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Suitability in Assessing PV Potential in UTHM Campus Pagoh Using Homer Simulation

Nur Aini Zulkarnain, Nor Aira Zambri[1]

[1]University Tun Hussein Onn Malaysia, 86400, Pagoh, Johor, MALAYSIA

*Corresponding Author Designation

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Abstract: The increasing adoption of renewable energy sources, such as photovoltaic (PV) systems, is driven by their ability to reduce reliance on non-renewable energy and it has prompted UTHM Campus Pagoh to explore these sustainable alternatives in order to address the price increase faced when purchasing power from the utility company. The main objective is to achieve an optimal implementation of PV systems at UTHM Campus Pagoh by measuring real-time irradiance on-site, comparing it with Solcast's solar forecasting data, and systematically processing the collected data using Homer software to conduct a comprehensive economic statement. The study was conducted using the simulation of Homer and PVsyst software to determine the most cost-effective method to install solar PV panel and monitoring the efficiency, energy generation potential, and overall performance of the PV system. The key finding and trends that can be observed from the data include the optimal time for the solar energy production, the substantial contribution of particular building within Tx6 to the total energy requirements, the feasibility of installing an optimal number of module based on energy demand and rooftop area comparison, the project viability based on economic analysis using Homer software and the efficiency demonstrated by the PVsyst analysis in covering at least 50% of the daily energy demand for specific buildings on the campus. For future work, it is recommended to gather data on the electrical consumption of each building, conduct a thorough assessment of electrical consumption across all buildings, prioritize the implementation of photovoltaic (PV) systems based on high electricity usage, consider adding a storage system to capture and store excess energy, and adopt an effective energy management system to optimize energy efficiency and enable informed decision-making.

Keywords: Photovoltaic (PV) systems, Energy Consumption, Homer Software

1. Introduction

The cost of providing electricity is constantly changing, especially as the population continues to grow. This has increased the cost of meeting the growing demand. When power is transmitted from power plants to customers through substations, the power system faces challenges such as power loss

*Corresponding author: aira@uthm.edu.my

and strangulation due to resistance in transmission lines, electric motors, and power outages, so these issues affect system efficiency and cost [1]. To support this information, a study stated that buildings in Malaysia have used 48% of the country's total electricity generation [2]. UTHM campus Pagoh shares similarities, experiencing an increase in electricity bills due to associated demand. The university also faces the challenge of excessive power consumption due to extended business hours and load demands. In order to address this problem and propose effective solutions to reduce energy consumption, detailed analysis is conducted in this study to identify the causes. Since this study is to examine the suitability of the PV system at UTHM Campus Pagoh, an overview on solar cell is important since it play a vital role in converting sunlight into electricity through the photovoltaic effect [3]. The increasing demand for renewable energy and the decreasing costs of solar technology have led to a significant rise in the use of photovoltaic cells [4]. Various types of PV panels, including monocrystalline, polycrystalline, and thin-film cells, have been extensively studied. Monocrystalline PV cells offer high efficiency but come at a higher cost, while polycrystalline cells are cost-effective and widely utilized. Thin-film PV panels are less expensive to produce but require more space and have shorter lifespans compared to crystalline solar panels [5][6][7]. This study seeks to promote an understanding of the use of solar energy and support the integration of sustainable and cost-effective energy solutions at UTHM Pagoh. First, real-time radiance measurements are performed to collect accurate and up-to-date solar radiation level data. This allows for an accurate assessment of the solar energy at the UTHM Campus Pagoh site. Second, the obtained real-time radiation data will be compared with solar forecast data from Solcast to enable the accuracy and reliability of the forecast model to be evaluated. This comparison will provide insights into whether the solar energy prediction of UTHM Campus Pagoh is possible and efficient. Finally, Homer software will be used systematically to enable a comprehensive economic analysis. By conducting this study, the project aims to assess the economic feasibility and potential benefits of integrating solar power into the energy system of UTHM Campus Pagoh.

