INTERNATIONAL JOURNAL OF ACADEMIC RESEARCH IN ECONOMICS & MANAGEMENT SCIENCES

OPEN ACCESS JOURNAL

Vol 12, Issue 3, (2023) E-ISSN: 2226-3624

Techno-Economic Appraisal of A Rooftop Solar Pv Project for A University Campus

Nur Aliah Haziqah Muhamad Yusri, Azlin Mohd Azmi, Nur Farzana Athirah Mohd Fadzli

To Link this Article: http://dx.doi.org/10.6007/IJAREMS/v12-i3/18500 DOI:10.6007/IJAREMS/v12-i3/18500

Received: *15* July *2023,* ***Revised:*** *17* August 2023*,* ***Accepted:*** *06* September 2023

Published Online: *21* September 2023

In-Text Citation: (Yusri et al., 2023)

To Cite this Article: Yusri, N. A. H. M., Azmi, A. M., & Fadzli, N. F. A. M. (2023). Techno-Economic Appraisal of A Rooftop Solar Pv Project for A University Campus. *International Journal of Academic Research in Economics and Management and Sciences*, *12*(3), 99–117.

Techno-Economic Appraisal of A Rooftop Solar Pv Project for A University Campus

Nur Aliah Haziqah Muhamad Yusri[1], Azlin Mohd Azmi[1,2], Nur Farzana Athirah Mohd Fadzli[3]
[1]School of Mechanical Engineering, College of Engineering, Universiti Teknologi MARA, 40450 Shah Alam, Selangor, Malaysia, [2]Solar Research Institute, Universiti Teknologi MARA, 40450 Shah Alam, Selangor, [3]School of Electrical Engineering, College of Engineering, Universiti Teknologi MARA, 40450 Shah Alam, Selangor, Malaysia
Email: azlinazmi@uitm.edu.my

Abstract
In order to address environmental challenges, particularly climate change, and lessen institutions' carbon footprints, sustainable energy sources are deemed essential. Universities are dealing with rising electricity bills due to increasing student enrolments and multitude operations. Introducing a solar PV system would help to reduce universities carbon footprint and subsequently the annual electricity bill. This study aims to conduct a techno-economic assessment of installing a grid-connected solar Photovoltaic (PV) power generation system at the Universiti Teknologi MARA (UiTM) campus in Shah Alam. The PV-syst software were used to design and analyse the PV system for suitable building rooftops in Shah Alam campus, followed by the cost-benefit analyses. This study suggests an 8MW solar PV system for UiTM Shah Alam, with an MYR28,786,907 installation cost, and MYR0.298/kWh Levelized Cost of Electricity (LCOE) with a total payback period of 8 years, avoiding a total of 149,195 tonnes CO_2 over the project lifetime. The Net Present Value, NPV is MYR 16,725,250.79, demonstrating that the PV system is a financially viable and profitable long-term investment. While comparing between the two mode of payments, the outright purchase has higher NPV in comparison to the Solar Power Purchase Agreement (SPPA) of zero capital expenditure, indicating better return. The UiTM Shah Alam solar PV system proposal has the potential to considerably lessen the university's reliance on non-renewable energy sources while decreasing its electricity costs, making it a financially feasible and sustainable alternative.
Keywords: Sustainable Energy, Solar PV System, PVSYST Software, Economic Analysis, Carbon Footprint

Introduction

Solar energy has been harnessed extensively as a renewable energy source and is widely recognized as one of the most environmentally friendly sources available. Malaysia, situated close to the equator, experiences monthly sun radiation levels between 400 and 600MJ/m2 (Qazi et al., 2023). Large-scale solar power projects hold considerable potential for the future. However, their widespread implementation needs to be improved by the high cost of photovoltaic (PV) cells and the prevailing tariff rates for solar electricity. As a result, solar energy is still in its nascent development phase. To address most electricity demand in Peninsular Malaysia, the government has focused on increasing the integration of renewable energy (RE) sources in the power capacity mix. In line with the power generation strategy, Malaysia aims to raise the share of RE in its installed capacity to 31% by 2025 and 40% by 2035. The Ministry of Energy and Natural Resources reports that the current installed capacity for RE stands at 7,995 megawatts (MW) in the country, with projections indicating growth to reach 18,000 MW by 2035. The objective of Malaysia's energy transition strategy aligns with Sustainable Development Goal 7, which emphasizes universal access to affordable, reliable, sustainable, and modern energy while also considering the importance of cost-effectiveness (Jalil, 2021).

