Journal of Physics Special Topics

An undergraduate physics journal

P4 6 King Solar Power Stadium

J. Owusu Boamah, A. McCrea, A. Fotedar

Department of Physics and Astronomy, University of Leicester, Leicester, LE1 7RH

December 4, 2024

Abstract

This study investigates the potential of photovoltaic (PV) systems to offset non-renewable energy use at Leicester's King Power Stadium by harnessing solar power. Through modelling the performance of a monocrystalline-silicon PV system installed on the stadium's roof, we estimate that the system could provide renewable energy equivalent to 20% of the stadium's annual energy demand.

Introduction

Leicester's King Power Stadium, features an expansive roof that remains largely underutilised, making it an excellent candidate for solar energy generation. By installing solar panels on its surface, sunlight can be efficiently converted into electrical energy, offering a sustainable solution to increasing energy demands.In this paper we model the performance of solar panels throughout the year, assessing the potential contribution to meeting energy requirements.

Theory

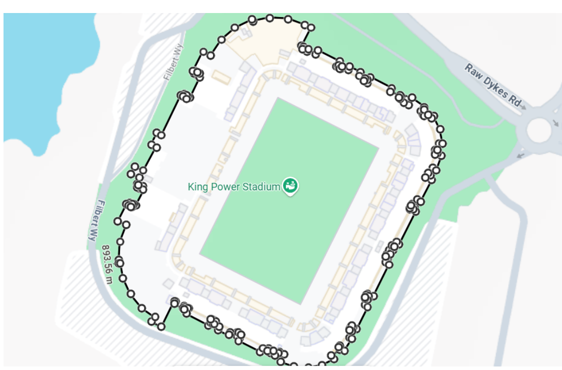

Figure 1: Traced area of King Power Stadium [1]

The performance of solar panel systems relies on various technical and environmental factors including the area available for panel installation and the efficiency of the chosen solar device. We estimated the roof-size area by using the Google Maps drawing tool, as this data was unavailable elsewhere. Although the specific dimensions for the King Power stadium are unavailable to us, in Figure 1 we utilised Google Maps draw tool to determine a roof area of approximately 20,000 m^2 [1].

The energy produced by a photovoltaic (PV) system depends on the available solar irradiance and the efficiency of the solar panels under operational condition. The electrical efficiency η_c can be expressed using the Evans-Florschuetz PV efficiency [2]:

$$\eta_c = \eta_{ref} \cdot [1 - \beta_{ref} \cdot (T_c - T_{ref})] \qquad (1)$$

where 'η_{ref}' is the efficiency at a reference temperature, 'T_{ref}' = 25 (°C). 'β_{ref}' is the temperature coefficient (°C^{-1}) and 'T_c' is the temperature at a particular moment in time [2].

Power is the rate of energy transfer. Therefore, the monthly energy output of a PV system can be calculated using the equation:

$$E = Pt \cdot \eta_c = (IA)t \cdot \eta_c \quad (2)$$

where solar irradiance, 'I' is defined as the power per unit area, 'A' received from the sun, over a time period, 't', of 1 month.

To determine the solar irradiance and temperature we extracted data from the PVGIS-ERA5 database, after inputting the stadium's precise location [3].

Month	Average Temperature (°C)	Irradiation (kWh/m^2)
January	4.5	25.75
February	6.5	40.09
March	7.1	88.11
April	8.9	130.33
May	12.7	145.42
June	15.2	161.73
July	18.8	155.77
August	19.0	140.11
September	14.1	85.32
October	12.6	59.09
November	8.8	25.59
December	3.5	19.21

Table 1: Monthly average temperature and solar irradiation values in 2022. [3]

Discussion

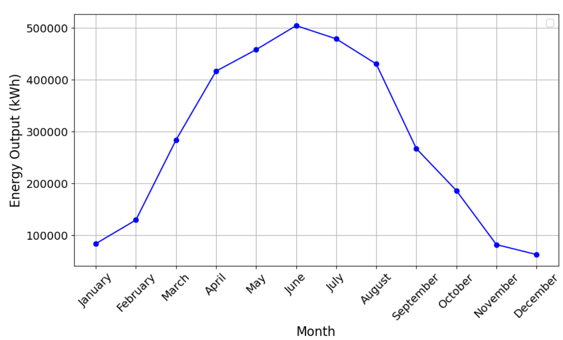

Figure 2: Monthly energy output (kWh) based on irradiation and efficiency in 2022

Monocrystalline-Silicon is the most commonly used photovoltaic cell, with an $\eta_{\text{ref}} = 0.15$ and a $\beta_{\text{ref}} = 0.0041\ ^{\circ}\text{C}^{-1}$ [4]. By substituting these parameters along with the temperatures in Table 1, into Equation 1, we calculate the efficiency of the solar cell with respect to the temperature is about 0.16 for all months.

To calculate the total energy output, we take the sum of the solar energy multiplied by its corresponding efficiency and multiplied by the area of the roof, which is described by Equation 1.

Figure 2 displays the total energy generated by our photovoltaic system. In the summer months, higher levels of irradiance enable more sunlight to be converted to electrical energy. The total energy output was calculated to be 3384725 kWh.

Conclusion

In 2022, Leicester football club used 17,017,229 kWh of energy [5], meaning that integrating a photovoltaic cell system could supply nearly 20% of its annual usages. The club has already committed to sustainable practices in the past; future advancements in more efficient solar panel technology are expected to significantly reduce both it's environmental and energy costs.

References

[1] Google Maps. *Google Maps*. Google Maps, 2019. URL: `https://www.google.co.uk/maps/place/King+Power+Stadium/@52.6203662` (visited on 11/20/2024).

[2] Swapnil Dubey, Jatin Narotam Sarvaiya, and Bharath Seshadri. "Temperature Dependent Photovoltaic (PV) Efficiency and Its Effect on PV Production in the World – A Review". In: *Energy Procedia* 33 (2013), pp. 311–321. DOI: `10.1016/j.egypro.2013.05.072`. (Visited on 11/20/2024).

[3] European Commission. *JRC Photovoltaic Geographical Information System (PVGIS) - European Commission*. re.jrc.ec.europa.eu, 2022. URL: `https://re.jrc.ec.europa.eu/pvg_tools/en/`.

[4] E. Skoplaki and J.A. Palyvos. "On the temperature dependence of photovoltaic module electrical performance: A review of efficiency/power correlations". In: *Solar Energy* 83 (May 2009), pp. 614–624. DOI: `10.1016/j.solener.2008.10.008`. (Visited on 11/20/2024).

[5] Leicester City Football Club. *LCFC Financial Results 2021/22*. www.lcfc.com, 2022. URL: `https://www.lcfc.com/news/3099851/lcfc-financial-results-202122?lang=en`.