Research Square

Preprints are preliminary reports that have not undergone peer review.
They should not be considered conclusive, used to inform clinical practice,
or referenced by the media as validated information.

Comparison of practical efficiencies of solar pv panels used for solar pv power plants and solar powered electric vehicles

Turhan Koyuncu
Adıyaman University
Fuat Lule
flule@adiyaman.edu.tr

Adıyaman University

Article

Keywords: EV, Efficiency, pv power plant, Firat Force, Commagene

Posted Date: May 22nd, 2026

DOI: https://doi.org/10.21203/rs.3.rs-9354025/v1

License: This work is licensed under a Creative Commons Attribution 4.0 International License.
Read Full License

Additional Declarations: No competing interests reported.

Comparison of practical efficiencies of solar pv panels used for solar pv power plants and solar powered electric vehicles

Turhan Koyuncu1 [a] Fuat Lule2 [b,*]

[a,b] Adıyaman University, Vocational School of Technical Sciences, Department of Machine, Adıyaman, Türkiye.

Orcid Turhan Koyuncu 1: https://orcid.org/0000-0003-2279-9899

Orcid Fuat Lule 2: https://orcid.org/0000-0002-9332-0761

Abstract. In this work; the efficiencies of solar PV panels used in two different applications were investigated. One of these applications is fixed solar PV power plant and the other is solar powered electric vehicles. The application of solar PV power plant has three similar fixed solar PV power plants consisting of 1025 MW each power. The other application is solar powered electric vehicles consisting of an automobile and a minibus called "Firat Force" and "Commagene", respectively. The main purpose of this study is to determine the practical efficiencies of solar PV panels used in these two different applications and to compare them with their efficiencies both in STC conditions and in different applications. Thus, the practical efficiencies of fixed and mobile solar PV panels and the differences between them has been determined. As a result of this work; It was determined that the peak efficiency of solar PV panels used in fixed solar power plants is 16.32% under Standard Test Conditions (STC) and is 15% in practice. In addition, the peak efficiency of solar PV panels used in solar powered automobile and minibus was found as 18% under STC and was determined as 13% in practice.

Keywords : EV, Efficiency, pv power plant, Firat Force, Commagene.

*Corresponding author

Email: flule@adiyaman.edu.tr (Fuat LULE)

1.Introduction

The increasing demand for energy in the world has also increased the demand for conventional energy sources. This has led scientists to conduct research in the field of renewable energy sources, especially solar energy (Goura, 2015, Kumar and Sudhakar 2015). Conventional energy sources cause environmental pollution, global warming and greenhouse effect. As a result of this, the ozone layer is gradually thinning (Arblaster et al. 2011, Dyominov and Zadorozhny, 2008, Lykhovyd, 2021, Larin, 2020, Karpechko et al. 2010, Ramanathan and Feng, 2009). In order to solve this problem; clean and endless renewable energy sources, especially solar energy, are accepted as alternative energy sources (Ibrahim et al. 2025, Babu, et al. 2025, Arora et al. 2021, Sharma et al. 2022). For example, the average amount of solar energy reaching our world is 6000 times more than the world's total energy consumption. The development of easy-to-reach, clean, maintenance-free solar energy-based transportation systems should be a priority alternative to fossil fuel-based transportation systems. For this reason, academic studies on this subject are increasing rapidly. In particular; It is becoming attractive to provide electricity to grid systems using photovoltaic (PV) panels or to store electricity in batteries to run the DC motors of solar-powered electric vehicles (Omar et al. 2007, Shukla et al. 2016, Dayem 2011, Garrison 2008, Hazami et al. 2005, Tsai and Ting 2010, Ustun et al 2009). In small and medium sized settlements that with high solar radiation intensity, sunshine duration and low road slope; it is considered a smart solution to provide electricity for city grid and to provide electricity to solar powered vehicles for transportation by using solar PV panels.

When some studies related to this subject of this work are searched, it is observed that the studies differ from each other and different results are obtained. For example; an investigation found that 25% of electric vehicle owners had installed rooftop solar panels, while only 8% of non-electric vehicle owners had installed rooftop solar PV panels. The results revealed that electric vehicle use and system installation subsidies are increasing the PV panel use (Sharda et al. 2024). In an other research, a solar photovoltaic-based EV charging system was developed. The system was applied by using MATLAB/Simscape. The results indicated that it supports electric vehicle charging under changing solar irradiance conditions and grid outages (Acharige et al. 2021). In a study about PV

