

RESEARCH ARTICLE

The Design and the Application of Off-Grid Solar Power System for a House in Kastamonu

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ABSTRACT

Off-grid solar power systems are becoming a more and more practical option for residential buildings looking to be environmentally friendly and achieve energy independence. This research offers a summary of an off-grid solar power system design specifically for a Kastamonu residential home. The study investigates the significance of using solar energy for a sustainable and dependable source of electricity, with an emphasis on the particular geographic and meteorological circumstances of the province. A system for creating off-grid solar energy systems is designed in this study with consideration for the weather and solar radiation in order to suit the unique energy requirements of a house in Kastamonu. It has been observed that 37.7% of the annual consumption of the selected house can be covered by the designed system and the system can amortize itself in 7.8 years. In general, residential off-grid solar power system design signifies a revolutionary turn towards sustainable energy methods, enabling homeowners to welcome a greener, more self-sufficient energy future.

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1. Introduction

The concept of energy was initially proposed in the 17th century, and as scientists worked to understand life's mysteries, they advanced their research on it. A few centuries later, energy was first defined, enabling quantitative expression in already-existing physical systems. Numerous physical theories that derive from the principles of thermodynamics uphold the principle of energy conservation. Energy can therefore cause its own change and transformation, but it cannot be formed from nothing, nor can it destroy things that already exist. There are various types of energy, such as chemical, thermal, kinetic, potential, electrical, mechanical, magnetic, nuclear, sound, and light energy. Today, technology is allowing the energy that

drives technological advancement to continue developing on its own. Its energy has grown to such an extent that it is regarded as one of the most significant future building blocks. In the past, balancing production against consumption -which is currently the world's most pressing need- and even maintaining it at even higher levels, as well as the future discovery and development of a new world, were significant scientific concerns. Since their origin over millions of years ago, fossil fuels like coal, oil, natural gas, and nuclear power have been used for centuries to meet the energy needs of many regions worldwide, particularly in the domains of heat, electricity, and fuel. However, while it fosters economic leadership in areas with abundant resource reserves, it leaves these regions dependent on nations without

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reserves that are unable to supply their energy needs. Resources for energy appear to be more and more needed annually.

Energy has an impact on industry, communication, technology, the global economy, and political relations due to its necessity. The lack of sufficient production notwithstanding consumption and the impacts of fossil fuel usage on global warming are projected to generate energy crises in the future, prompting a quest for alternative energy sources. The most important criterion in energy production is that the resources are inexhaustible, reusable, recyclable and not as harmful to the environment as fossil fuels. There is a growing recognition that renewable energy sources, including geothermal, hydroelectric, solar, and wind power, are essential in meeting the pressing demand for sustainable energy generation. The shift to renewable energy is now essential due to the impending challenges of climate change, depleting fossil fuel supplies, and environmental damage. Numerous advantages come with renewable energy technologies, such as decreased air pollution, reduced greenhouse gas emissions, improved energy security, and stimulation of economic growth through the creation of jobs and new technology advancements. Furthermore, the decentralized energy system provided by renewables enables people and communities to produce their own electricity and contribute to a more egalitarian and resilient energy environment. Adopting renewable energy sources is socially and economically just as well as environmentally responsible, given the rising worldwide demand for energy (IPCC, 2024; IRENA, 2024; UNEP, 2024).

Solar power systems for houses have been a game-changer in the fight for sustainable energy. Through the installation of solar panels on roofs, homeowners can efficiently produce clean electricity to power their homes. Solar power systems benefit the environment by lowering carbon emissions and lowering reliance on fossil fuels, but they also improve the economy by lowering electricity costs and possibly earning money from selling extra energy back to the grid. Additionally, advancements in solar technology and declining installation costs have increased the availability of solar electricity for homeowners worldwide. A dependable and affordable investment for residential properties, solar panels also have a long lifespan and require little maintenance. Solar power systems are quickly becoming a necessary part of sustainable living for homes because of their ability to increase energy independence and contribute to a cleaner future (Solangi et al., 2011; Sahoo, 2016). Simple and dependable, solar power offers a steady, limitless supply of electricity without emitting any greenhouse gases. This is what makes it so beautiful. Solar panels give homes a practical means of lowering electricity bills in addition to lowering carbon footprints, offering long-term financial benefits as energy costs rise. Furthermore, solar installations are now more reasonably priced and within the reach of homes with different budgets because to technological advancements and economies of scale. Solar power systems not

only offer energy independence but also the opportunity for homeowners to become energy producers, adding to a more robust and decentralized energy infrastructure. An additional benefit of net metering is the ability to sell excess electricity back to the grid. Essentially, solar power systems for houses represent the perfect union of sustainability and usability, enabling people to take charge of their energy usage and fostering a cleaner, brighter future for future generations (Panwara et al., 2011; Bathaei & Streimikiene, 2023).

