. It was demonstrated that the importance of location specific system is planning and demand-generation matching through optimal sizing of the PV. Bortolini et. al. (2014) investigated a technical and economic model for the design of a grid connected PV plant with battery energy storage (BES) system. It was highlighted that the technical feasibility and the economic profitability of such a system for the proposed context. Ucgul et. al. (2014) investigated the chance to benefit from Suleyman Demirel University, photovoltaic energy, the eligible faculty building rooftops; photovoltaic roof systems by considering the model. Lang et. al. (2015) modelled a small scale roof top PV system on a typical modern grid-connected residential building, and assess its economic performance considering the influencing factors identified as decisive in the literature review. Campana et. al. (2015) investigated the photovoltaic water pumping technology as a sustainable and economical solution to provide water for irrigation. It was demonstrated that the optimal configuration can guarantee continuous operations and leads to a substantial reduction of photovoltaic array size and consequently of the investment capital cost and the payback period.

In this study, Turkey's solar energy potential was discussed in detail. At the same time example of a PV system to meet the energy needs of a house in Adiyaman conditions, was investigated for economic analysis.

2. SOLAR ENERGY POTENTIAL IN TURKEY

Turkey, due to its geographic location, is a country with rich solar energy potential. Turkey's solar energy potential atlas is given in Figure 1. As shown in Figure 1. Turkey, especially in the southern, eastern, and southern interior is rich in solar radiation. The highest solar radiation potential seems to be in the south-east and south-west areas with the value of 1800-2000 kWh/m^2-year. It is understood that the north-west and north-east of the coastal areas has the least amount of solar radiation.

Figure 2 shows the global solar radiation values according to months for Turkey. As shown in Figure 2, the maximum solar radiation is observed in June. The highest value is not in the hottest August but occur in June because of the angle of incidence of the sun. The monthly total solar radiation is the highest in June with 6.57 kWh / m^2-day and in December seems to be at the lowest level with the value of 1.59 kWh/m^2-day. Although it has a high proportion of the solar energy potential in Turkey, it is observed that less than 1 % of total energy production comes from solar energy.

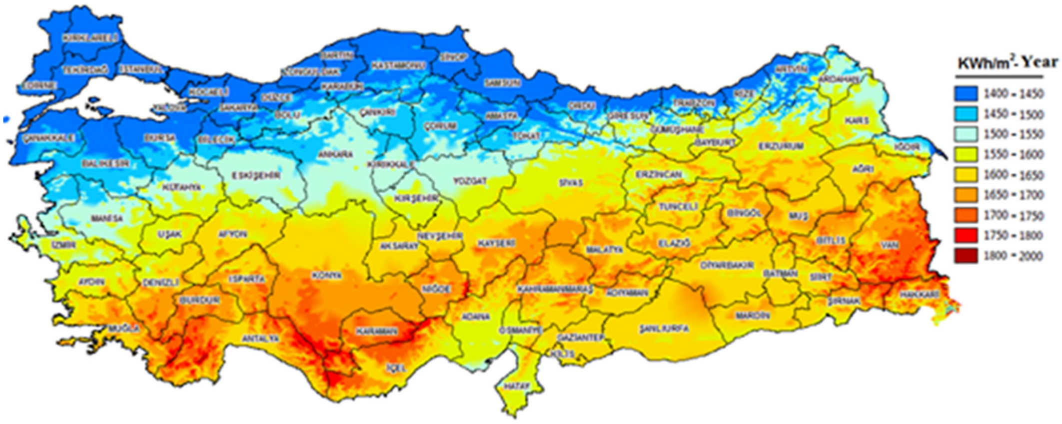

Figure 1:
Turkey's solar energy potential atlas (EIE, 2015)