charging system, the electric vehicle's charging system was supported by photovoltaic PV panels installed on the vehicle. It was determined that PV panels increased the performance of the electric motor and battery system (Mishra et al. 2022). In an applied study; a small, commercially usable solar-powered vehicle was developed for developing countries like Pakistan, Bangladesh, and Nigeria, where fossil fuel shortages and energy crises are prevalent. A design was developed and tested to generate its power from solar photovoltaic panels mounted on the vehicle. The results demonstrated that this design could be considered a major revolution in the country's transportation systems. It was determined that this vehicle, which cost $950 in 2012, could be easily expanded and manufactured to carry 3-4 people. It was concluded that such vehicles would be beneficial not only to developed countries but also to humanity. It was also determined that the vehicle's battery charged in 3-4 hours and that it could travel approximately 40 km at a speed of 40 km/h (Farooq et al. 2014). Another study on electric vehicles in Jordan states the following: The rise in electric vehicle use in Jordan has placed a significant load on the national electricity grid. This study used a vehicle parking lot covered with photovoltaic panels as an off-grid electric vehicle charging station. The study investigated whether student and employee electric vehicles could be charged with solar energy between 8:00 AM and 5:00 PM. The results showed that this system offers convenience and cost-effectiveness for consumers, is beneficial by reducing the national grid load, has high potential for success, and reduces greenhouse gas emissions by reducing dependence on fossil fuels (Awada et al. 2024). An other study examined the integration of solar PV EV charging stations with grid electric vehicle charging stations. The benefits, challenges, and environmental impacts of this integration were examined. The investigation was conducted by considering case studies from various regions, including Los Angeles, Detroit, Japan, and the Netherlands. The results demonstrated that this integration could significantly improve energy sustainability, reduce range limitations and CO_2 emissions, and strengthen environmentally friendly and sustainable urban transportation (Tripath et al. 2025). Other study analyzed solar-powered electric vehicles (SPEVs). The analysis was conducted when the battery in an EV is charged from both an external source and PV panels. The results indicate that the electric vehicle's complete dependence on energy generated by onboard photovoltaic PV panels results in limited range and high initial costs. However, it is stated that this can be overcome by using high-efficiency solar cells, such as 30-35%, and that solar-powered electric vehicles will become more functional in the future (Nivas et al. 2022). In an other study, a hybrid vehicle combining an internal combustion engine and solar photovoltaic panels was designed and tested. It was found that using solar panels with an efficiency of 15-20% was beneficial for long-distance travel, increasing efficiency and reducing pollution (Mohan et al. 2018). Other work evaluated the benefits and costs of providing solar photovoltaic (PV) support to plug-in electric vehicle (PEV) users. It concluded that providing PV support would approximately cost $0.13/day or $50/year per PEV, but this annual cost could be reduced to $5/year under favorable market conditions (Foster et al. 2013). In a research; different algorithms that can be used for charging electric vehicles developed and tested . Possibility of integration of PV panels installed on smart buildings with the city grid for electric vehicle charging was investigated. The results demonstrated that this integration is feasible. It was determined that using the appropriate algorithm could minimize energy costs and grid stress (Yayla and Ozdemir, 2024). In an other research; the integration of parking lots in Berlin in case of covered with PV panels for charging electric vehicles was investigated. The study mainly focused on possibility of integrating this PV modules and grid system for charging electric vehicles in Berlin. The study aimed to increase daily EV range, reduce operating costs, and support carbon-neutral transportation. 48827 parking spaces in Berlin were evaluated using open datasets and software. The results showed that by covering these spaces with solar PV, electric vehicles could be integrated with the public grid charging system. The results also revealed that the range of electric vehicles could be increased by an average of 7-14 km/day and 2527 km/year, resulting in annual cost savings of €154 per electric vehicle, and reducing grid stress (Hoth et al. 2024).

In this study; practical efficiencies of solar PV panels used in three similar solar PV power plants and practical efficiencies of solar PV panels used in two solar powered electric vehicles were determined. Three similar solar PV power plants were installed in Adıyaman City Türkiye and all test of solar powered electric vehicles were also made in the same city. Here, the solar PV panels used in solar PV power plants are fixed, but the solar PV panels used in solar powered electric vehicles are mobile. The practical efficiencies of solar PV panels were compared with their peak efficiencies in Standard Test Conditions (STC) and compared for both different applications. The results showed us that the efficiency of solar PV panels used in solar powered electric vehicles is lower when compared with both STC and fixed solar PV panel usage.

2.Materials and methods

This study was conducted within the borders of Adıyaman province of Türkiye. The latitude, longitude and altitude of Adıyaman city is 37.45°, 38.17° and 672 m, respectively. The practical efficiency of solar PV panels was determined by taking the first year data of three similar fixed solar PV power plants installed in Adıyaman. Each solar PV power has an installed capacity of 1025 MW. Each solar PV power plant mainly consists of a steel frame, fixed polycrystalline silicon type solar PV modules, maximum power point tracker (MPPT), inverter, busbars, transformer, cable lines and grid connections. (Fig. 1).

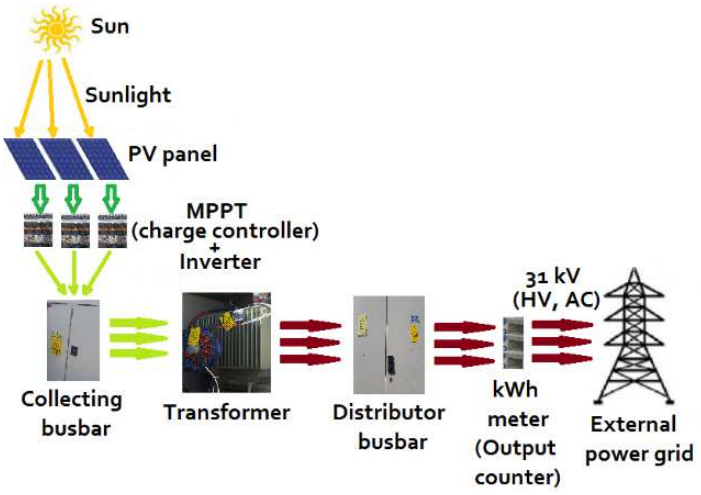


Figure 1. Schematic view and main parts of solar PV power plant that is installed in Adıyaman City, Türkiye.