In recent years, the demand for home solar power systems has increased due to the increasing energy demand and the high cost of supplying energy. For this purpose, solar power system in residential area studies are intensively carried out in the literature (Faiers & Neame, 2006; Chehri & Mouftah, 2013; Wermager & Baur, 2013; El-Shahat et al., 2019). In Karaca and Dincer (2020), an integrated solar-based nature-friendly multi-generation power system containing a heat pump, an absorption chiller, photovoltaic-thermal panels, photo-electrochemical reactors, and a proton exchange membrane fuel cell to provide the useful outputs of heating, cooling, electricity, hot water, hydrogen production, and domestic wastewater treatment has been designed for residential houses. Energy and exergy methodologies along with thermodynamic analysis have been used to assess the system's overall performance. This study's findings have indicated that the suggested system can attain energy and energy efficiencies of 40% and 71.8%, respectively. In Tabassum et al. (2020), a small-scale Photo Voltaic (PV) based system has been designed within a housing compound or on the rooftop to generate sufficient power to support a household daily electricity usage. It has been observed that installing the solar PV system in the residential area has been viable in this study. In Shahabad et al. (2022), a model has been developed to assess the impact of subsidies after a thorough investigation into the relationship between the several elements influencing Iran's energy system's sustainability and the consequences of developing these power plants on it. The findings of this study have demonstrated that the technical aspect of the energy system's sustainability is positively impacted by the use of subsidies for the development of hybrid solar power plants (HSPPs) through distributed generation.

Makkiabadi et al. (2021) examine the quantity of electricity generated in Iran from solar energy. An economic and technical analysis is also conducted about the development of a 10 MW power plant in the city of Sirjan. The findings in this study indicate that a solar power plant in the Sirjan region may be constructed for US\$16.14 million, with a four-year payback period for the original investment. According to the data produced by the Homer software, July has the highest possible power generation. In Hamad et al. (2024), geospatial and techno-economic aspects with validated meteorological, social, and environmental parameters are blended in order to assess the potential and viability of solar power plants in Afghanistan. It has been noted that the most ideal locations are those that are

close to the transmission lines, where there is low water stress in addition to abundant solar resources and reasonably cool temperatures in this study. The poly-si REC module with the dual-axis tracking system is determined to have the largest yearly energy generation potential (166336 MWh/year), whereas the same module with the single-axis tracking system is projected to have the lowest levelized cost of electricity (0.031 \$/kWh). Kowsar et al. (2023) focus on a techno-economic and environmental assessment utilizing PVsyst simulation tools for a 50 MW FSPV power plant for a marsh area in a very densely populated country. According to the study's findings, the 50 MW FSPV plant's levelized cost of energy (LCOE) is US\$ 0.051/kWh, which is somewhat less than the US\$ 0.087/kWh of fossil fuel-based power plants in the case study country.

In this study, it is investigated how outdoor lighting in landscape applications can be included as a design element in providing energy in solar energy systems and what should be taken into account in the design dimension, as well as how it can be used more efficiently within the framework of saving and renewal opportunities. The main purpose of the research is to evaluate the use of solar energy in lighting the house and its interaction with the landscape. The research also aims to use energy more efficiently and reduce fossil fuel consumption.

1.1. Solar Energy Capacity in Kastamonu

Although the use of renewable energy sources increases every year, it takes time to renew and transform energy production systems based on fossil resources. The total global renewable energy capacity as of the end of 2018 is shown in Figure 1, within the data provided by the International Renewable Energy Agency (IRENA, 2024). When the data in Figure 1 is investigated, it is observed that there has been a significant increase in solar energy investments and installations among renewable energy sources in the last 10 years.



Figure 1. Renewable energy capacity in the world between 2008-2018.

Türkiye is located in a region called the sun belt, which is rich in solar energy. Türkiye, which has a high solar energy potential due to its geographical location, has an average annual total sunshine duration of 2.640 hours (total of 7.2 hours per day) and an average total radiation intensity of 1.311 kWh/m²-year (total of 3.6 kWh/m² per day). The solar energy potential is 380 billion kWh/year (EİGM, 2024). In 2023, 679 solar power plants are actively operating, providing a total installed power of 8.335 MW (Enerji Atlası, 2024). In Figure 2, the Total Solar Radiation is shown for all of Türkiye (EİGM, 2024).

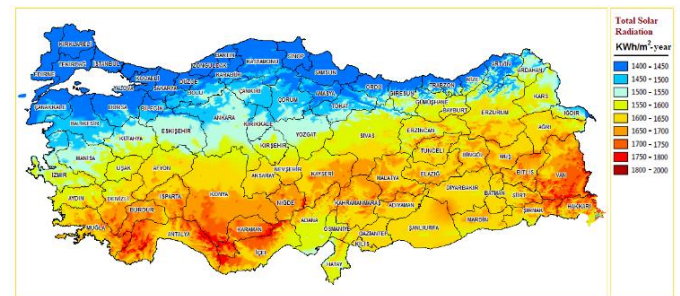


Figure 2. Solar energy potential atlas for Türkiye.