The anticipated outcomes of this study include various measures to improve solar energy utilisation and energy efficiency at UTHM Campus Pagoh. These outcomes include improving energy efficiency for solar energy installations by exploring solar systems. Implementing targeted energy storage strategies and solutions in areas that contribute most to energy needs will significantly reduce infrastructure and operating costs in line with objectives related to sustainability. Careful design and planning around sustainability will ensure that energy demands are adequately met by maximising the roof. A feasibility study, including a HOMER simulation, verifies the feasibility of the project, estimates a reasonable payback period, and identifies the most economically optimal policy changes. Insights from the PVsyst study reveal the energy capabilities of PV systems, exceeding the daily energy requirements required for typical buildings by 50%. These anticipated impacts contribute to the advancement of sustainable energy objectives at UTHM Campus Pagoh, which include improved solar installations, energy conservation, space efficiency, economic growth, and increased energy efficiency

2. Methodology

To achieve the objectives of the study, the researchers will conduct a comprehensive review of existing literature to gather information on the current load demand at UTHM Campus Pagoh. They will also collect and analyze solar irradiation data from Solcast Software and use an irradiance meter to collect additional data. By comparing these datasets, the solar resource potential of the campus and the suitability of PV systems will be determined. The researchers will then utilize the Homer simulation tool to model and optimize the PV system design based on the collected data. The simulation results will be used to determine the appropriate size and configuration of the PV system to meet the total load demand of UTHM Pagoh campus and evaluate the economic viability of the proposed system.

2.1 Load Analysis

Data on UTHM's energy consumption was obtained from the facility management division, providing valuable insights. An interview was conducted with Encik Zulfaris, an electrical engineer at

UTHM Pagoh, to gain a better understanding of the topic. However, it was discovered that the most recent data did not include the electrical consumption of each UTHM structure. Despite attempts to obtain updated information, it was communicated that the data for individual building consumption is currently unavailable. As a result, the load analysis in this report will utilize data from 2018. UTHM's electrical supply and distribution system consists of three substations, each housing two transformers. Substation 1 contains Transformers 1 (Tx1) and 2 (Tx2), Substation 2 houses Transformers 3 (Tx3) and 4 (Tx4), and Substation 3 accommodates Transformers 5 (Tx5) and 6 (Tx6). The analysis will focus on identifying the buildings that significantly contribute to the overall energy consumption.

2.2 Solar Radiation Potential

To evaluate the solar radiation potential at UTHM Campus Pagoh, real-time data from the Solcast software was utilized in this study. Figure 1 presents the live and forecast graph for irradiation at UTHM Campus Pagoh, showcasing the variation in solar radiation levels throughout the day. This data was further compared to on-site measurements obtained using an irradiance meter. The purpose of this comparison was to assess the solar energy generation capacity in the area and determine the feasibility of installing a photovoltaic system on campus. Assessing the solar radiation potential is crucial in understanding the potential for solar energy production and evaluating the costs and benefits associated with implementing a PV system.

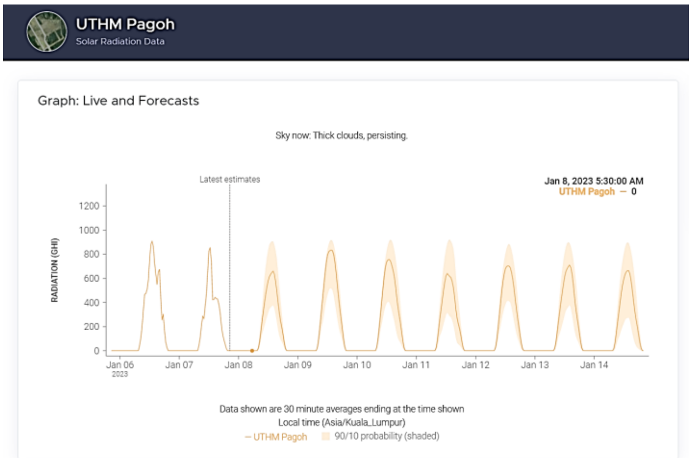

Figure 1: Live and forecast graph for irradiation at UTHM Campus Pagoh

2.3 Economic Evaluation and Module Sizing using Homer Software HOMER

HOMER (Micropower Optimization Model) is a simulation tool used for designing and analyzing small-scale power systems. Its primary focus is on optimizing the economics of the system. By conducting multiple simulations with different constraints, HOMER assesses the system's performance under uncertainties or changes. It assists users in selecting the most economically viable system configuration based on the net present cost (NPC) calculation. NPC represents the total cost and revenue of a project adjusted for inflation over its lifetime. HOMER assumes a constant growth rate for costs throughout the project's lifespan. Figure 2 provides an example of cost classification performed by HOMER.

