Uluslararası Mühendislik Araştırma ve Geliştirme Dergisi
International Journal of Engineering Research and Development

UMAGD, (2022) 14(3), s255-s260.

10.29137/umagd.1216762

Cilt/Volume:14 Sayı/Issue:3 Aralık/December 2022 Özel Sayı / Special Issue

Seçilmiş Konferans Makalesi / Selected Conference Paper

Meeting the Electricity Need of a House with Solar Energy- Applying Solar PV to Heat Pump in İzmir House

Seda Kırmacı Arabacı [1*], **Fatih Tunç**[1], **Baran Tosun**[1]

[1]*Department of Mechanical Engineering, Manisa Celal Bayar University, 45140,Manisa, TURKEY*

***Başvuru/Received**: 09/12/2022* ***Kabul / Accepted**: 29/12/2022* ***Çevrimiçi Basım / Published Online:** 31/12/2022*

***Son Versiyon/Final Version**: 31/12/2022*

Abstract

Solar energy is the most popular alternative energy resource application. Humanity has continued to search for different energy sources since its existence. While energy resources have been found to meet energy needs, they have also brought about environmental pollution. Solar energy is a solution to energy needs and does not cause environmental pollution. Solar collectors are needed to use solar energy. In this study, the design to meet the electricity needs of a house with solar energy has been made. In this study, a system that meets the electrical energy requirement of a house in İzmir, Turkey, with photovoltaic panels has been designed and examined. According to the results, panel prices are very high, and the manufacturers should reduce the initial installation cost. In this project, the heat requirement of a duplex house of 175 m^2 is calculated. It is decided to use a heat pump to meet this thermal need. The electrical energy consumed by the duplex house's heat pump and other electronic appliances is calculated, and a system that generates electricity from solar energy is designed to meet this energy demand. The system payback period is 10-11 years, excluding the heat pump, and 14-15 years, including the heat pump.

Key Words

"Solar Energy, Cost Analysis, Heat Pump, Photovoltaic Panels"

***Corresponding Author:** seda.kirmaci@cbu.edu.tr*

1. Introduction

It is seen that the days when the natural resources of the world will be exhausted are not far away. Energy consumption is very high in homes, schools, hospitals, and factories. Until recent years, energy needs were met from fossil sources. Recently, the importance of using renewable energy sources has increased. Renewable energy sources reduce the external dependency of countries, do not have fuel costs, do not pollute the environment, and have advantages such as providing very cheap energy. Due to all these advantages, the interest in renewable energy sources is increasing day by day (Başaran, 2013).

The new investments in the renewable energy field are examined, and it is seen that the investments made in the wind and solar fields are at the forefront (Başaran &Börekçi, 2013). Considering that %35-40 of the fossil fuels consumed in the world are used in buildings, reducing the energy used in buildings is very important in terms of energy saving and energy efficiency. In this direction, it is necessary to work on increasing the use of renewable energy in buildings and tending to these sources as much as possible (Yıldırım & Güngör, 2011). In order to respond to the increasing energy need, human beings have started to turn towards alternative energy sources by taking into account the environmental factor by aiming to use all resources. Turkey has large reserves in terms of renewable energy resources. Considering the growth rates of Turkey, it is predicted that Turkey's energy needs will increase rapidly. Turkey is approximately 74% dependent on foreign sources to meet its energy demand. To meet this energy need, regionally renewable and non-renewable energy sources should be utilized (MFRTEHFP, 2022). The literature is reviewed, and many articles deal with the self-consumption of solar PV energy (Stauffer et. al., 2018). Considering the electricity bills paid for a 120m^2 house in Bursa, the amortization period has been determined for the solar panel system that can only pay for itself in the long term, such as 8-10 years (Güneş&Karagöz, 2017). Using heat pumps in the residential sectors will decarbonize the energy. The use of solar-assisted heat pump systems will also support global emission reduction (Vaishak and Bhale, 2019).

In this project, the heat requirement of a duplex house of 175 m^2 is calculated. It is decided to use a heat pump to meet the thermal needs. The electrical energy consumed by the heat pump and other electronic appliances of the duplex house is calculated, and a system that generates electricity from solar energy is designed to meet this energy.