Some basic technical specifications of the power plant used in this work are given in Table 1. It is seen from this table that the solar PV panel efficiency is 16.32% under STC. This number is the peak value of efficiency of these panels. Here; irradiance is 1000 W/m2 with an air mass 1.5, module temperature is 25 °C and wind speed is 0 m/s (Darwish et al. 2015, Maghami et al. 2016, Cozta et al. 2016, Ketjoy and Konyu 2014, Menoufi et al. 2017, Kumar et al. 2013).

Table 1. Some basic technical qualifications of the solar PV power plants used in this study

installation place	Adıyaman City, Türkiye
Number of similar solar PV power plants	3 power plants
installation power of eachpower plant	1025 MW
types of used solar pv modules	Polycrystalline silicon type
Maximum possible efficiency at STC	16.32%

The calculation of practical efficiency of solar PV panels used in solar PV power plants is not complicated and is simple. In simple terms, practical efficiency is equal to the ratio of electrical energy produced by the panels to the solar radiation reaching the panel surface. In order to calculate the practical efficiency of the panels Equations 1 and 2 given below can easily be used. The data used in these equations are the data obtained in the first year of the solar PV power plants.

$$\eta_{PPE}\ (\%) = \frac{E_{GENERATE}\ (kWh)}{E_{SOLAR}\ (kWh)} \quad (1)$$

$$E_{SOLAR}\ (kWh) = I_{ISR}\ (kWh/m^2\ day)\ x\ A_{PSA}\ (m^2)\ x\ A_{NSD}\ (day) \quad (2)$$

Where :

η_{PPE} Panel practical efficiency [%]

$E_{GENERATE}$ Generated electric energy by panels during first year [kWh]

E_{SOLAR} Solar radiation reaching the panel surface during first year [kWh]

I_{ISR} Average daily incident solar radiation [kWh m^{-2} day^{-1}]

A_{PSA} Total PV panel surface area [m^2]

A_{NSD} Number of yearly sunshine days

In addition, solar PV panel efficiencies of two different types of solar powered electric vehicles were also determined for this study. These vehicles are an automobile named "Firat Force" and a minibus named "Commagene". Each of these solar powered electric vehicles mainly consist of solar PV modules, battery pack, regenerative brushless DC electric motor, maximum power point tracker (MPPT) and electronic control unit

(ECU). The schematic view of the connection and operating principle of the basic parts of these vehicles is given in Figure 2, images showing the location and position of PV panels on vehicles are given in Figure 3, and some general technical features of both of these vehicles are also given in Table 2.

Table2. Some general technical features of Firat Force and Commagene

Technical Features	Vehicle types	
	Fırat Force	Commagene
Vehicle class	Prototype	Prototype
Wheels	4	4
Axles	2	2
Driven axle	Rear axle	Rear axle
Curb weight (kg)	705	1550
Full weight (kg)	1025	2600
Electric motor	Regenerative brushless DC	Regenerative brushless DC
Power (kW)	4.5	6.3
Speed (km/h	40	40
Panel	Monocrystal Si	Monocrystal Si
Panel efficiency (%)	18	18
Panel surface area (m^2)	2.19	4.38
Battery type	Maintenance free, gel	Maintenance free, gel
Stored energy (Wh)	9120	13680
Nominal voltage (V)	48	72

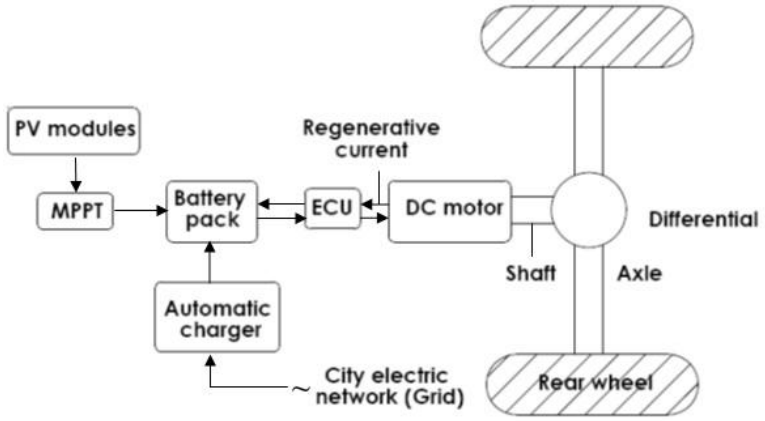


Figure 2. The schematic view of the connection and operating principle of the basic parts of the solar powered electric vehicles.





Figure 3. Images showing the location and position of PV panels on vehicles.