Malaysia benefits from ample sunlight year-round, experiencing a monthly average of 400–5000 Wh/m2 for daily solar radiation. According to Mohammad et al (2020), the country enjoys an annual average of 2200 hours of sunshine, with monthly averages ranging from four to eight hours. It is indicating that the use of renewable energy reduces the CO_2 emission (Khezri et al., 2022). Recognizing the significance of solar energy in preserving the environment and ensuring energy security, the Malaysian government has actively pursued measures to encourage and advance its utilization. Through the implementation of legislation and the initiation of projects, the government has been dedicated to promoting and strengthening the adoption of solar energy resources. In addition to that, solar energy is extremely inexpensive when compared to other traditional energy sources. While Yu et al., (2022) focuses on the low cost and multipurpose of solar energy, (Wilberforce et al., 2019) are more concerned on the vulnerability of the solar system towards weather changes, which makes them expensive since they need an energy storage system.

The Net Energy Metering (NEM) programmed was upgraded with NEM 3.0, available between 2021 and 2023 (Zambri et al., 2022) that allow indirect connection to commercial buildings and a hybrid system approach. Unlike NEM 2.0, which has a maximum of 75% of the Maximum Demand (MD) for installed capacity, NEM 3.0 permits participation in net energy metering by commercial buildings (Husain et al., 2021). The maximum capacity of the installed renewable energy system for net metering is therefore limited to 75% of the maximum power demand of the business building. Commercial buildings can participate in net metering by using the hybrid system/indirect connection function to combine on-site renewable energy generation with an external renewable energy source. Remembering that NEM 3.0 legislation and specifics may change depending on the country or region where the programmed is being implemented is crucial (Zambri et al., 2022).

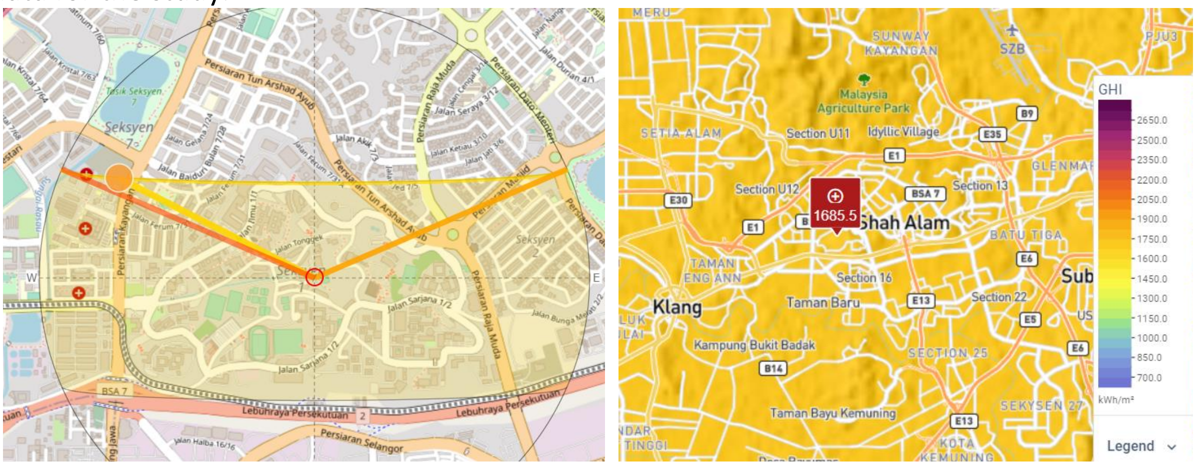
Several studies have examined the viability of introducing solar energy systems to educational institutions and campus areas because of the crucial role the play in promoting environmentally sustainable policies and practices as they possess access to the latest information on environmental issues and technological advancements. In 2019, (Alnoosani et al., 2019) published a paper in which they described the installation of 100MW solar PV on-Grid Power Plant at an institution that was able to decrease load shedding and cut down on the cost of providing power to its buildings. Taking it further, (Husain et al., 2021) argues that using the unused space on rooftops via the construction of grid-connected solar PV systems offers significant potential benefits in terms of energy and cost savings. Along the same line, implementation of rooftop solar PV systems have been proposed by (Kamanja et al., 2022) in order to lessen reliance on fossil fuels and reduce harmful emissions, contributing to a more sustainable future. Within the Universiti Teknologi MARA (UiTM) community, the UiTM Solar Research Institute actively contributes to energy-related education, research, consultation, and community involvement. Overall, the findings of these research highlight the need of installing a solar energy system at a university. However, the appropriate sizing and capacity of the installation of the solar rooftop in UiTM Shah Alam is unknown and further studies need to be done to work on the structures of the PV panels on the rooftop especially or a limited space available such as rooftops.