Architecture				Cost				System	Gen					PV		Grid	
PV (kW)	Gen (kW)	Grid (kW)	Dispatch	COE (RM)	NPC (RM)	Operating cost (RM)	Initial capital (RM)	Ren Frac (%)	Hours	Production	Fuel (L)	O&M Cost	Fuel Cost	Capital Cost	Production	Energy Purchased	Energy Sc
1,876	86.0	999,999	CC	-RM0.169	-RM5.85M	-RM2.09M	RM16.5M	77	8,760	753,360	213,791	22,601	106,895	16,415,000	2,499,157	0	3,024,380
	86.0	999,999	CC	-RM0.313	-RM2.51M	-RM239,529	RM43,000	0.000017	8,760	753,360	213,791	22,601	106,895			0	525,224
1,876		999,999	CC	-RM0.0686	-RM1.90M	-RM1.72M	RM16.4M	96						16,415,000	2,499,157	92,772	2,363,792
		999,999	CC	RM0.365	RM888,886	RM83,270	RM0.00	0.000014								228,136	0

Figure 2: Cost Classification Performed by HOMER

2.4 Designing and sizing a PV system Using PVsyst

The PVsyst software was used in this study to design and size the PV system at UTHM Campus Pagoh. PVsyst offers powerful tools and capabilities to model different system configurations, input parameters, and simulate system performance. Key parameters such as geographic location, solar irradiance data, meteorological data, system configuration, and electrical characteristics were carefully incorporated using PVsyst.

The first step in PVsyst is to set the geographic location. For this study, the PV system was planned for UTHM Campus Pagoh, with specific longitude and latitude values. This allows for detailed analysis and simulation of solar energy potential at the site. The system's plane tilt and azimuth were also set for precise orientation.

Accurate solar irradiance data is essential and was incorporated into PVsyst. This data enables the simulation and analysis of the system's performance under varying solar conditions. Monthly meteorological data, including solar irradiance, were used for accurate simulations throughout the year, providing insights into the solar resource availability at the installation site.

System configuration, including the chosen photovoltaic module and inverter, is crucial in design and sizing. Detailed specifications and information about the selected module and inverter are provided in the appendices. The module's electrical characteristics, physical dimensions, efficiency ratings, and other relevant details are considered. An appropriate inverter model was selected based on system requirements and further adjusted to ensure compatibility and optimization.

The adjustments made during the inverter selection process included considering parameters such as overload loss and Pnom ratio. This fine-tuning minimized overload loss and allowed the system to generate power beyond its nominal rating under favorable conditions. These adjustments were necessary to maximize the efficiency and output of the PV system, aligning it with the desired performance objectives.

3. Result and Discussion

3.1 Irradiation Analysis with Solcast Software and an Irradiance Meter

Data from a 10W solar panel was analysed to understand its output pattern over time. Figure 3 shows a graph comparing the solar panel's output in kilowatt-hours. The graph indicates that the solar panel generates the highest output at 10 a.m., producing 0.03213 kWh, followed by 0.0206528 kWh at 1:00 p.m. This pattern aligns with the previous data on irradiance at UTHM Campus Pagoh, confirming that the sun shines brightest at 10 a.m. These findings suggest a correlation between sunlight and energy production at the campus.