To calculate the panel efficiency, the equations 3, 4 and 5 were used. Basically, the efficiency of the PV panel is equal to the ratio of the produced electrical power to the power of solar radiation reaching on the entire panel surface. This situation is clearly seen in equation 5 (Koyuncu et al. 2014, Koyuncu 2015, Cengel and Boles 1994, Gibson and Kelly 2010, Goktan et al 1995, Holman 1994, Poulek and Libra 2006).

$$\boldsymbol{q_{PV}} = V.C \qquad (3)$$

$$\boldsymbol{q_{SR}} = I_R \,.A_{PV} \qquad (4)$$

$$\boldsymbol{\eta_{PV}} = \frac{q_{PV}}{q_{SR}} \qquad (5)$$

Where:

q_{SR} Incident solar power [W]

I_R Incident solar radiation [Wm^{-2}]

A_{PV} Solar PV panel area [m^2]

q_{PV} Solar PV panel power [W]

V Average voltage [V]

C Average current [A]

η_{PV} Photovoltaic efficiency [%]

The tests of solar powered electric vehicles were made in Adiyaman City, Türkiye during test year. These vehicles were tested under city normal traffic conditions. The vehicles test were continued while PV panels off (no charge by PV panels)) and PV panels on (charged by PV panels during use). The standard (gradient is approximately 0%) and the mixed road (gradient is 0%...20%) were used for tests. Tests were also continued during months of June, July and August under city traffic conditions. Hours of 10.00 -17.00 were chosen for the tests. The solar powered car was loaded with concrete blocks that equls to 2 and 5 average mass persons (70 kg) and the solar powered minibus was loaded with concrete blocks that equls to 5 and 10 persons for tests. The difference of transportation distance between panels off and panels on positions was recorded as transportation distance supplied by PV panels.

3.Results and discussion

Test of identical three solar PV power plants and two solar powered electric vehicles were conducted in Adıyaman City, Türkiye. All tests conducted in the first year of the installation of solar PV panels but both at different years. In the first year of the solar PV power plants test, the average solar radiation intensity in Adıyaman City was measured as 4919 kWh/m^2 and given in Figure 4 (Anonymous. 2019). In this test year, it is observed that the solar radiation intensity during months of April - November were approximately 4000 kWh/m^2 or more (Figure 4). For this test year, the produced electrical energy by these solar PV

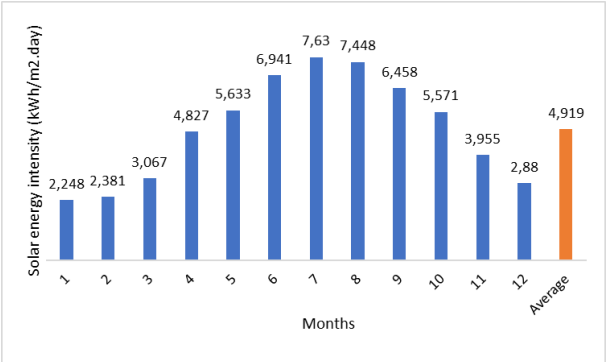


Figure 4. Monthly solar radiation intensity of Adiyaman City, Türkiye during test of three identical solar PV power plants.

power plants measured by kWh-meters separately. The generated electrical energy amounts were found to be 1697489 kWh/year, 1693711 kWh/year and 1698794 kWh/year for solar PV power plants numbered as 1, 2 and 3, respectively. The average annual electricity production of these three identical solar PV power plants was determined as 1696665 kWh/year (Figure 5). In the test year, the practical efficiencies of the polycrystalline silicon type solar PV panels used in these solar power plants were found to be 15.054%, 15.021% and 15.066% for solar PV power plants of 1, 2, and 3, respectively (Figure 6). Although the average peak (labeled) efficiency of these solar panels was 16.320%, their average practical efficiency was determinea as 15.047% (Figure 6). This indicates that there was a difference of approximately 7-8% between the labeled and practical efficiencies of these modules in the first test year. These value is the average value of three identical solar PV power plants and is significant.

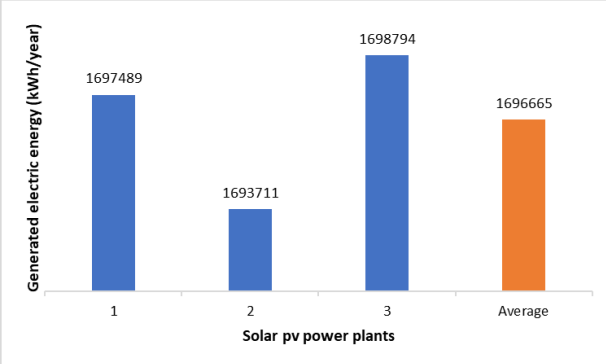


Figure 5. Generated electric energy by PV power plants for test year.

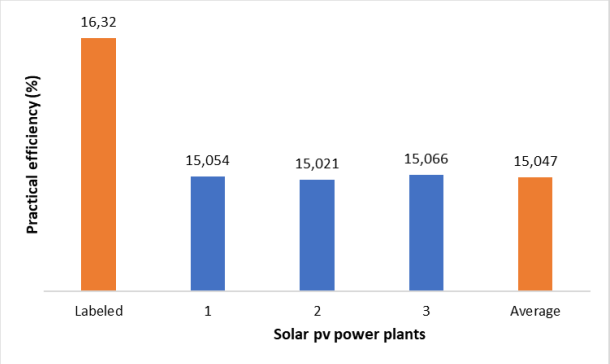


Figure 6. Peak (labeled) and practical efficiencies of polycrystalline silicon type solar PV modules used for solar power plants