2. Solar Energy

2.1. Turkey's solar energy potential

The Ministry of Energy and Natural Resources and the General Directorate of Meteorology continues the potential determination studies initiated to determine the places where the systems developed on solar energy can be applied throughout our country and the energy that can be obtained.

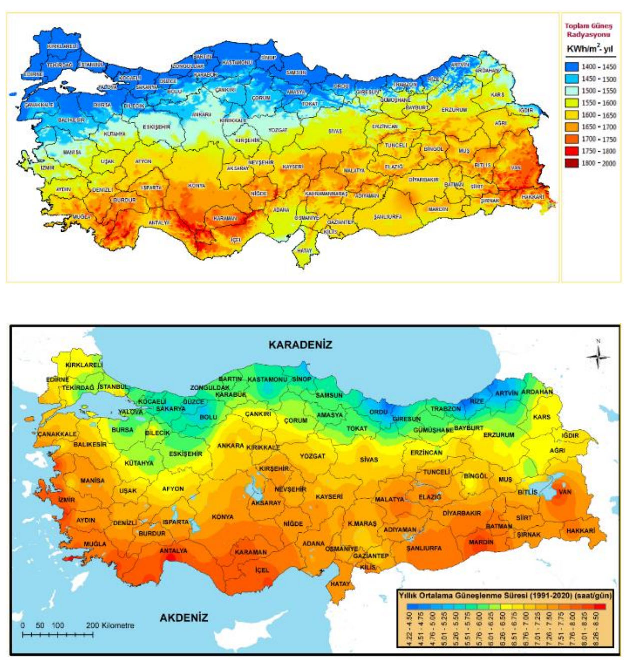

Figure 2. Average annual sunshine duration in Turkey (TR-MEUCCGDM, 2022)

According to the Renewable Energy Resources Institution Turkey's average annual sunshine duration is 2640 hours (7.2 hours per day), annual radiation intensity value is 1.311 kWh/m^2 -year (3.6 kWh/m^2 per day).(Figure 1) Average annual sunshine duration in Turkey is shown in Figure 2. Data on solar energy parameters of Turkey in general and regionally are analyzed statistically on a monthly, seasonal and annual basis (Taşova,2018).

Photovoltaic systems (PV) are less preferred in Turkey.The PV power used in Turkey is about 40 MW (CEET, 2022). These PV systems are generally preferred in hard-to-reach districts, places far from cities, forest watchtowers, lighting of highways, and chalets (Öztürk&Yüksel, 2016). Seasonal normals for Provinces in İzmir shown in Table 1.

Table 1. Seasonal Normals for Provinces in İzmir (TRMEUCCGDM, 2022)

İZMİR	Jan.	Feb.	Marc.	Apr.	May	Jun.	July	Aug.	Sept.	Oct.	Nov.	Dec.	Yearly
Measurement Period (1938-2021)													
Average Temperature (ºC)	8.8	9.6	11.7	15.8	20.8	25.4	27.9	27.7	23.7	18.9	14.3	10.5	17.9
Average Max.Temperature (ºC)	12.4	13.6	16.3	20.9	26.1	30.7	33.2	33.0	29.2	24.0	18.6	14.1	22.7
Average Lowest Temperature (ºC)	5.8	6.2	7.7	11.1	15.5	19.8	22.5	22.4	18.7	14.6	10.8	7.6	13.6
Average Sunbathing Time (hours)	4.3	5.2	6.4	7.9	9.8	11.6	12.3	11.9	10.1	7.6	5.6	4.2	8.1
Average Number of Rainy Days	12.82	11.47	10.47	7.47	6.82	4.06	0.29	0.71	2.76	5.59	8.82	12.88	84.2
Average Monthly Total Rainfall (mm)	136.9	102.9	75.8	46.0	31.5	12.3	4.1	5.6	15.3	44.6	92.0	146.8	713.8
Measurement Period (1938-2021)													
Highest Temperature (ºC)	22.5	27.0	30.5	32.5	37.6	41.3	42.6	43.0	40.1	36.0	30.3	25.2	43.0
Lowest Temperature (ºC)	-8.2	-5.2	-3.8	0.6	4.3	9.5	15.4	11.5	10.0	3.6	-2.9	-4.7	-8.2

2.2 Solar photovoltaic batteries

Solar cells can be used in applications where electrical energy is available. Solar cell batteries are used together with battery charge control devices to form a solar cell system (photovoltaic system).

