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Meeting a dwelling's energy need with solar energy: An application study from Turkey

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Abstract

Electricity generation and having energy resources are one of the most important issue for societies from past to these days. Fossil fuels that providing three quarters of world's basic energy needs cause global warming with greenhouse gases becomes progressively smaller as well. Energy consumption is constantly increasing in parallel with population growth in the world, urbanization, industrialization and expansion of technology. While fossil fuels are quickly running out, energy demand is increasing rapidly. It is assumed that Petroleum is getting run out 2050 years. Natural gas and coal will have reserve until 2050 and 2150. In addition, the uses of fossil fuels have many negative effects to our environment. Cities are covered with black exhalations and sometimes it is hard to breathe because of air pollution. The Ozone layer has pierced and has became unable to fulfill the task of filtering. We have started to feel the effects of global warming strongly with each passing day. In such an environment, electricity generation with solar energy is becoming really important which is an endless source of clean energy. However, Dwellings to fulfill their own electricity need contribute significantly to environmental pollution and energy production. In this study, meeting a dwelling's energy need with clean energy that is one of the future energy generation methods has been examined. A system which generates electricity from solar energy was designed for this purpose. In this study we want to show the applicability of solar energy system at houses and make a practice about cost and productivity analyses.

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Keywords: Electricity Generatio; Renewable Energy; Solar Energy; A House's Electricity Need; Air Pollution.

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1. Introduction

Solar cells generate power by absorbing the energy of photons from the Sun. When a photon strikes the surface of a solar cell, electrons are transferred through the cell, and a measurable current is formed. This process is known as the photoelectric effect, and it is the basis for solar power. The total power produced by a solar module is limited by the total amount of solar energy, in the form of photons, striking the surface of the panels. [1] The most abundant fuel source in the realm of renewable energy is the sun. Solar panels produce electricity through individual photovoltaic cells connected in series. This form of energy collection is viable in regions of the world where the sun is plentiful, and can be used in isolated regions or on houses to supplement the rising cost of electricity from a power grid. To convert the sun's energy, the cells capture photons to create freed electrons that flow across the cells to produce usable current [2]. The efficiency of the panel is determined by the semiconductor material that the cells are made from as well as the process used to construct the cells. Solar panels come in three types: amorphous, monocrystalline, and polycrystalline [3]. The more efficient of panel material is constructed from, the greater cost. To maximize results, there are many features that can be used to control the output of the photovoltaic panels. The power needs determine what components are used to produce the desired voltage and current for the project such as converters, solar trackers, and the size of the panel [2].

2. Electricity generation from solar PV

Photovoltaic (PV) energy applications can be divided into two categories: one is stand-alone system and the other is grid-connected system. Stand-alone system requires the battery bank to store the PV energy and it is suitable for low-power system [5]. Stand-alone PV systems, shown in Fig. 1, are used in remote areas with no Access to a utility grid [6].

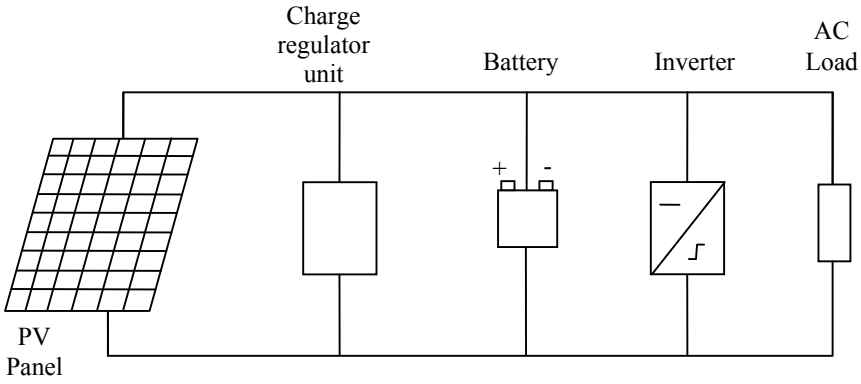

Fig. 1. Stand-Alone Photovoltaic Systems Block Diagram [6]

Grid-connected system does not require the battery bank and has become the primary PV application for high-power applications. The main purpose of the grid connected system is to transfer maximum solar array energy into grid with a unity power factor. Because of the high cost of PV modules, PV generation systems are attractive only for remote isolated areas and for small-scale applications such as PV refrigerators and water-pumping systems [4].

A PV system for the grid-connected applications is typically composed of five main components: 1) a PV array that converts solar energy to electric energy, 2) a dc-dc converter that converts low dc voltages produced by the PV arrays to a high dc voltage, 3) an inverter that converts the high dc voltage to a single- or three-phase ac voltage, 4) a digital controller that controls the converter operation with maximum power point tracking (MPPT) capability, and 5) a AC filter that absorbs voltage/current harmonics generated by the inverter [7]. Block diagram of grid-connected photovoltaic system is shown in Fig. 2.