In the first year of solar powered electric vehicles test in Adıyaman City, solar radiation intensity and sunshine duration were determined for each month (Figure 7). These values appear to be sufficiently high between March and October. From these values, it is seen that the annual average solar radiation intensity and sunshine duration are 525.22 W/m^2 and 8.11 h/day, respectively (Figure 7). In this year, tests of Firat Force and Commagene solar powered electric vehicles were carried out. The data obtained as a result of these tests are given in Figures 8 and 9, respectively. It was determined that the practical efficiency of these semiflexible monocrystal Si panels was approximately equal for both solar powered vehicles and was 13%. It was observed that the average efficiency of these panels, which has a peak (labeled) efficiency of 18%, was 13% in practice, with a loss of approximately 27-28% (Figures 8 and 9). It should not be forgotten that in solar powered electric vehicles, there is also an energy loss in the drivetrain from the electrical energy reaching the battery pack to the wheels. Therfore, the total efficiency of the system from PV to the wheels was found to be 9%. When the values are examined in this case; It has been determined that practical PV efficiencies reach the wheels with a 30-31% loss, while the labeled PV efficiency reaches the wheels with a 50% loss.

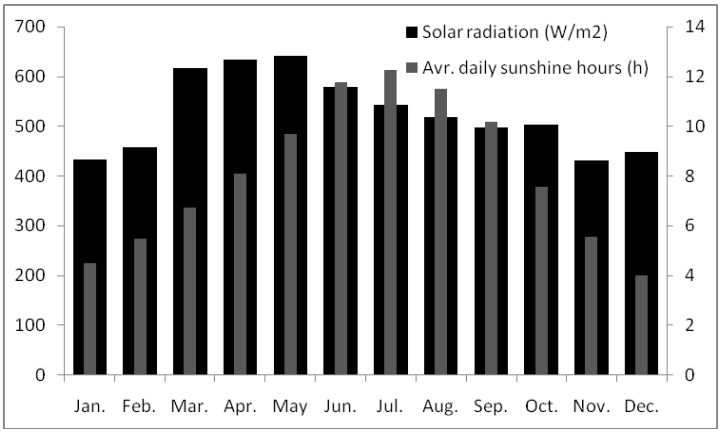


Figure 7. Monthly solar radiation intensity (0-700 W/m^2) and average daily sunshine (0-14 h) of Adiyaman City, Türkiye, during test of solar powered electric vehicles

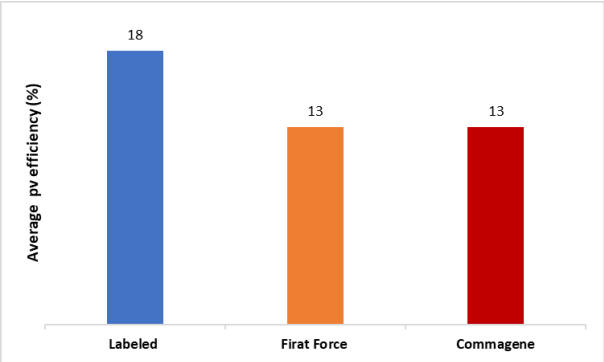


Figure 8. Peak (labeled) and practical efficiencies of semiflexible monocrystal Si panel used for solar powered electric vehicles.

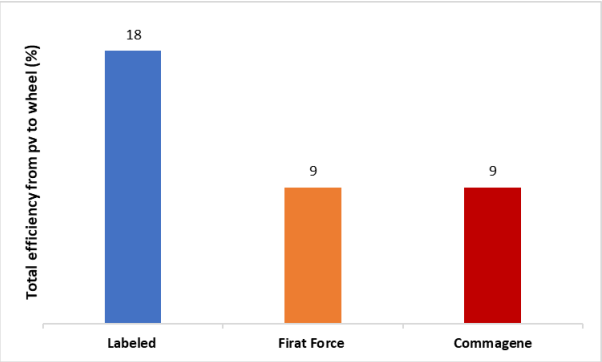


Figure 9. Peak (labeled) and total efficencies of semiflexible monocrystal Si panel used for solar powered electric vehicles.

Besides, the average calculated transportation distance depending on monthly solar radiation during test year was given for Firat Force and Commagene in Figures 10 and 11, respectively (Anonymous. 2019, Redpath et al. 2011). As seen from these figures that daily transportation distance is changing between 15km/day and 180 km/day depending on months. It should be noted that during test of transportation distance, it is assumed that all solar powered vehicles are full loaded and battery pack charged with solar energy only. The percentage of battery pack fully charged with solar PV panels related to months during test year were also given for Firat Force and Commagene in Figures 10 and 11, respectively (Redpath et al. 2011, Sorrentino et al. 2011). As seen from Figures 10 and 11 that the charge percentage of fully charged battery pack is changing between 15% and 60%.

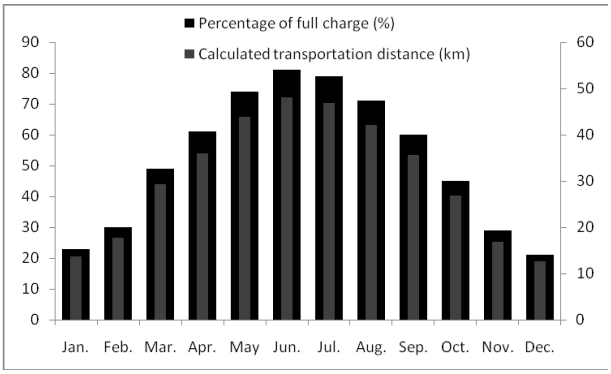


Figure 10. Firat Force calculated transportation distance (0-90 km) and solar charge as percentage of battery pack capacity (0-60%).