Kastamonu located in the Western Black Sea part of the Black Sea Region has a surface area of 13.108,1 km². Total energy consumption in Kastamonu with a population of 372.633, is 778.497 MWh. With this rate, the province has a rate of 0.39% in energy consumption in Türkiye. While the installed power (production) of power plants in the province is 41 MW, the installed power share in energy in Türkiye is 0.06%. The only source of energy production in the province is hydroelectric power plants (Arslan, 2016). In Figure 3, total solar radiation is given for Kastamonu. Figure 4 shows global radiation values in kWh/m²-day, sunshine times in hours and PV type-area-produced energy in kWh-year for Kastamonu.

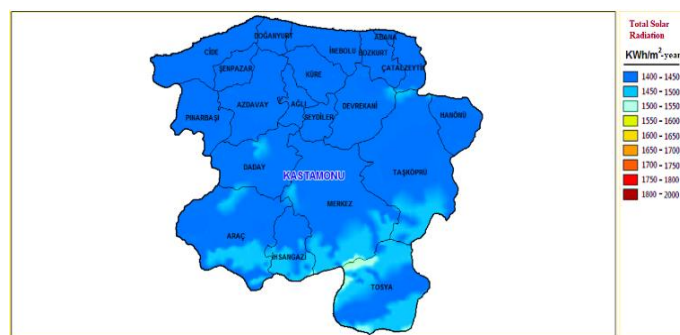


Figure 3. Solar energy potential atlas for Kastamonu (EİGM, 2024).

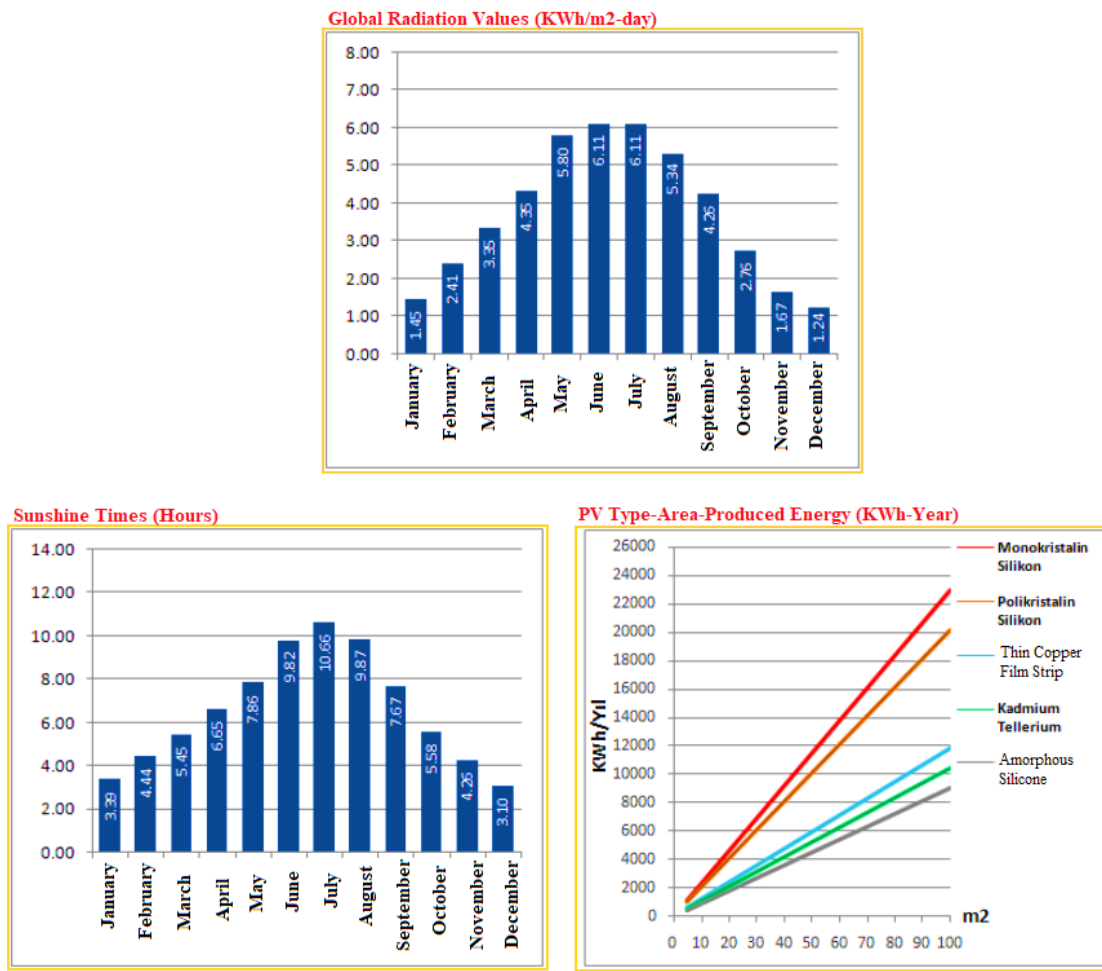


Figure 4. Global radiation values, sunshine times and PV type-area-produced energy (EİGM, 2024).