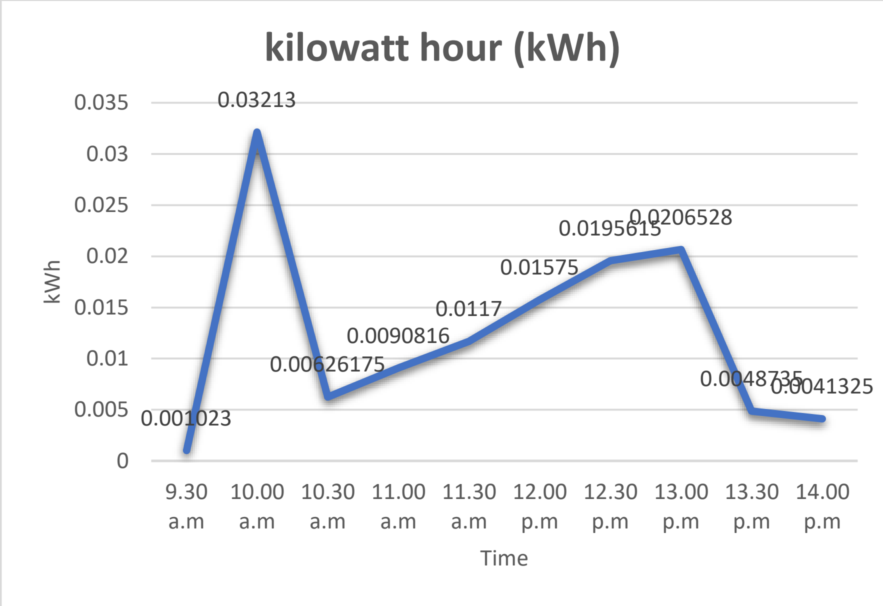

Figure 3: Generated kWh over time

3.2 Load Analysis

In 2018, the monthly power consumption at UTHM Campus fluctuated between 400 kWh and 600 kWh, except in June when it dropped to 440,276 kWh due to the semester break. The highest consumption occurred in October and December, possibly due to increased activity during the new semester. The main contributor to power consumption was the air conditioning system, accounting for around 60% of the total utility bill. Lighting accounted for 10%-15% of consumption, while other contributors included audio-visual and miscellaneous equipment. The total electricity consumption for 2018 was estimated to be 5,869,049.39 kWh, with the air conditioning system making up 52% of the building's usage. The energy cost for the year was expected to be RM 2,142,203.027.

In Figure 4 is a pie chart that contain comparison of the energy consumption for each transformer was conducted, revealing interesting findings. Among the transformers, Tx6 contributed the highest, accounting for approximately 23.01% of the total energy consumption. Following closely behind were Tx2, Tx5, Tx4, Tx1, and Tx3, contributing 21.72%, 18.88%, 13.72%, 13.21%, and 9.46% respectively. This analysis highlights the varying power consumption of each transformer, indicating the significance of their respective loads within UTHM Campus Pagoh.