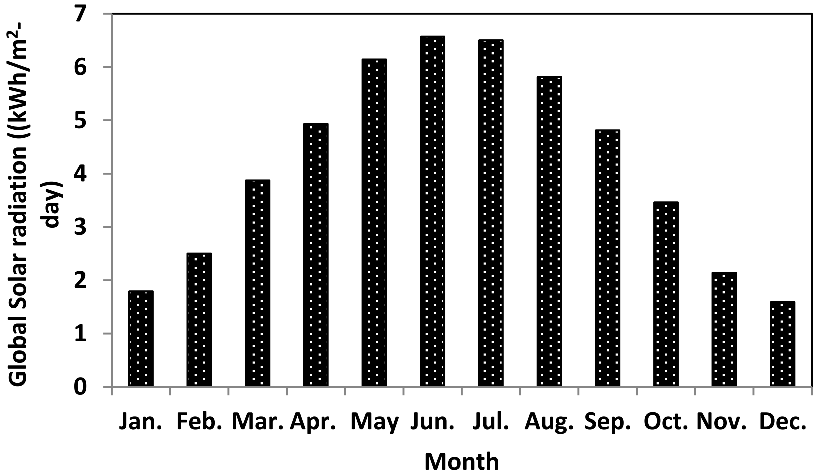

Figure 2:
The monthly global solar radiation of Turkey (EIE, 2015)

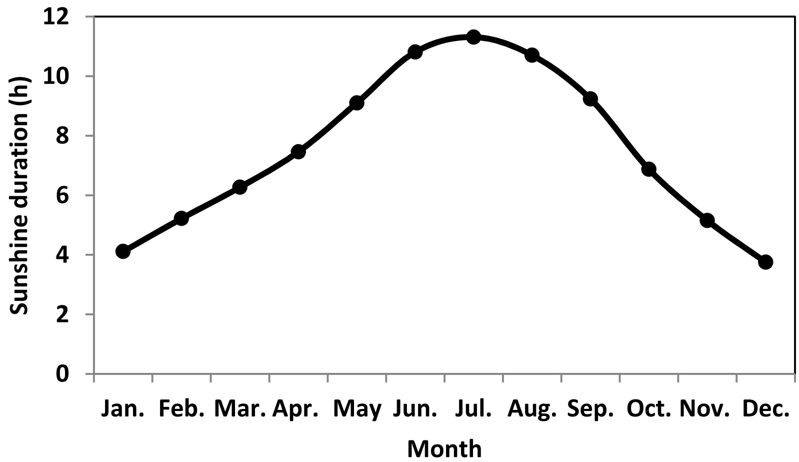

Figure 3:
The average daily sunshine duration of Turkey (EIE, 2015)

Figure 3 shows daily average sunshine duration according to months for Turkey. As shown in Figure 3, the average daily sunshine is the highest duration in July with 11.31h, and the lowest level with 3.75 h is seen in December.

3. RESULTS AND DISCUSSION

Solar cells are systems that can convert solar energy directly into electrical energy. Solar cells, in terms of materials and construction types used have many varieties. This study determined the daily and annual electricity needs of a home in Adiyaman conditions in Turkey and installation of solar cells system to meet this need were examined.

In the calculations Adiyaman solar energy data were used. Adiyaman's solar energy potential atlas is given in Figure 4. As shown in Figure 4 Adiyaman is rich in solar radiation. Solar radiation potential in Adiyaman was observed in the range of 1600-1750 of kWh/m^2-year.

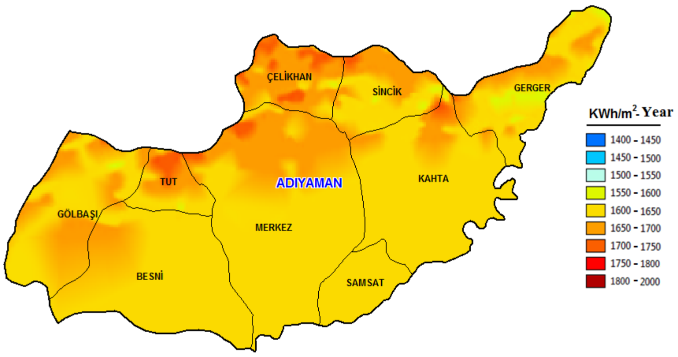

Figure 4:
Adiyaman's solar energy potential atlas (EIE, 2015)

Figure 5 shows global solar radiation values by months in Adiyaman. As it is shown in Figure 5, the monthly total solar radiation is the highest in June with 6.82 kWh/m^2-day, and seems to be at the lowest level in December with 1.80 kWh/m^2-day.