When it comes to total sun radiation, the Black Sea region, which includes Kastamonu, is one of the less promising areas. When Figure 3 is investigated, it is observed that the annual total solar radiation in no region within the borders of Kastamonu is more than 1650 kWh/m². The annual solar radiation rate throughout the province is mostly at the level of 1400-1450 kWh/m². This situation shows that the potential for solar energy production in Kastamonu is quite low on a provincial basis.

2. Materials and Methods

2.1. The Design

The main purpose of this study is to evaluate the use of solar energy and its interaction with the landscape in the lighting of a house in Kastamonu. The research also aims to use solar energy more efficiently and reduce fossil fuel consumption. In developing the proposed method for interior lighting of the house and evaluating the general features of the area has been formed with the "Protected Area Planning and Management" published in September 2007 by the General Directorate of Nature Conservation and National Parks under the Republic of Türkiye Ministry of Environment Urbanization and Climate

Change. The PV panels to be used have been placed at a 45-degree angle around the southwestern perimeter of a building in Kastamonu.

Systems independent of the grid are called off-grid systems. It is preferred in places where there is a network. In this case, the system also uses it connected to the network. Its most important feature is that it provides power supply via the grid line when needed in environments where electricity is not produced in sufficient quantity. However, when it is not fed back to the grid, it is considered an off-grid system (Boztepe, 2017). Such use would not be efficient or economical. Figure 5 shows the operation diagram of an off-grid system. These panels use photovoltaic cells to absorb sunlight and transform it into power. Usually, they are installed in arrays on the ground or on rooftops. The voltage and current from the solar panels that go to the battery are controlled by the charge controller. It guarantees that the batteries are charged effectively and avoids overcharging. Batteries are used to store the energy produced by the solar panels for use at a later time, usually when sunshine is scarce (such as at night or in overcast conditions). Lead-acid and lithium-ion batteries are typical battery types seen in off-grid systems. An inverter is required to transform the DC (direct

current) electricity generated by the solar panels and stored in the batteries into AC electricity as the majority of household appliances and gadgets run on AC (alternating current). These parts offer together an enduring and dependable electrical source for off-grid uses such distant houses, cottages, RVs, boats, and telecommunications systems.

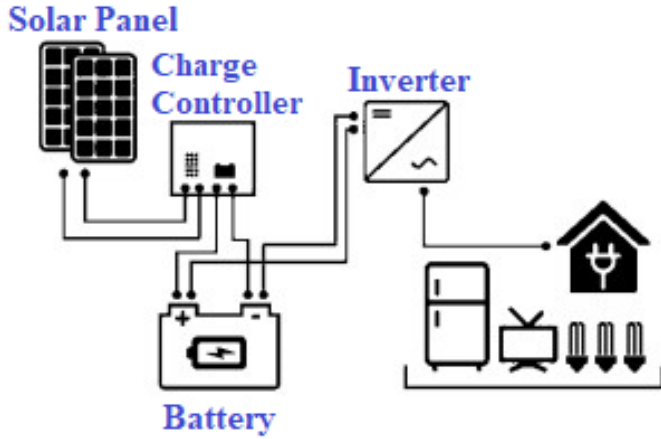


Figure 5. Off-grid system diagram.

The fact that the land chosen in this study is a flat area and there are no restrictive factors does not pose any obstacle to the use of the land. Inclined placement of the panel is also one of the factors that increases the amount of energy. The panel is positioned at a 45-degree angle on the southwestern facade of the building selected within the scope of the study. The panels are arranged according to the southwest facade and a total of 2 are placed. The PV generator output of the panel, PV system climate data, PV generator surface, slope and placement direction of the PV module are given in Table 1.

Table 1. Features of the panel used and its placement.

PV System Climate Data	Kastamonu, TUR (1991-2010)
PV Generator Output	0.91 kWp
PV Generator Surface	4.4 m ²
Number of PV Modules	2
Number of Inverters	1
Slope	6°
Placement Direction	18° South
Cell Type	Half-Cut
Maximum Power	455 W
Maximum Voltage	42 V
Maximum Current	10.83 A
Open Circuit Voltage	50.4 V
Short Circuit Current	11.43 A
Maximum System Voltage	1500 VDC
Weight	24.0 kg
Dimension	2096x1039x35

Crystalline silicon cells are commonly used in solar panels. More efficient monocrystalline cells are more expensive. Two panels with a capacity of 455 W connected in series are used in this study. The operating values of the panel used depending on temperature and radiation are shown in Figure 6. The physical properties of the panel used are also given in Figure 7.