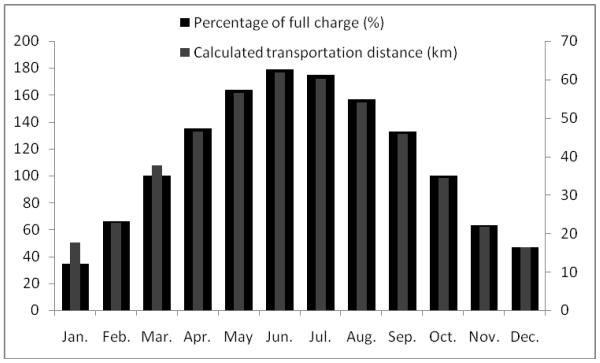


Figure 11. Commagene calculated transportation distance (0-90 km) and solar charge as percentage of battery pack capacity (0-60%).

4.Conclusion

The main objective of this study is to determine and compare the practical efficiencies of polycrystalline silicon type solar PV panels used in solar power plants and semiflexible monocrystalline Si type solar PV panels used in solar powered vehicles. As a result of the study; although the labeled efficiency of solar PV panels used in solar power plants is 16.32%, the average practical efficiency was obtained as 15.047% in the first test year. It was concluded that there was a 7-8% loss in practice compared to the efficiency determined under STC conditions. Although the labeled efficiency of semiflexible monocrystalline Si type solar PV panels used in solar powered vehicles is 18%, the average practical efficiency was found to be 13% in the first test year. It was observed that these panels had a 27-28% loss in practice compared to their efficiency under STC conditions. In addition, considering the losses in the transmission components from the battery pack to the wheels in solar powered vehicles, the practical efficiency of the panels was determined to be 9%. In this case, the total efficiency of the system was determined to be 9% and the loss according to the label efficiency was 50%. For all these reasons; to design any solar PV power plant or solar powered electric vehicle with minimal errors, it is essential to consider the differences in efficiency between the solar PV panels used and their practical efficiency. Otherwise, the theoretical approach will not meet practical needs. The results obtained in this study will significantly contribute to minimizing errors in related calculations.

Data Availability and Author Contributions

Material collection: Fuat LÜLE and Turhan KOYUNCU; Data assessment: Fuat LÜLE and Turhan KOYUNCU; Literature review and Writing: Fuat LÜLE and Turhan KOYUNCU

Conflict of Interest

Authors declare that there are no conflict of interests

Funding Information

Authors did not receive any funding or grants for this research

References

Acharige, S. S. G., Haque, Md E., Arif, M.T., Hosseinzadeh, N., Saha, S. 2021. A Solar PV Based Smart EV Charging System with V2G Operation for Grid Support Australasian Universities Power Engineering Conference, AUPEC 2021, Perth, Australia, September 26-30, pp. 1-6. https://doi.org/10.1109/AUPEC52110.2021.9597741

Anonymous. 2019. T.C. Çevre, Şehircilik ve İklim Değişikliği Bakanlığı, Meteo. Gen. Müd., URL:https://www.mgm.gov.tr/kurumici/radyasyon_iller.aspx?il=adiyaman (accessed date: 15 May 2019)

Arblaster, J. M., Meehl, G. A. and Karoly, D. J. 2011. Future climate change in the Southern Hemisphere: Competing effects of ozone and greenhouse gases. GEOPHYSICAL RESEARCH LETTERS, VOL. 38, L02701, doi:10.1029/2010GL045384

Arora, K., Kumar, A., Kamboj, V.K., Prashar, D., Shrestha, B., Joshi, G.P., 2021. Impact of Renewable Energy Sources into Multi Area Multi-Source Load Frequency Control of Interrelated Power System. Mathematics 2021, 9, 186. https:// doi.org/10.3390/math9020186

Awada, E., Radwan, E., Abed, S., Al-Mahrouk, A. 2024. Economic Analysis and Design of Sustainable Solar Electric Vehicle Carport at Applied Science Private University in Jordan. Energies, 17, 4321; pp. 1-20. https://doi.org/10.3390/en17174321

Babu R.M., Alam MD. S., Islam. A., Islam MD K. 2025. Toward Sustainable and Clean Energy Futures: A Techno-Economic Review of Solar PV Systems, Challenges, and Opportunities. IEEE Access Volume 13 Digital Object Identifier 10.1109/ACCESS.2025.3614771

Cengel, Y.A. and Boles, M.A. 1994. Thermodynamics: an engineering approach (Second edition). McGraw-Hill, Inc., New York. ISBN: 0-07-911652-3.

Costa, S. C., Diniz, A. S. A., & Kazmerski, L. L., 2016. Dust and Soiling İssues and İmpacts Relating to Solar Energy Systems: Literature review update for 2012–2015. *Renewable and Sustainable Energy Reviews*, *63*, 33-61. DOI: 10.1016/j.rser.2016.04.059

Darwish, Z. A., Kazem, H. A., Sopian, K., Al-Goul, M. A., & Alawadhi, H., 2015. Effect of Dust Pollutant Type on Photovoltaic Performance. *Renewable and Sustainable Energy Reviews*, *41*, 735-744.