There is usually a battery in the system to be used, especially during the night when the sun is insufficient. Solar cell modules produce electrical energy throughout the day and store it in the battery. Solar panels by combining multiple solar cells to obtain more energy, solar panel systems or solar farms by using the panels together and adding other components created (Çolak, 2010). Energy flows in the electrical, heating and cooling systems system is shown in Figure 3.

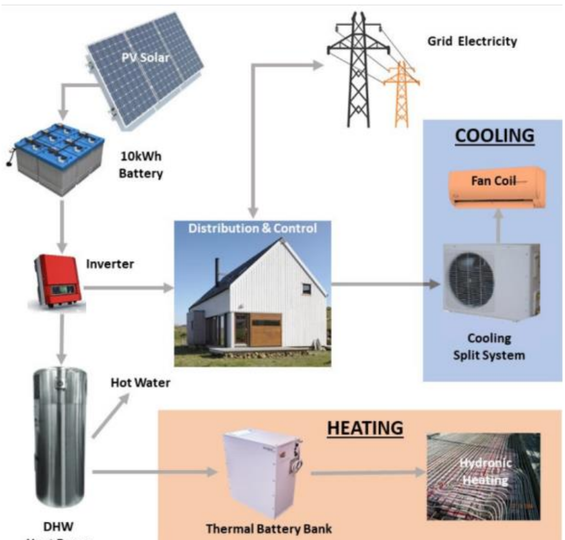

Figure 3. Energy flows in the electrical, heating and cooling systems (Simko, 2021).

3. Materials and Methods

3.1 Calculating the heating energy need of the building

The total amount of heating energy of the building for each assumed case in the study is calculated according to the calculation method in the TS 825 "Thermal Insulation Rules in Buildings" standard (TS 825, 2022)

Heat loss in the window is calculated as below:

$$H_{window} = \sum AU + H_h \quad (1)$$

In this equation (1), ΣAU is the amount of heat lost from windows by conduction and is the product of the heat conduction value accepted for windows and the total window area. H_h is the heat loss through ventilation and is calculated according to the following equation.

$$H_h = \rho c V'' = n_h V'_h \quad (2)$$

where n_h number of air changes and V_h volume (m^3) is. According to the standard, the product of ρc is considered constant and is 0.33.is taken. $n_h$value is taken as 1.

The monthly total heating energy requirement of the building is calculated as below;

$$Q_{month} = [H(T_i - T_o) - \eta_{month}(\text{Ø}_i + \text{Ø}_s)]t \quad (3)$$

Monthly heating energy needs from windows are as follows;

$$Q_{month,window} = [H_{window}(T_i - T_o) - \eta_{month}(\text{Ø}_i + \text{Ø}_s)]t \quad (4)$$

H and H_window are the specific heat loss of the building and the conductive heat loss from the windows, T_i, respectively, and T_o (°C) are the indoor and outdoor temperatures, respectively, the indoor temperature is 19°C and the monthly average values given in TS 825 are taken as the outdoor temperature. η is the heating utilization factor. Ø_i and Ø_s (W) values are the internal and solar radiation gain of the building, respectively. The internal heat gain (Ø_i) for the residence is calculated using the following equation using the building's usage area and the building's gross volume.

$$\text{Ø}_{month} \leq 5A_N \quad ; \quad A_N = 0.32V_{gross} \quad (5)$$

The radiative heat gains Ø_s obtained from the windows throughout the year is the sum of the monthly radiative heat gain Ø_s values obtained from the windows. The heat gain by the radiation obtained from the windows varies according to the direction and the number of layers.