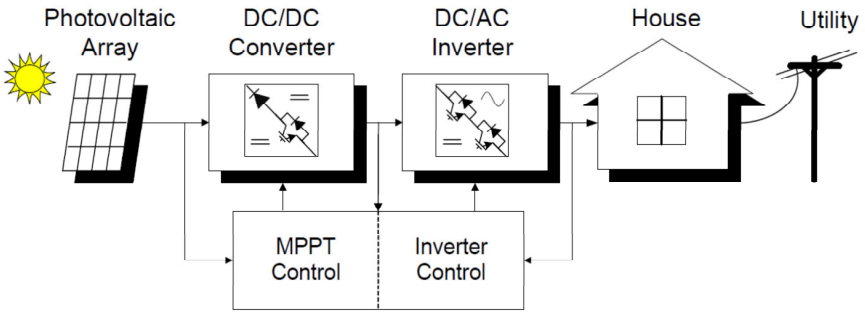

Fig. 2. Block diagram of grid-connected photovoltaic system [7]

3. Solar energy potential in Turkey

The Turkish economy has been growing rapidly, especially since the 1980s. Despite limitations in domestic resource availabilities, primary and secondary energy demand is growing very rapidly, parallel with its industrialization efforts. Turkey is an energy-importing country. The main energy resources are hydro and lignite. It hasn't very much oil or natural gas reserves. For this reason, a significant part of oil and gas is imported. In Turkey, electricity is produced by hydro power plants and thermal power plants, consuming lignite, coal, natural gas, and fuel oil. It also has a large potential for renewable energies [8].

Solar radiation arriving on earth surface is the most fundamental renewable energy source. In recent years, solar energy utilization in various applications has increased significantly. Turkey is promising country for solar energy potential. Its geographical location is highly favorable for the utilization of solar energy. It is geographically located (36-42°N latitudes) in a useful position for the solar power [9]. Turkey's monthly average solar potential is shown in Table 1.

Table 1. Monthly Average Solar Potential of Turkey

Months	Monthly Total Solar Energy (kWh/m2-month)	Sunshine Duration (hours /month)
January	51.75	103
February	63.27	115
March	96.65	165
April	122.23	197
May	153.86	273
June	168.75	325
July	175.38	365
August	158.4	343
September	123.28	280
October	89.9	214
November	60.82	157
December	46.87	103
Total	1311	2640
Average	3.6 kWh/m2-day	7.2 hours/day

Solar Energy is the most important alternative clean energy resource in Turkey. The yearly average solar radiation is 1311 kWh/m² a year and 3.6 kWh/m^2 a day. The total yearly insulation period is approximately 2460 hours per year and 7.2 hours a day. [4] Solar radiation map is shown in Figure 3.

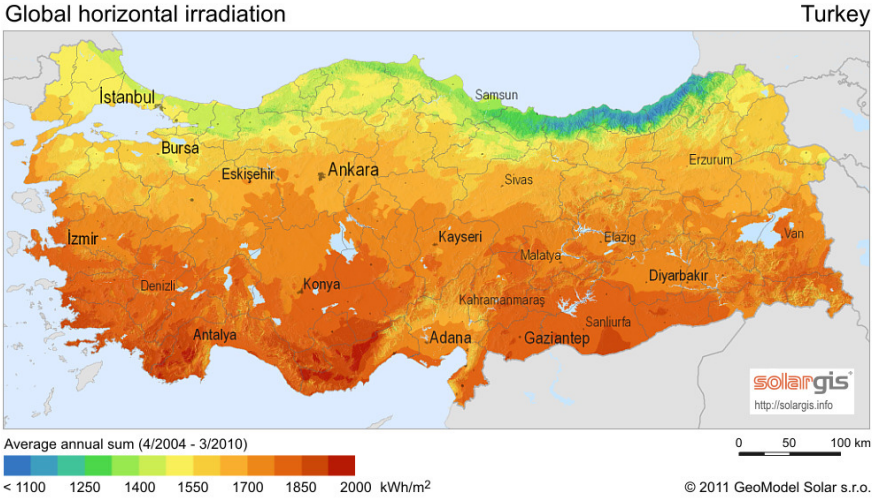

Fig. 3. Turkey's solar radiation map

According to the data of Electrical Power Resources Survey and Development Administration, Konya city has the total annual 1785 KWh/m^2 solar energy potential. The month with the highest potential of solar energy is july with 231 KWh/m^2 value and december has the lowest value with 62 KWh/m^2 for the potential of solar energy in Konya.

4. Electricity needs of a house

When we look at electricity consumption values of a house, we see that refrigerator is in first order with a share of 30%, lighting is the second with 28%, electric furnaces with 10% third-place, TV 10%, washing machine 7%, dishwasher 6%, iron 4%, vacuum cleaner 3% and hair dryer 2% share.
A house's daily, weekly and monthly energy consumption amounts shown on the following Table 2. When the table data determining, a medium-sized family and home considered, values calculated according to these conditions. Also it assumed that, this house has all electrical equipments and they are using actively.