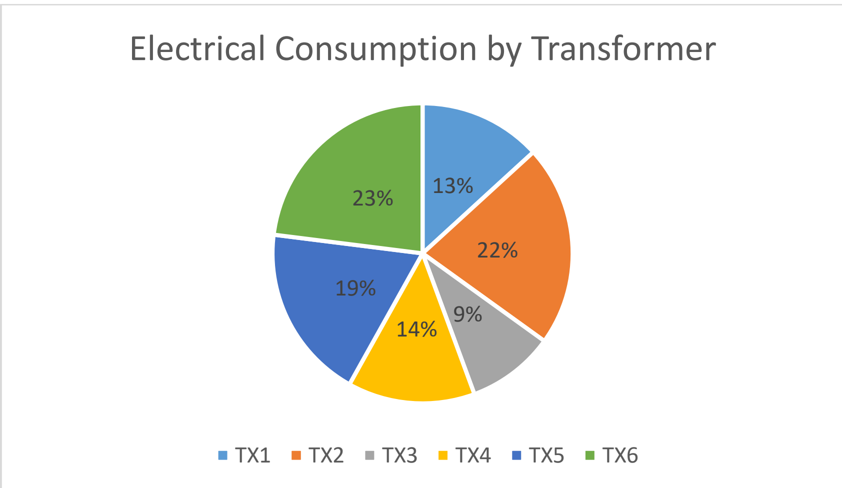

Figure 4: Comparison of Power Consumption Contributions by Transformers

Based on the pie chart analysis, the high power consumption in Tx6 can be attributed to the chemical room, hex room, and laboratory located in Blocks 2B, 2C, 2D, and 2E of the building. These areas have a large number of people and equipment, resulting in higher energy requirements. In contrast, the power consumption in the classrooms and administration building appears to be relatively low, having a minimal impact on the power demands of Tx3 and Tx4. As a result, the power demand in these areas is comparatively lower.

3.3 HOMER Analysis

According to Figure 5, the HOMER simulation provides two economically optimal design options. The first option suggests implementing both PV and grid designs, while the second option proposes relying solely on the grid. Choosing the grid-only option would result in total energy purchases of 1,350,427 kWh, with a net production cost of RM492, 906. However, this option does not generate any returns. On the other hand, the hybrid solution allows consumers to generate profits through the sale of excess energy. The negative values in the "Cost" column represent reimbursements of operational expenses with revenue from energy sold to the grid, totaling RM746, 038. The hybrid option offers a shorter payback period of 8.1 years.

Architecture		Cost				System		PV		Grid	
PV (kW)	Grid (kW)	NPC (RM)	COE (RM)	Operating cost (RM/yr)	Initial capital (RM)	Ren Frac (%)	Total Fuel (L/yr)	Capital Cost (RM)	Production (kWh/yr)	Energy Purchased (kWh)	Energy Sold (kWh)
1,272	999,999	RM3.92M	RM0.206	-RM61,556	RM4.48M	78.3	0	4,481,974	1,641,205	455,261	746,038
	999,999	RM4.47M	RM0.365	RM492,906	RM0.00	0	0			1,350,427	0

Figure 5: Cost evaluation for Block B, C, D and E

In Figure 6 the load distribution pattern for March is illustrated. The graph shows that the highest electrical consumption occurs from 8.00 a.m. to 6.00 p.m., aligning with the findings mentioned earlier.

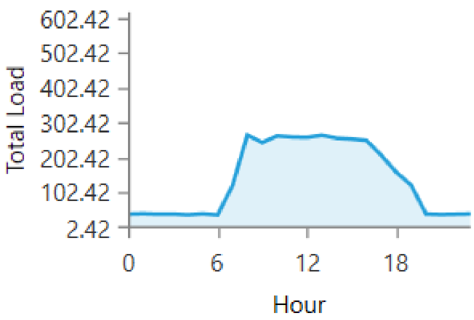

Figure 6: Total load according to time for Block B, C, D and E

In Figure 7 the load distribution pattern for March is illustrated. The graph shows that the highest electrical consumption occurs from 8.00 a.m. to 6.00 p.m., aligning with the findings mentioned earlier.

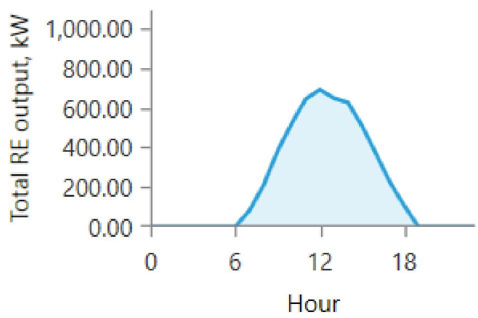

Figure 7: Total RE load according to time for Block B, C, D, and E

Figure 8 illustrated the total grid purchase graph. As noted by the graph, the grid purchase shows dropping value at 6.00 am to 6.00 pm, as the power produced being compensate by the PV cell that can be translated by comparing it to Figure 7.