A duplex house with an area of 175 m^2, located in western Turkey, Izmir, with a latitude of 37°, is required to meet the thermal need with a heat pump. The electrical energy consumed by the heat pump and other appliances in the house was calculated and a system that generates electricity from solar energy was designed to meet this energy.

The roof area of the house where the solar panel is planned to be placed is 48 m^2. While installing the solar panel, step gaps should be left between them, 16 m^2 of the roof area will be left empty and 32 m^2 will be reserved for solar panels. 400 Watt 72PM X brand Monocrystalline Solar panel has 2m^2 area and 16 pieces can be placed on the roof. The Monocrystalline Solar panel is shown in Figure 4.

Figure 4. Monocrystalline Solar panel

4. Results

4.1 Heat pump selection and electricity consumption

The heat loss of the house is calculated as 13695 kCal/h (=16kW). 16 kW and X brand Heat Pump has been selected. The COP of the heat pump is taken as 4. The energy saving provided by the room thermostat is 25%. Electricity consumption is 4 kWh, when a thermostat is used the value of electricity consumption is 3 kWh.

Daily electricity consumption after 9 hours of average daily use is 36.7 kW. The maximum daily electricity consumption was found by summing the electricity consumption excluding heating and the required electricity consumption for heating.

4.2 Solar panel selection

For the province of Izmir, 400W electricity can be produced for 7 hours per panel on average. The sunbathing times in İzmir are 7 hours. The electrical energy produced daily from a panel is 2800 W, for 16 panels it is 44800 W. This annual amount has been calculated as 16352 kWh.

4.3 Battery selection

Batteries are needed to continue using the electricity produced during the day at night. In this project, gel batteries are preferred due to their high efficiency and cycle life. 200Ah Ultra Power Gel Battery 12V 200Ah is used. Electricity Storage Amount is 2400 W. (the amount of electricity storage of a single battery) 18 kW of storage will be sufficient since electricity will be taken from the panels, not from the battery, during the daytime. 9 batteries are needed and it stores 21.6 kW.

$$\text{Numb. of Battery} = \frac{\text{Daily energy need x battery losses}}{\text{battery voltage(V) x battery capacity(Ah)}} \tag{6}$$

$$\text{Numb. of Battery} = \frac{\text{18 kW x 1.10}}{\text{12(V) x 200(Ah)}} = 8.25$$

Charge controller and inverter are also included in the system, and then depreciation of the system has been calculated.

4.4 Depreciation of the system

The cost table of the system is shown in Table 2. The first thing that draws attention in the table is the number of photovoltaic panels. If the efficiency of the panels used is increased and therefore the amount of energy to be obtained is increased, the number of panels to be used will decrease proportionally.

Table 2. The cost analysis of the system

System elements	**Amount ($)**
Heat Pump	$ 4500
16 x Solar Panel	$ 4550
9 x Battery	$ 3600
2 x Charge Controller(not required)	$ 500
Inverter	$ 830
TOTAL	$ 13980

In addition, this system can only pay for itself in the long run, considering the annual electricity bills paid for a 175 m^2 house.

10-11 years (the system payback period excluding the heat pump)
14-15 years (the system payback period including the heat pump)

The costs of the PV elements used in the system should be tried to be reduced. The use of this solar energy potential in Turkey, which is so valuable and unlimited, should be encouraged. The fact that the features of the system to be used for electricity generation with solar panels are based on technical calculations creates an obstacle for users who want to benefit from this system.

5. Discussion and Conclusion

This study is aimed to increase the efforts to reach more people in the use of solar energy in our country. In this age where environmental pollution and global warming are a big problem, Solar Energy systems represent a considerable opportunity to reduce carbon footprint and contribute to a sustainable environment, which the world longs for, in order to help keep a sustainable world.
The low number of companies producing panels is one of the reasons for the increase in costs. Studies should be supported to reduce the costs of solar panels. Research and development studies should be carried out in every region of Turkey in order to benefit from

the potential of solar energy. The behavior of the system in different regions of Turkey can be investigated in the other studies. It is necessary to encourage and support users in all regions in terms of electricity generation with solar panels.