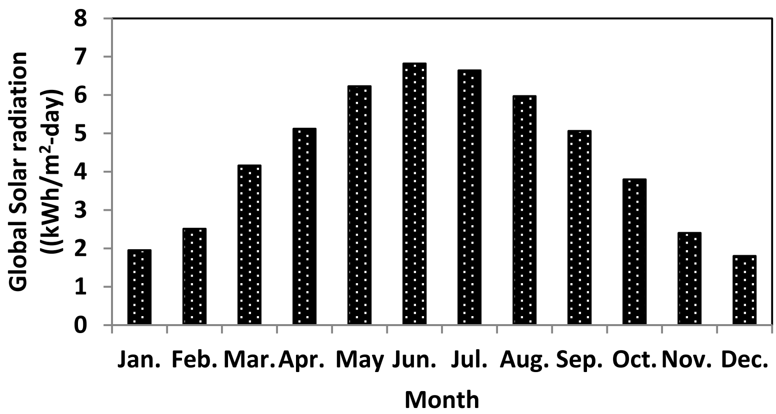

Figure 5:
The monthly global solar radiation of Adiyaman (EIE, 2015)

Figure 6 shows average daily sunshine duration by months for Adiyaman. As shown in Figure 6, the average daily sunshine duration in July is 12.25 h with the highest, it is seen that the lowest level of 4.01 h in December.

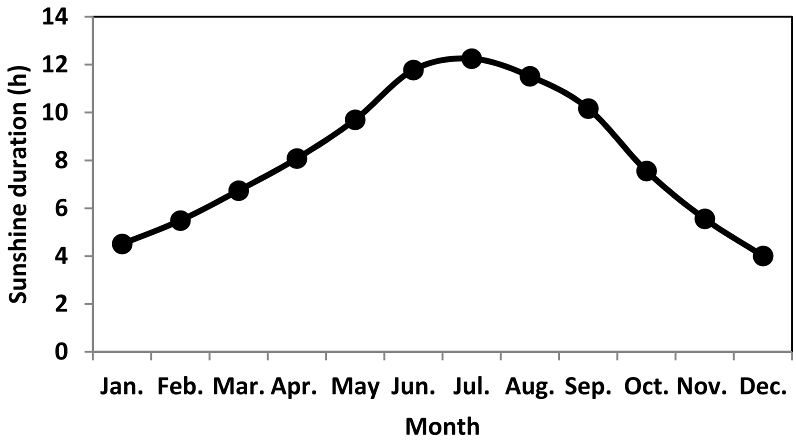

Figure 6:
The average daily sunshine duration of Adiyaman (EIE, 2015)

The average consumption diagram of a house was prepared by taking into account regional conditions differences for Adiyaman and is given in Table 1. A fully equipped home consumption was calculated by taking into account the regional situation.

Table 1. The average consumption diagram of a house

Electrical appliances	Power (Watt)	Used Days	Used Hours	Annual Consumption (kWh)
Refrigerator (400 liters, A+ energy class)	42	365	24	368
Air conditioning (A+ energy class) cooling mode	2200	70	8	1232
Vacuum cleaner	1000	104	0.5	52
LCD TV	100	365	5	182.5
Laptop	75	240	4	72
Washing machine AAA (cotton 60 °C)	2000	208	0.75	312
Iron	1000	104	2	208
Hairdryer	400	365	0,3	43.8
Bulb (CFC - 5 pieces)	50	365	5	91
Electric furnace	2500	52	1.5	195
Toaster	1000	52	1.2	62.4
Mixer	100	52	0.16	1
Cooker Hood	150	365	0.66	36.1
Dish-washing machine	1200	260	1	315
Phone charger	4	300	2	2.4
Other uses	1300	365	1	474
	TOTAL			3647
	DAILY TOTAL			10

Daily consumption of a house according to the table is about 10 kWh. However, extra 1.3 kWh consumption for other uses was taken into consideration and added to the table. Taking into account seasonal variations in day length, over 50 % of the total consumption was added to the total account. Thus daily consumption was thought to be about 15 kWh. Adiyaman's solar radiation map is given in Figure 4. According to the measurement Adiyaman sunshine duration based on experimental measurements varied between 12.25 and 4.01 hours. According to measurements made in Adiyaman, average daily sunshine duration was calculated as 7.49 hours and daily average radiation varied between 6.82 kWh to 1.80 kWh. Yearly total amount of solar energy per square meter surface for Adiyaman is about 1573 kWh. The daily average amount of radiation throughout the year was calculated as 4.30 kWh. In this case 13 % yield from one solar panel, the amount of energy that can be generated per square meter varies between 0.234 kWh-6.82 kWh and the average is 0.559 kWh.