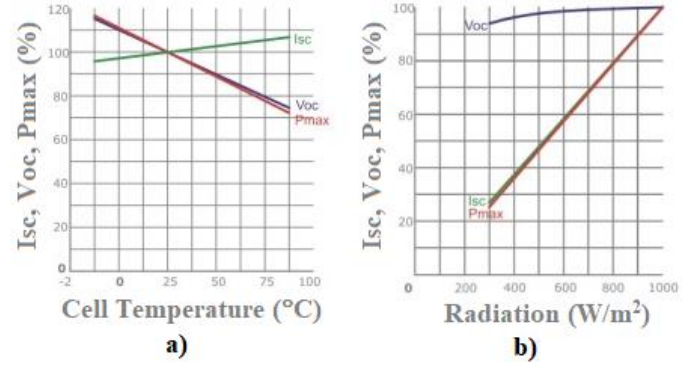


Figure 6. Variation of Isc, Voc and Pmax depending on a) temperature and b) radiation.

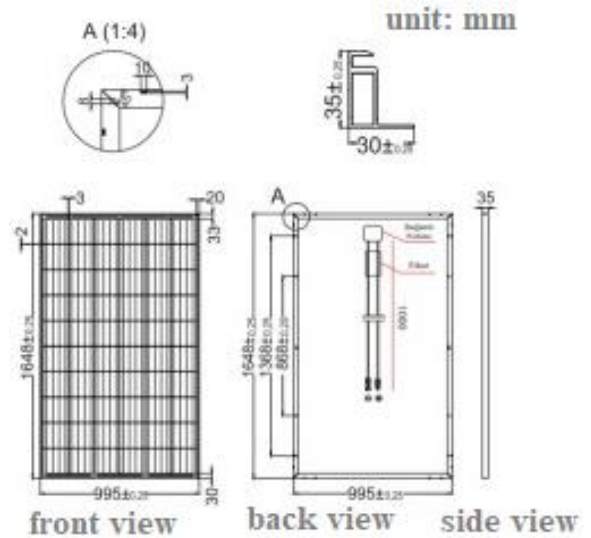


Figure 7. Physical properties of the used panel.

A converter with 10 kW DC-AC capacity is used in this study. The converter operates at a maximum efficiency of 82%. It has a maximum of 17 Amperes and 12-230 Volt adjustable output values. The technical specifications of the inverter used in the study are also given in Table 2.

Table 2. The technical specifications of the inverter used in the study.

Continuous Power	1200 W
Instantaneous Power (30 ms)	2400 W
DC Input Voltage	12 V
AC Output Voltage	230 V
Efficiency	82%
No-Load Current Consumption	0.5 A
AC Output Waveform	Modified sine wave
Operating Temperature	0 °C - 40 °C
Low Voltage Battery Alarm Range	10 V - 10.4 V
Low Battery Voltage Shutdown Interval	9.7 V - 10 V
High Battery Voltage Shutdown Value	15 V
Weight	2.4 kg
Dimension	335x155x70 mm

While the solar charge controller or solar charge regulator prevents the battery and/or battery group from being damaged by overcharging or high voltage, it also serves to balance the voltage and current coming to the solar panel. The radiation values reaching the PV panel surface during the day cause different formation current and voltage values. The charge controller regulates the current coming from the panel and then ensures its transmission to the battery. It prevents the battery from overcharging and discharging according to its filling level by cutting off the current coming from the panels. The technical specifications of the solar control device used in the study are given in Table 3.

Table 3. The technical specifications of the solar control device used in the study.

Battery Voltage	12 V/24 V automatic
Charging Current	50 A
Discharge Current	50 A
Equalization	B01 off 14.4 V
B02 Jel	14.2 V
B03 Sel	14.6 V
Float Charge	13.7 V (default, adjustable)
Discharge Stop	10.7 V (default, adjustable)
Discharge Reconnection	12.6 V (default, adjustable)
USB Output	5 V/3 A
Self-Consumption	<10 mA
Operating Temperature	-35 °C ~ +60 °C
Weight	150 g
Dimension	13.3x7x3.5 cm