Acknowledgment

This study was presented at the 1st International Conference on Scientific and Academic Research ICSAR 2022.

References

Başaran, K. (2013). Bulanık Mantık Kontrollü Otonom ve Şebeke Bağlantılı Rüzgar-Güneş Hibrid Güç Sisteminin Optimizasyonu ve Adnan Menderes Üniversitesi Kampüs Alanında Uygulanması, PhD Thesis, Solar Energy Department, İzmir, 131 s.

Başaran, K. & Börekçi, S. (2013). 150 kW Şebeke Bağlantılı Çatı Kurulumlu Fotovoltaik Sistem Fizibilitesi, 2. Solar Symposium, Antalya

Chamber of Electrical Engineers of Turkey, Turkey Electrical Energy Statistics (CEET), (2022), Retrieved from (http://www.emo.org.tr/genel/bizden_detay.php?kod=88369#.WH1GRfmLTIU)

Çolak, S. Ç. (2010). "Fotovoltaik Paneller Yardımı ile Güneş Enerjisinden Elektrik Enerjisi Üretiminin Maliyet Analizi ve Gelecekteki Projeksiyonu" Yıldız Technical University Graduate School of Natural and Applied Sciences, 2010

Stauffer, Y., Koch, N., Hutter, A. & Pflugradt, N.D. (2018). Quantifying the Potential of Smart Heat-Pump Control to Increase the Self-Consumption of Photovoltaic Electricity in Buildings. Retrieved from: http://proceedings.ises.org/paper/eurosun2018/ eurosun2018-0158-Stauffer.pdf

Güneş, N. & Karagöz, İ. (2017). Türkiye'de Güneş Enerjisi ve Bursa İli için Bir Uygulama, 13. National Plumbing Engineering Congress, 19-22 April 2017, İzmir

Ministry of Foreign of the Republic of Turkey-Entrepreneur and Humanitarian Foreign Policy (*MFRTEHFP*), (2022). Retrieved from: https://www.mfa.gov.tr/turkiye_nin-enerji-stratejisi.tr.mfa

Öztürk M. & Yuksel Y. E. (2016). Renewable and Sustainable Energy Reviews 53, 1259-1272, 2016.

Simko, T., Luther, M. B., Li, H. X. & Horan, P. (2021). Applying Solar PV to Heat Pump and Storage. Technologies in Australian Houses Energies, 14(17), 5480.

Taşova, M. (2018). Türkiye'nin Güneş Enerjisi Parametre Değerleri ve Güneş Enerjisinden Faydalanma Olanakları, Journal of Advanced Technology Sciences, 7(3), 10-17

TR Ministry of Environment, Urbanization and Climate Change General Directorate of Meteorology -Solar Energy, (*TR-MEUCCGDM*). (2022). Retrieved from: https://www.ilbank.gov.tr/sayfa/solar-energy

TR Ministry of Environment, Urbanization and Climate Change General Directorate of Meteorology (*TR-MEUCCGDM*). (2022). Retrieved from: https://mgm.gov.tr/kurumici/turkiye-guneslenme-suresi.aspx

TR Ministry of Environment, Urbanization and Climate Change General Directorate of Meteorology (*TR-MEUCCGDM*). (2022). Retrieved from: https://www.mgm.gov.tr/veridegerlendirme/il-ve-ilceler-istatistik.aspx?m=IZMIR

Turkish Standards Institution. *(TS 825).* (2008). Standard of Thermal Insulation Rules in Buildings, Ankara.

Vaishak, S. & Bhale, P.V. (2019). Photovoltaic/thermal-Solar Assisted Heat Pump System: Current Status and Future Prospects, Sol. Energy 2019, 189, 268–284.

Yıldırım, U. & Güngör, A. (2011). Yeşil Evler ve Türkiye'deki Uygulamaları. Chamber of Mechanical Engineers 5th Solar Energy Systems Symposium and Exhibition Proceedings, Publication no: E/2011/562, Ankara, s. 66-67.