This research aimed to identify appropriate structures within UiTM Shah Alam, Selangor, suitable for installing rooftop solar PV panels. The appropriate sizing of the solar panels was determined. A detailed economic assessment was conducted to determine whether installing solar panels at UiTM Shah Alam was a valuable investment. The study also quantified the carbon emission savings that could be achieved by installing solar PV panels on the campus of UiTM Shah Alam.

Methodology

A. Data Collection

A methodical technique was used to ensure a systematic and thorough approach to data collecting, which included the meticulous completion of on-site surveys and the careful study of Google Earth images. These combined efforts allowed for gathering essential and pertinent data for the study.



(a) (b)

Fig. 1 Figure quality (a) UiTM Shah Alam sun path diagram (b) UiTM Shah Alam Global Irradiance

Table 1
Site Information

Latitude	3.0698
Longitude	101.5037
Elevated	45 m
Global Irradiance	1685.5
Peak Hour	4.71

B. Rooftop Analysis

Fig. 2 Buildings that are suitable for solar panels

Google Earth satellite imagery was used to assess the UiTM Shah Alam campus for potential solar PV panel installations. The aerial view provided by this technology allowed for the identification of suitable locations based on factors like orientation, inclination, and shading conditions. By analyzing the imagery, rooftops, open spaces, and other conducive areas were identified, ensuring maximum solar radiation exposure. This analysis provided valuable insights into the campus layout and facilitated informed decision-making for integrating solar PV systems. A total of 49 structures on the campus were evaluated based on variables such as orientation, inclination, and shadowing conditions. The rooftop area and tilt angle of the solar panels were determined using the ruler tool in Google Earth Pro.

C. Solar PV components

This section focuses on the critical aspects of the design and simulation of the grid-connected solar PV system. The system comprises several components: site layout, tilt angle, solar modules, various subsystems, and accessories.

Site layout: the available rooftop area is approximately 37901 m^2. The available rooftop area for installing solar panels was determined using Google Earth Pro. The tilt angle of the solar panels was determined based on the specific characteristics of the building's roof.

Tilt angle & Azimuth: The amount of solar radiation received on a PV module depends on latitude, day of the year, slope or tilt angle, surface azimuth angle, time of the day, and the angle of incident radiation (Božiková et al., 2021). Therefore, the tilt angle of the panels for this project follows the roof angle. In the case of flat roofs, a tilt angle of 10 degrees is implemented to prevent dirt accumulation. Tilted mounting structures can greatly reduce the build-up of dust and soil on solar panels, which can seriously impair their functionality, lowering their output and efficiency (Abdeen et al., 2017). The Azimuth of the solar system also varies, determined by the location of the building.

Solar modules: Jinko Solar model JKM575M-7RL4-V was selected for the design. These panels utilize TR technology and a half-cell design, reducing cell gaps and improving module efficiency. With a power output of 575W, these modules can achieve an efficiency of up to 21.40% for mono-facial panels (Husain et al., 2021). Opting for modules with high wattage or power output brings several advantages, especially for installations with limited roof space or remote sites. It allows for optimal restricted area utilization, maximizing energy production and yield. Furthermore, higher-wattage modules often exhibit superior efficiency, ensuring better performance even in low-light conditions. It means they can generate electricity even during overcast or foggy days. Ultimately, selecting modules with the highest wattage can yield a more substantial return on investment, as the increased power output contributes to excellent energy production throughout the system's lifespan. 13,865 solar photovoltaic panels in total are suitable for mounting on the buildings. Each building's installation consists of a distinct string, each consisting of 18 solar panels wired in series.

Inverters: To convert the direct current (DC) into alternating current (AC) while successfully reducing the creation of harmonics that result from the conversion process (Alnoosani et al., 2019). For best results, the DC-AC ratio should be within 1-1.25; otherwise, the inverter will be undersized or oversized (Kamanja et al., 2022). Therefore, the inverter chosen for this project is SUN2000-100KTL-M1. The number of inverters in the system varies depending on the unique needs of each structure, and each building in the system has its inverter. The total of inverters for all buildings suitable for solar panels is 84, with an average of 2 inverters for each building. The system also comes with 73.2 Maximum Power Point Trackers (MPPT).

Various subsystems and accessories. It encompasses the mounting structures on which panels, inverters, and other accessories are placed. Additionally, the sub-station and its components, such as transformers, are essential for grid connection. Furthermore, DC/AC cables are necessary for interconnecting the panels, inverters, and the grid (Baitule & Sudhakar, 2017).