According to the calculation daily average consumption of a sample house is thought to be 15 kWh. For this case study, 12 pieces 250 W panels were planned to purchase. When the system is installed, the amount of the total installed capacity will be 3,000 W. Considering total production time and winter days, daily average generation time is estimated to be 5 hours. Accordingly, considering the fact that the generation of each panel is in the range of 220-250 W and daily production will be in the range of 13.2 kW-15 kWh.

Surplus production will be evaluated using for extra cooling in summer and the extra heat in the winter. For the system to operate 4000W smart inverter is needed. When the stored electricity is not enough, electricity from the grid will be used. For storing the generated electricity 8 pieces 150 A gel batteries were considered. Accordingly, the total amount of energy will be stored is14 kWh per day. The working diagram of system is given in Figure 7.

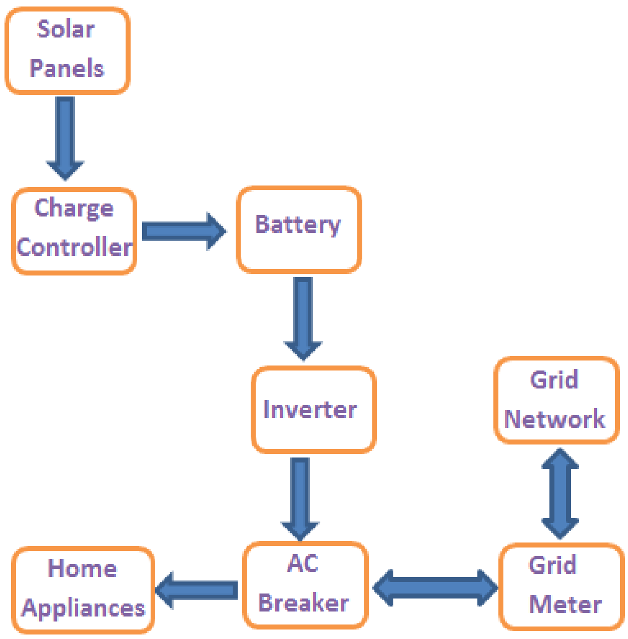

Figure 7:
Setup diagram of the system

Tools for the establishment of the system with price list are given in Table 2. The price given is valid for Turkey conditions and prices can vary in other countries. A total of 15,600 ₺ is required for installation of the system.

Table 2. System component price list

Item list	Amount	Unit price ₺	Total price ₺
250 W solar panels	12	600	7200
Full sine inverter 4000 W	1	2000	2000
150 A gel batteries	8	750	6000
Charging control unit	1	400	400
TOTAL			15,600

Consuming 300 kWh of electricity per month for a family, monthly bill (taken into account the data of April 2015) is 120 ₺. The annual electricity bill would be 1440 ₺. However, when annual inflation share is taken into consideration, price will be a little more expensive than a year before. If the electricity share price doesn't change, the invoice amount will be paid is14,400 ₺ over 10 years. However, there is a range of 6-10 % annual inflation in Turkey. Considering the annual reflected inflation rate is 4 %, regular electricity bill is to be paid amount 27,323 ₺ in ten years. If the annual reflected inflation rate is 10 %, ten year electricity bill will be 33,805 ₺. These situations pay off the invested money in 9 years. If the system is considered to serve a highly profitable situation consists of 20-30 years. 9 years after the initial installation family can profit.

If 1 kWh of electricity generated from fossil fuel, CO_2 emissions arise in the 800-950 g range. If annual consumption is considered to be 3600 kWh, range of 2880-3420 kg CO_2 would be released into the atmosphere. If the 10-year period CO_2 released into the atmosphere, it would be in the range of 28-34 tons. If this installation built 1000 home throughout the city, around 3,000 tons of CO_2 would not release into the atmosphere in a year. This will give chance to new generations to leave a cleaner World.

4. CONCLUSION

In this study, electricity usage of a house to be supplied with PV in Adiyaman and economic conditions were investigated. Solar energy systems were designed to generate 10-15 kWh of electricity per day. Prices of required system components were investigated in Turkey conditions and used actual prices. The system's total cost was estimated to be 15,600 ₺. According to data from the electricity distribution companies, electricity consumption per family per month was found as 300 kWh. As a result of the calculations made, if we also take into account the maintenance costs, it was determined to pay off investment to be about 10 years.

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