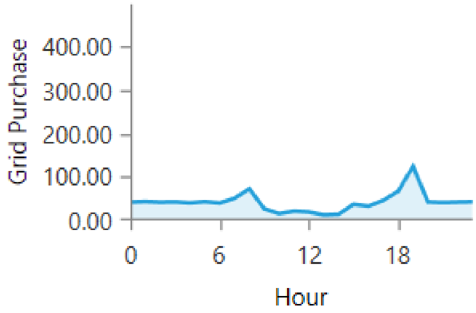

Figure 8: Total Grid Purchase according to time for Block B, C, D, and E

3.4 Analysis on Design and Sizing using PVsyst Simulation

The PVsyst simulation provides insights into the energy production of the PV system, allowing for evaluation of its capacity to meet 50% of the daily energy demand for buildings B, C, D, and E. The daily energy usage for these buildings is reported as 1848.89 kWh. By multiplying the daily demand by 0.5 (50%), the target energy production is approximately 924.445 kWh per day. Comparing this target with the simulated produced energy from PVsyst, which is 385,356 kWh per year, we can convert the annual energy production to daily energy production by dividing it by 365 days. This yields an average daily energy production of approximately 1056.366 kWh per day. Since the PV system's average daily energy production exceeds the target of 924.445 kWh per day, the simulation indicates that it can cover more than 50% of the daily energy demand. The simulated energy production is more than sufficient to meet the 50% target.

4. Conclusion

In conclusion, this study has provided valuable insights into the use of solar energy at UTHM Campus Pagoh. The analysis of solar irradiance patterns identified the best time for energy production, helping optimize solar installations and align energy use with sunlight availability. The investigation of power consumption revealed key areas, such as laboratories and rooms in Tx6, contributing significantly to energy requirements. Implementing energy-saving measures in these areas can lead to reduced consumption and operational costs. The study also highlighted the importance of careful planning and design of solar installations, considering module orientation and rooftop utilization. Economic analyses, including the HOMER simulation, confirmed the feasibility and economic benefits of the project. Futhermore, the findings offer actionable recommendations to improve energy efficiency, reduce costs, and advance sustainability goals through solar utilization. By implementing energy-saving measures, optimizing solar installations, and considering economic viability, UTHM Campus Pagoh can lead the way towards a greener and more sustainable future. The utilization of PVsyst software has also played a crucial role in this study. PVsyst provided powerful tools and capabilities for system design, sizing, and simulation, enabling accurate analysis of various system configurations and critical parameters. By incorporating geographic location, solar irradiance data, meteorological data, system configuration, and electrical characteristics, PVsyst facilitated effective design and sizing of the PV systems. The software allowed for detailed analysis of the solar energy potential at UTHM Campus Pagoh and provided valuable insights into system performance under varying solar conditions. The use of PVsyst greatly enhanced the accuracy and reliability of the study's findings, contributing to the overall understanding and optimization of solar energy utilization at the campus.

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References

[1] Abas, N., Kalair, A., & Khan, N. (2015). Review of fossil fuels and future energy technologies. Futures, 69, 31–49.

[2] J. S. Hassan, R. M. Zin, M. Z. Abd Majid, S. Balubaid, and M. R. Hainin, "Building Energy Consumption in Malaysia: An Overview," Jurnal Teknologi, vol. 70, no. 7, Oct. 2014, doi: https://doi.org/10.11113/jt.v70.3574.

[3] L. King, "Reducing Peak Demand with Solar Energy," blog.solect.com, Jul. 12, 2016. https://blog.solect.com/blog/reducing-peak-demand-solar-energy (accessed Jul. 12, 2023).

[4] Lee, T. D., & Ebong, A. U. (2017). A review of thin film solar cell technologies and challenges. Renewable and Sustainable Energy Reviews, 70, 1286–1297.

[5] Phuangpornpitak, N., & Tia, S. (2013). Opportunities and Challenges of Integrating Renewable Energy in Smart Grid System. Energy Procedia, 34, 282–290.

[6] R. Bayindir, I. Colak, G.Fulli, K.Demirtas,Smart grid technologies and applications,Renewable and Sustainable Energy Reviews,Volume 66,2016,Pages 499- 516,ISSN 1364-0321.

[7] Subramani, G., & Ramachandaramurthy, V. (2021). Optimised Solar PV-BESS Sizing for Maximum Demand Reduction.