Table 2. A house's daily, weekly and monthly average electricity consumption values

Product Name	Daily Average Power Consumption (kWh/24 hours)	Weekly Average Power Consumption (kWh/A week)	Monthly Average Power Consumption (kWh/A Month)
Refrigerator	0.90 kWh	6.3 kWh	27 kWh
Lighting (3 bulb x 5 hours)	15x30w=0.45 kWh	3.15 kWh	12.6 kWh
Electric Oven (1 hours x 3 days) /week	1x1100w=1.1 kWh	3.3 kWh	13.2 kWh
TV (4 hours per day)	4x100w=0.4 kWh	2.8 kWh	12 kWh
Washing Machine (2 hours x 2 days) /week	1x0.95 kWh=0.95 kWh	3.8 kWh	15.2 kWh

Dish Machine (1 hour x per day)	1x0.85 kWh=0.85 kWh	5.95 kWh	25.5 kWh
Iron (2 hours / week)	-	2x1800w=3.6 kWh	14.4 kWh
Vacuum Cleaner (3 hours / week)	-	3x1200w=3.6 kWh	14.4 kWh
Hair Dryer (2 hours / week)	-	2x1200w=2.4 kWh	9.6 kWh
Computer (2 hours / day)	2x300w=0.6 kWh	4.2 kWh	16.8 kWh
Water Heater (3 hours / week)	-	3x3000w=9	36 kWh
Electric Kitchen Appliances	300w	2.1 kWh	8.4 kWh
Total	5 kWh	50.1 kWh	205.1 kWh

When we look at the values in the above table, this sample home needs 5kWh electricity a day, 50.1 kWh a week and 205.1 kWh a month. We made an example solar energy power generation system design for daily 5 kWh of electricity consumption in our study.

5. Solar PV system design

The study was carried in accordance with climate conditions of Konya Province in Turkey. Monthly average of all energy expenditures of a dwelling was inferred. Meeting the need of electricity with solar energy according to weather data of Konya was analyzed. A renewable energy system was established with solar panels at Selcuk University campus area in Konya. On this clean energy system we used 6 solar panels with 130 watt power shown in Fig. 4.

Fig. 4. Solar Panels used in the study

The generated electricity stored on 12V, 140Ah gel batteries. We used computer software to record real time data and also make daily, weekly and monthly records. It was also possible to get remote access to these data. Measurements were made during 1 year period and the produced electricity was used at Technical Education Faculty of Selcuk University. Solar panel data recording area is shown in Fig. 5.

Fig. 5. Solar panel data recording area

Solar panels produce direct current (DC) but devices used in homes work with alternating current (AC). Inverter converts direct current to alternating current. 12-14 volts direct current converts to 220 volts 60 Hz mains electricity by inverter. The inverter with 2000 watt capacity used in the study is shown in Fig. 6.

Fig. 6. Sinus inverter used in the study

An example of a weekly record of data recording software is shown in Fig. 7. In this screenshot we see records from the first week of September of 2012. Three types of data are recorded on a daily basis in our PV system. These are the occupancy rate of batteries, voltage and current values on batteries. In Fig. 7 we see max battery voltage and min battery voltage that means highest and lowest voltage value reached during the day.

Day1 is the latest:	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
Max Battery Voltage	28,9	28,9	28,9	29	28,9	28,9	28,9
Min Battery Voltage	25	25	25	25	25	25	25
State Of Battery Charge in % morning	66	73	66	66	66	73	66
State Of Battery Charge in % evening	100	100	100	92	92	92	92
Used PV Amperehours	61	61	64	64	61	64	67
Load Amperehours	0	0	0	0	0	0	0
PV Excess Amperehours	107	107	107	75	107	109	101
max PV current in A	23,1	23,8	23,8	25,6	23,8	24,4	24,4
max Load current in A	0	0	0	0	0	0	0
Fully Charged Battery							

Fig. 7. An example of a weekly record of data recording software

6. Conclusion

Konya has values above the average of Turkey about solar radiation and sunshine duration. When we analyze our recorded solar data, we have seen that if we have big enough clean energy system for a house, it covers the house's all electricity needs. In our study, as a result of seven-hour working a day 780 Watt solar panels producing 5.5 kW of electricity energy. This is good enough value to meet an average size house's daily electricity needs.When we look at the cost of the initial installation, we have seen that there is need an average of 6 thousand Euros budget for this renewable energy system including solar panels, solar batteries, AC to DC converter and charge controller device. A family with 4 members uses approximately 5 kW electricity energy in a day for lighting and all electrical appliances. So this sample house needs 150 kW power in a month. You pay 25 € each month for this electricity use in Turkey conditions. The renewable energy system will meet the cost of the initial installation nearly in 20 years.

Cost of first installation is the most important factor for using solar energy system at dwellings. Because the cost of first installation still has quite high rates. Development of solar panel production technologies and finding more economical ways are a requirement for widely use. The use of renewable energy sources will be a necessity rather than a preference in the future. Therefore, producers and scientists should give more importance to research and development activities about solar energy technologies. A wind turbine can be added to the clean energy system by this way wind power can be used at sunless days. The hybrid system with wind and the sun will give better performance.

Acknowledgements

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