Dayem, A. M. A. 2011. Set-up and performance investigation of an innovative solar vehicle. 1st International Workshop on Diffusion of New Energy Technologies in Chine, March 25-27, Shanghai, China. DOI:10.1063/1.4717512

Dyominov I. G. and Zadorozhny A. M. 2008. Greenhouse gases and future long-term changes in the stratospheric. Temperature and the ozone layer International Journal of Remote Sensing Vol. 29, No. 9, 10 May 2008, 2749–2774 DOI: 10.1080/01431160701767583

Farooq, M., Salman, A., Siddiqui, S.A., Khalil, M.I. Mukhtar, W. 2014. Economically Designed Solar Car for Developing Countries (Pakistan). 4 IEEE 2014 Global Humanitarian Technology Conference pp.356-360.

Foster, J.M., Trevino, G., Kuss, M., Caramanis, M.C. 2013. Plug-In Electric Vehicle and Voltage Support for Distributed Solar: Theory and Application. IEEE Systems Journal, vol. 7, no. 4, December, 2013; pp. 881-888. https://doi.org/10.1109/JSYST.2012.2223534

Garrison, M. 2008. The 2007 solar D house. 5th International Conference on Urban Regeneration and Sustainability, Skiathos Isl., Greece, September 24-26, www.witpress.com. ISSN 1743-3541 (on-line).

Gibson, T.L. and Kelly, N.A. 2010. Solar photovoltaic charging of Lithium-ion batteries. Journal of Power Sources, (195): 3928-3932. https://doi.org/10.1016/j.jpowsour.2009.12.082

Goktan, A.G., Guney, A. and Ereke, M. 1995. Tasıt frenleri (vehicle brakes: in Turkish). ITU Machine Faculty, Automotive Main Science, Istanbul. https://www.researchgate.net/publication/267404864

Goura, R., 2015. Analyzing the On-Field Performance of a 1-Megawatt-Grid-Tied PV System in South India. International Journal of Sustainable Energy, 34(1), 1-9. https://doi.org/10.1080/14786451.2013.824880
Hazami, M., Kooli, S., Lazaar, M., Farhat, A. and Belghith, A. 2005. Performance of a solar storage collector. Desalination, (183): 167-172. https://doi.org/10.1016/j.desal.2005.03.033
Holman, J.P. 1994. Experimental methods for engineers (Sixth edition). McGraw-Hill Inc., New York. ISBN-10: 0070296669
Hoth, P., Heide, L., Grahle, A., Gohlich, D. 2024. Vehicle-Integrated Photovoltaics—A Case Study for Berlin. World Electr. Veh. J., 15, 113; pp. 1-20. https://doi.org/10.3390/wevj15030113
Ibrahim, T., Durillon, B., Faraj, J., Ali, S., Saudemont, C., Jean-luc H. J. , Khaled M. A. 2025. Comprehensive Review Of Solar Energy Systems: Technical, economic, and environmental perspectives for sustainable development. International Communications in Heat and Mass Transfer. Volume 165, Part B, June 2025, 109095. https://doi.org/10.1016/j.icheatmasstransfer.2025.109095
Karpechko A. Y., Gillett, N. P., Gray L. J., and Dall'Amico M. 2010. Influence of ozone recovery and greenhouse gas increases on Southern Hemisphere circulation. JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 115, D22117. doi.org/10.1029/2010JD014423
Ketjoy, N., & Konyu, M., 2014. Study of Dust Effect on Photovoltaic Module for Photovoltaic Power Plant. *Energy Procedia*, *52*, 431-437. https://doi.org/10.1016/j.egypro.2014.07.095
Koyuncu, T., Engin, K.E. and Lule, F. 2014. Design, manufacture and test of a solar powered minibus (Commagene) for transportation of people in Adiyaman city, Turkey. 29th European Photovoltaic Solar Energy Conference and Exibition (EU PVSEC 2014), Amsterdam, The Netherlands, September 22-26. https://www.researchgate.net/publication/366658454
Koyuncu, T. 2015. Design, manufacture and test of a solar powered car (Firat Force) for transportation of governmental officers in Adiyaman city, Turkey. The 6th International Congress of Energy and Environment Engineering and Management (CIIEM15), Paris, France, July 22-24. https://www.researchgate.net/publication/366658454
Kumar, E. S., Sarkar, B., & Behera, D. K., 2013. Soiling and Dust İmpact on the Efficiency and the Maximum Power Point in the Photovoltaic Modules. *International Journal of Engineering Research & Technology (IJERT)*, *2*(2), 1-8. DOI :10.17577/IJERTV2IS2092
Kumar, B. S., & Sudhakar, K., 2015. Performance Evaluation of 10 MW Grid Connected Solar Photovoltaic Power Plant in India. *Energy Reports*, *1*, 184-192. https://doi.org/10.1016/j.egyr.2015.10.001
Larin, I.K. 2020. On the Influence of Global Warming on the Ozone Layer and UVB Radiation. Izvestiya Atmospheric and Oceanic Physics 57(1):110-115. DOI: 10.1134/S0001433821010096
Lykhovyd, P. 2021. The Evidence For Ozone Preservation Importnace In Restraining Global Warming. International Journal of Ecosystems and Ecology Science (IJEES) Vol. 11 (3): 389-394. https://doi.org/10.31407/ijees11.305
Maghami, M. R., Hizam, H., Gomes, C., Radzi, M. A., Rezadad, M. I., & Hajighorbani, S., 2016. Power Loss Due to Soiling on Solar Panel: A review. *Renewable and Sustainable Energy Reviews*, *59*, 1307-1316. https://doi.org/10.1016/j.rser.2016.01.044
Menoufi, K., Farghal, H. F., Farghali, A. A., & Khedr, M. H., 2017. Dust accumulation on Photovoltaic Panels: A Case Study at the East Bank of the Nile (Beni-Suef, Egypt). *Energy Procedia*, *128*, 24-31. https://doi.org/10.3390/su9060963
Mishra, S., Varshney, A., Singh, B. 2022. An Improved Observer for Flux & Speed Estimation of Sync-Rel Motor for Electric Vehicles with Solar PV Support. *IEEE* 2022 IEEE International Conference on Power Electronics, Drives and Energy Systems (PEDES), pp. 1-6., DOI: 10.1109/PEDES56012.2022.10080138
Mohan, K., Sankaranarayanan, S., Prasada, S.S.D. Sivasubramaniam, V., Sairam, V. 2018. Solar powered Hybrid vehicle. The 3rd International Conference on Materials and Manufacturing Engineering. IOP Conf. Series: Materials Science and Engineering 390; pp. 1-7. DOI:10.1088/1757-899X/390/1/012102
Nivas, M., Naidu, R.K.P.R., Mishra, D.P., Salkuti, S.R. 2022. Modeling and analysis of solar-powered electric vehicles. International Journal of Power Electronics and Drive Systems (IJPEDS), Vol. 13, No. 1; pp. 480-487. DOI: 10.11591/ijpeds.v13.i1.pp480-487
Omar, A., Ismail, D., & Muzamir, I., 2007. Simplification of Sun Tracking Mode to Gain High Concentration Solar Energy. *American Journal of Applied Sciences*, *4* (3), 171-175. https://doi.org/10.3844/ajassp.2007.171.175
Poulek, V. and Libra, M. 2006. Solar energy: photovoltaics-promossing trend for today and close future. Czech University of Agriculture in Prague, Prague, Czech Republic.
Ramanathan V. and Feng Y. 2009. Air pollution, greenhouse gases and climate change: Global and regional perspectives. Atmospheric Environment 43 (2009) 37-50 doi:10.1016/j.atmosenv.2008.09.063
Redpath, D.A.G., Mcllveen-Wright, D., Kattakayam,T., Hewitt, N.J. and Karlowski, J. 2011. Battery powered electric vehicles charged via solar photovoltaic arrays developed for light agricultural duties in remote hilly