D. *Software Modelling*

i. *Detailed Technical Analysis*

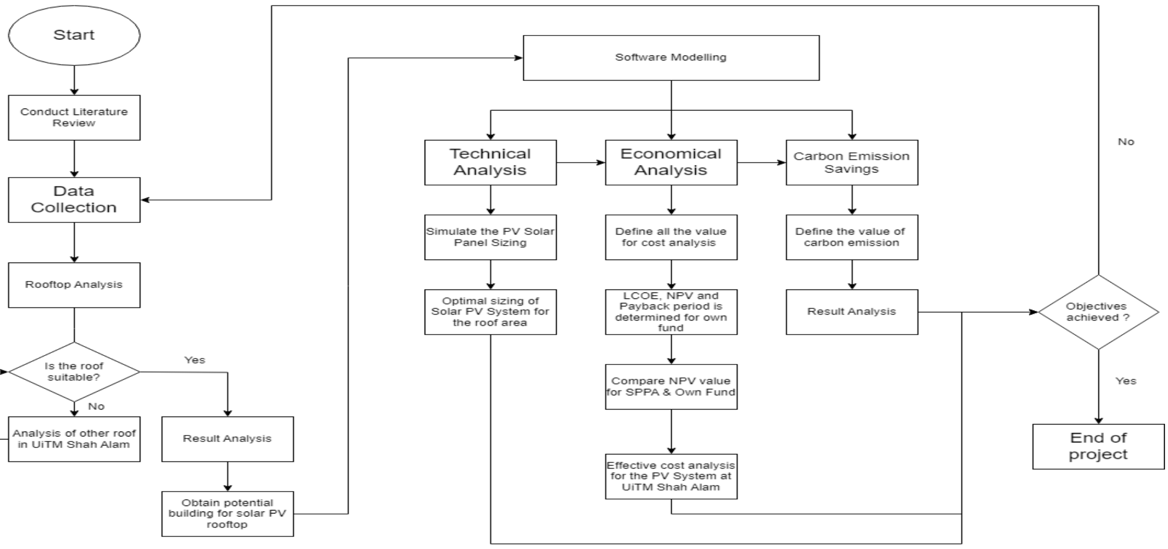
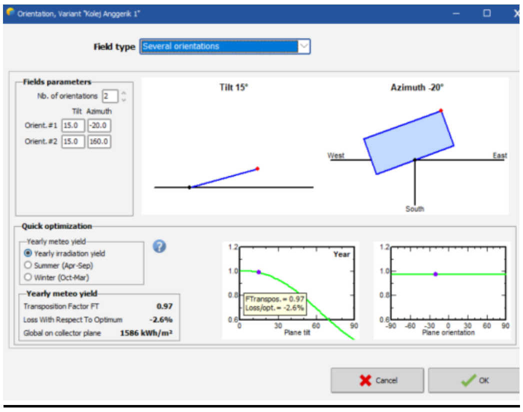
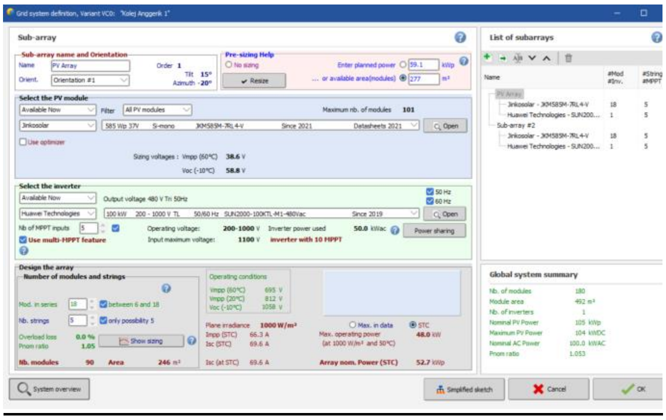


Fig. 3 Overall project flowchart of the project

PVsyst is a well-known and industry-standard software application for modeling and simulating the operation and performance of photovoltaic (PV) system (Zaheb et al., 2023). By inputting relevant parameters such as solar PV panel specifications, system capacity, geographical location, and local weather data specific to UiTM Shah Alam, PVsyst generated informative reports and metrics. These inputs allowed for the simulation of energy production, considering factors like solar radiation levels, temperature, and shading. This analysis provided a comprehensive understanding of the anticipated energy generation capacity of the system throughout the year, facilitating the identification of potential variations based on seasonal and climatic factors.