Data is monitored and recorded every 5 minutes for 24 hours. In the efficiency calculation, solar radiation per square meter should be taken into account first. Therefore, solar

radiation per square meter is calculated with the help of sensors located next to the panel group. This radiation is recorded by the system at 5-minute intervals. The energies entering the converter of the two panel series, which are formed by connecting two panels in series, are measured separately. After summing the energies of these two panel series, the efficiency of the panels is calculated as the ratio of the total solar energy falling on the panels as given below:

$$n_1 = (E_{input}/E_{solar}) \times 100 \quad (1)$$

$$n_2 = (E_{output}/E_{input}) \times 100 \quad (2)$$

$$n_s = (E_{output}/E_{solar}) \times 100 \quad (3)$$

$$k_1 = ((E_{input} - E_{output})/E_{input}) \times 100 \quad (4)$$

Here, n_1 , n_2 , n_s and k_1 represent the energy loss in the efficiency in the panels, the inverter, the AC output and the converter sources, respectively. E_{solar} is the total solar energy coming to the panels (kWh), E_{output} is the AC electrical energy coming out of the converter (kWh) and E_{input} is the DC electrical energy entering the converter (kWh). The total energy produced by the system is also calculated with Equation 5:

$$E(hour) = power \times (5min/60min) \quad (5)$$

The energy values in *Watt × minutes* found after multiplying the power values obtained every 5 minutes by 5 minutes are divided by 60 minutes and the energy is calculated in *Watt hours*. E_{solar} is calculated by multiplying the solar energy per square meter by the panel surface area of 5 m².

3. Results and Discussion

The total daily consumption of the house selected within the scope of the study is 1590 W. The daily loss of the designed system is 2160 W. The minimum daily sunshine duration for Kastamonu is 2.4 hours. Therefore, the hourly installed power of the installed system is $2160 W / 2.4 h = 900 W = 0.9 kW$. The required consumption amount is calculated monthly for the selected house. In Table 4, the energy consumption amounts of the house per device are given on a daily basis.

Figure 8 shows the annual values of total consumption for the pilot house, supplying the demand with the PV system and from the grid obtained using PV*SOL (PV*SOL, 2023). When Figure 8 is investigated, it is observed that while the annual consumption of the house is 1200 kWh, the amount supplied by the grid is 748 kWh and the amount supplied by the PV system is 452 kWh. This shows that 62.3% of the annual consumption can be supplied by the grid and 37.7% by the PV system. It is also observed that the autarky rate of the system is 37.7%. In Table 5, the average electricity consumption amount of the house and the average production amount of the power plant are given in W and Dollars. The calculation of production and consumption in Dollars is based on November 2023. When

Table 5 is examined, it is seen that the installed power of the system (hourly production) is 0.9 kW.

Table 4. Daily energy consumption values per device.

No	Device	Hourly Power (Watt)	Operating Time (hour)	Daily Energy Consumption
1	Lcd Tv	100 W	5	500 W
2	Lightbulb	12 W	5	60 W
3	Phone	5 W	4	20 W
4	Computer	15 W	4	60 W
5	Freezer	50 W	10	500 W
6	Deep freeze	40 W	10	400 W
7	Sconce	10 W	5	50 W