areas in the Southern Mediterranean region. Journal of Cleaner Production, (19): 2034-2048. DOI: 10.1016/j.jclepro.2011.07.015

Sharda, S., Garikapati, V.M., Goulias,, K.G., Reyna, J.L., Sun, B., Spurlock, C.A., Needell, Z. 2024. The electric vehicles-solar photovoltaics Nexus: Driving cross-sectoral adoption of sustainable Technologies. Renewable and Sustainable Energy Reviews 191, 114172, pp. 1-9. https://doi.org/10.1016/j.rser.2023.114172

Sharma V.K., Singh R., GehlotA., Buddhi,D., Braccio S., Priyadarshi N., Khan B. 2022. Imperative Role of Photovoltaic and Concentrating Solar Power Technologies towards Renewable Energy Generation. Hindawi. International Journal of Photoenergy Volume 2022, Article ID 3852484, 13 pages https://doi.org/10.1155/2022/3852484

Shukla, A. K., Sudhakar, K., & Baredar, P., 2016. Simulation and Performance anaLysis of 110 kWp Grid-Connected Photovoltaic System for Residential Building in India: A comparative analysis of various PV technology. *Energy Reports*, *2*, 82-88. https://doi.org/10.1016/j.egyr.2016.04.001

Sorrentino, M., Rizzo, G. and . Arsie, I. 2011. Analysis of a rule-based control strategy for on-board energy management of series hybrid vehicles. Control Engineering Practice, (19): 1433-1441. DOI:10.1016/j.conengprac.2011.07.017

Tripathi, A.K., Lakshmi, G.S., Mishra, H., Chapala, S., Alwetaishi, M., Atamurotov, F., Benti, N.E., Sura, S., Saleel, A. 2025. Integration of Solar PV Panels in Electric Vehicle Charging Infrastructure: Benefits, Challenges, and Environmental Implications. Energy Science & Engineering; pp. 1–18. https://doi.org/10.1002/ese3.70014

Tsai, C. S. and Ting, C.H. 2010. Evaluation of a multi-power system for an electric vehicle. International Conference on Control, Automation and Systems (ICCAS 2010), p.p. 1308-1311, Gyeonggi do, South Korea, October 27-30.

Ustun, O., Yilmaz, M., Gokce, C., Karakaya, U., Tuncay RN. 2009. Energy management method for solar race car design and application. IEEE International Electric Machines and Drives Conference (IEMDC 2009), Miami, FL., USA., May 03-06.

Yayla, S., Ozdemir, E. 2024. Smart Vehicle to Grid Energy Management Algorithm for Electric Vehicle Supported by Photovoltaic Energy Sources. Electric Power Components and Systems, 0(0): 1–17, 2024, Taylor & Francis Group, LLC, ISSN: 1532-5008 print / 1532-5016 online. DOI: 10.1080/15325008.2024.2330097

.