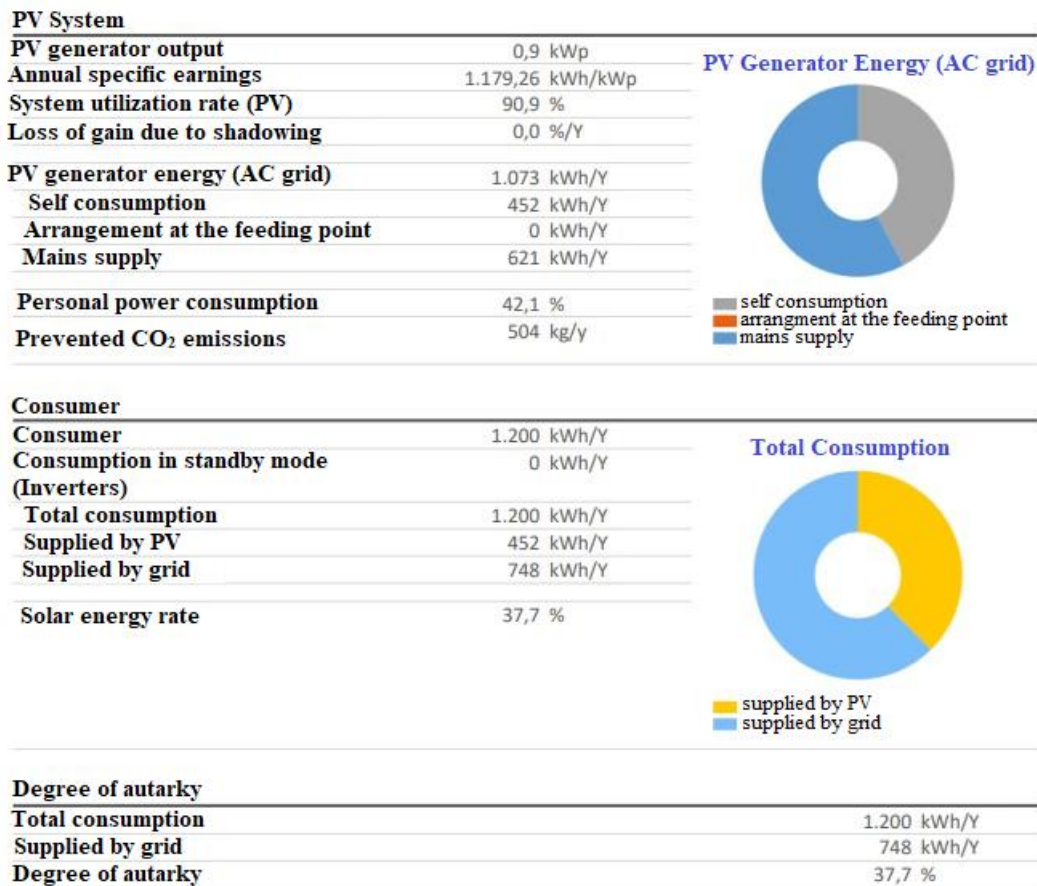


Figure 8. Annual values of consumption of the house and supplied by the grid and PV system.

Table 5. Average electricity consumption and production values of the house and the power plant in Dollars and W.

	Annual	Monthly	Daily	Hourly
Average Electricity Consumption of the House	\$62.17	\$5.18	\$0.52	\$0.035
	900W	100 W	10 W	0.4 kW
Average Electricity Production Amount of the Power Plant	\$82.90	\$6.4	\$0.8	\$0.04
	1200 W	125 W	15 W	0.65 kW

The annual radiation value in Kastamonu is 1.384 kW/m². The electricity sales price is \$0.133 per kW. The hourly lossy production power of the designed power plant is 6.55 kW. The installation cost of the power plant for 1 kW is \$600. According

to these data, Table 6 shows the financial analysis obtained using the PV*SOL application. When Table 6 is investigated, it is observed that the grid supply in the first year is 621 kW per year and the PV generator output is 0.9 kWp. It is also observed

that the amortization period of the installed power plant is 7.8 years. With the installed power plant, an annual profit of 12.65% is obtained from the consumption cost. Annual yield is

also increasing every year. Table 7 gives the detailed cost calculation of the installed power plant.

Table 6. Financial analysis of the installed system obtained from PV*SOL.

System Information		
Grid supply within two years (including module performance degradation)	621	kWh/Year
PV generator output	0.9	kWp
Commissioning of the system	30.12.2023	
Evaluation period	20	Years
Interest applied to principal	1	%
Economic Parameters		
Return on assets	12.65	%
Accumulated cash flow (cash balance)	79,88	\$
Amortization period	7.8	Years
Electricity Generation cost	0.0024	\$
Payments Overview		
Certain investment expenses	51,50	\$
Investment costs	46,80	\$
One-time payments	0,00	\$
Incoming subsidies	0,00	\$
Annual expenses	0,00	\$
Other income or savings	0,00	\$

Table 7. Detailed price display of materials.

	Piece	Price	Amount
Inverter	1	\$145	\$145
Panel	2	\$190	\$380
Battery	1	\$104	\$104
Grand total			\$629

A solar power system for a house in Kastamonu, where the sunshine duration is minimum 2.4 hours, is designed in this study. Two panels with a capacity of 455 W are used in the designed system. The inverter in the system operates with a maximum efficiency of 82%. Moreover, a solar controller is used to balance the voltage and current coming to the solar panels while preventing the system from being damaged by high voltage. The daily consumption of the pilot house is 10 W and the hourly loss production power of the designed power plant is 6.55 kW.

4. Conclusion

In summary, designing and installing off-grid solar power systems for residential buildings is a critical first step toward long-term, sustainable energy independence. These systems give homeowners the chance to reduce their carbon impact and break free from traditional energy dependence through careful planning and integration of cutting-edge technologies. In addition to being a dependable supply of electricity in isolated

or underdeveloped locations, off-grid solar power systems also provide resilience against power outages and natural catastrophes. Homeowners can benefit from a continuous power source, reduced energy costs, and a better environment by utilizing the sun's plentiful energy. Furthermore, developments in off-grid solar technologies, like better energy management and battery storage systems, are raising the systems' price and efficiency. Off-grid solar power systems are predicted to become more popular as the need for renewable energy sources increases, spurring innovation and further bringing down costs.

In order to save energy and lower energy costs, an off-grid solar power system has been designed for a house in Kastamonu in this work. The total cost of the system, including the inverter, panel and battery, is \$629. The average annual energy consumption of the pilot house is 1200 kWh. It is observed that approximately 452 kWh of the house's 1200 kWh consumption can be supplied by the designed system. This shows that 37.7% of the total annual energy consumption will be met and saved by the designed system. It is concluded that the amortization period of the designed system according to the total cost is 7.8 years. Off-grid solar power essentially signifies a paradigm change in domestic energy usage, enabling homeowners to embrace sustainability and take charge of their own energy future. Off-grid solar power systems open the door to a more promising and sustainable future for both homes and the

environment with their thoughtful planning, creative design, and continuous support.

Acknowledgment

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Conflict of Interest

The authors declare that they have no conflict of interest.

References

- Arslan, F. (2016). *The renewable energy potential in Kastamonu*. 1st International Abana Symposium. Kastamonu.
- Bathaei, A., & Streimikiene, D. (2023). Renewable energy and sustainable agriculture: Review of indicators. *Sustainability*, 15(9), 14307. <https://doi.org/10.3390/su151914307>
- Boztepe, M. (2017). Fotovoltaik güç sistemlerinde verimliliği etkileyen parametreler. *EMO İzmir Şubesi Aylık Bülteni*, 321, 13-17. (In Turkish)
- Chehri, A., & Mouftah, H. T. (2013). FEMAN: Fuzzy-based energy management system for green houses using hybrid grid solar power. *Journal of Renewable Energy*, 2013, 2-7. <https://doi.org/10.1155/2013/785636>
- EİGM. (2024). *Güneş enerjisi potansiyel atlası*. Enerji İşleri Genel Müdürlüğü (EİGM). <https://gepa.enerji.gov.tr/MyCalculator/> (In Turkish)
- El-Shahat, A., Haddad, R. J., Courson, J., Martenson, A., & Mosley, A. (2019). *Solar-powered house system design*. 2019 SoutheastCon. Huntsville.
- Enerji Atlası. (2024). *Güneş enerji santralleri*. Enerji Atlası. <https://www.enerjiatlası.com/gunes/> (In Turkish)
- Faiers, A., & Neame, C. (2006). Consumer attitudes towards domestic solar power systems. *Energy Policy*, 34(14), 1797-1806. <https://doi.org/10.1016/j.enpol.2005.01.001>
- Hamad, J., Ahmad, M., & Zeeshan, M. (2024). Solar energy resource mapping, site suitability and techno-economic feasibility analysis for utility scale photovoltaic power plants in Afghanistan. *Energy Conversion and Management*, 303, 1-14. <https://doi.org/10.1016/j.enconman.2024.118188>
- IPCC. (2024). *Reports*. The Intergovernmental Panel on Climate Change (IPCC). <https://www.ipcc.ch/>
- IRENA. (2024). *International renewable energy agency*. The International Renewable Energy Agency (IRENA). <https://www.irena.org/>
- Karaca, A. E., & Dincer, I. (2020). A new integrated solar energy based system for residential houses. *Energy Conversion and Management*, 221, 113112. <https://doi.org/10.1016/j.enconman.2020.113112>
- Kowsar, A., Hassan, M., Rana, M. T., Haque, N., Faruque, M. H., Ahsan, S., & Alam, F. (2023). Optimization and techno-economic assessment of 50 MW floating solar power plant on Hakaluki marsh land in Bangladesh. *Renewable Energy*, 216, 119077. <https://doi.org/10.1016/j.renene.2023.119077>
- Makkiabadi, M., Hoseinzadeh, S., Taghvirashidizadeh, A., Soleimaninezhad, M., Kamyabi, M., Hajabdollahi, H., Nezhad, M. M., & Piras, G. (2021). Performance evaluation of solar power plants: A review and a case study. *Processes*, 9(12), 2253. <https://doi.org/10.3390/pr9122253>
- Panwara, N. L., Kaushik, S. C., & Kothari, S. (2011). Role of renewable energy sources in environmental protection: A review. *Renewable and Sustainable Energy Reviews*, 15(3), 1513-1524. <https://doi.org/10.1016/j.rser.2010.11.037>
- PV*SOL. (2023). PV*SOL. <https://pvsol.software/en/>
- Sahoo, S. K. (2016). Renewable and sustainable energy reviews solar photovoltaic energy progress in India: A review. *Renewable and Sustainable Energy Reviews*, 59, 927-939. <https://doi.org/10.1016/j.rser.2016.01.049>
- Shahabad, M. E., Mostafaeipour, A., Nasab, H. H., Sadegheih, A., & Xuan, H. A. (2022). A new model to investigate effects of subsidies for home solar power systems using system dynamics approach: A case study. *Sustainable Energy Technologies and Assessments*, 49, 101706. <https://doi.org/10.1016/j.seta.2021.101706>
- Solangi, K., Islam, M., Saidur, R., Rahim, N., & Fayaz, H. (2011). A review on global solar energy policy. *Renewable and Sustainable Energy Reviews*, 15(4), 2149-2163. <https://doi.org/10.1016/j.rser.2011.01.007>
- Tabassum, M., Kashem, S. B., & Ahmed, J. (2020). Feasibility study of solar power system in residential area. *International Journal of Innovation in Computational Science and Engineering*, 1(1), 10-17.
- UNEP. (2024). *United nations environment programme*. The United Nations Environment Programme (UNEP). <https://www.unep.org/>
- Wermager, S., & Baur, S. (2013). Energy analysis of a student-designed solar house. *Energies*, 6(12), 6373-6390. <https://doi.org/10.3390/en6126373>