PVsyst also evaluated system losses, including electrical losses, shading losses, and soiling losses. Quantifying these losses aided in optimizing the system's design and configuration to maximize energy generation and minimize efficiency losses. Additionally, an energy yield analysis was conducted to provide detailed information on the system's potential energy generation under different operating conditions. This analysis factored in variables such as panel tilt, azimuth angle, and system configuration, ensuring an accurate estimation of the system's energy yield.





(a) (b)

Fig. 4 (a) Orientation setting of PVsyst (b) System setting of PVsyst

The determination of the PVsyst's ideal orientation based on the roof angle and the azimuth angle is shown in Figure 4 (a) of the study. It is important to evaluate these angles to produce the most power carefully. By maximizing the amount of sunlight that is accessible, the PV system is carefully aligned to work at optimal efficiency. The graph offers insightful information on how important orientation is for maximizing the efficiency of solar PV systems. The focus switches to the sizing factors for the PV module, inverter, and the number of strings in the system in Figure 4(b). The proper sizing criteria for these components are established after a thorough study. Various aspects are considered during this process, including anticipated power generation, load requirements, and system capacity. The system is set up to precisely match the project's requirements and limits by carefully choosing the appropriate module size, inverter capacity, and number of strings. The information shown in Figure 6 aids in a full understanding of the design of solar PV systems, ensuring that the system is designed correctly for the best performance and efficiency.

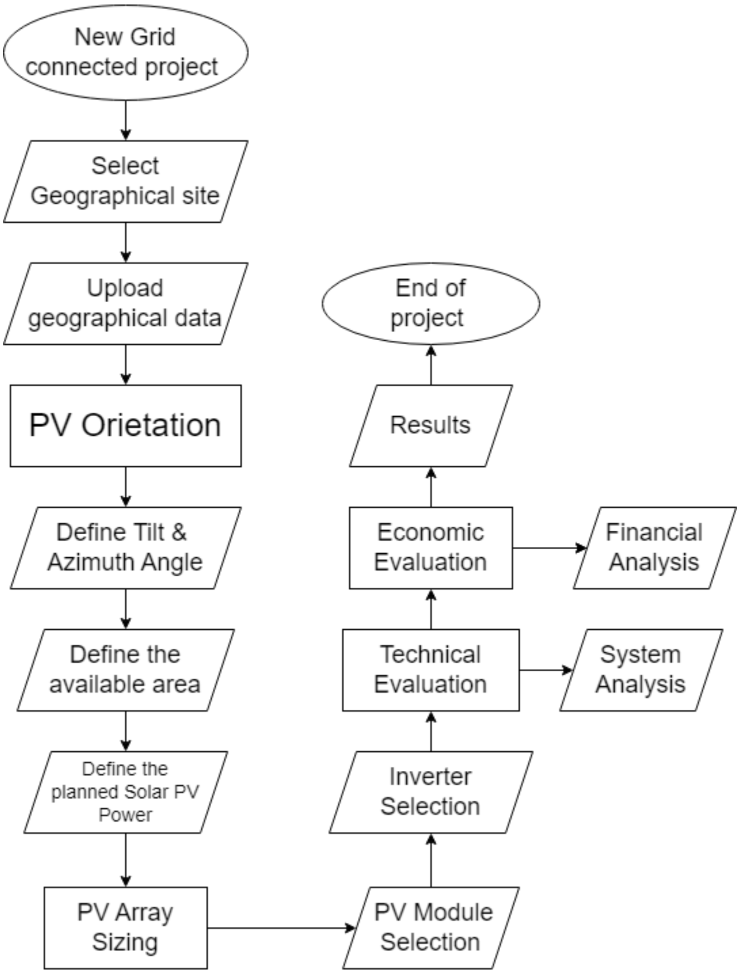


Fig. 5 Flowchart on technical analysis of project

Table 2
PV Modules Details

Brands	Jinko Solar
Size	575Wp
Models	JKM575M-7RL4-V

Table 3
Mechanical Characteristic of JKM575M-le

Cell Type	P type Mono-crystalline
No. of cells	156 (2x78)
Dimensions	2411×1134×35mm (94.92×44.65×1.38 inch)
Weight	31.1 kg
Front Glass	3.2mm, Anti-Reflection Coating, High Transmission, Low Iron, Tempered Glass
Frame	Anodized Aluminum Alloy
Junction Box	IP68 Rated
Output Cable	TUV 1×4.0mm2 (+): 290mm, (-): 145 mm or Customized Length

Table 4
Inverter details

Brands	Huawei Technologies
Size	100kW
Models	SUN2000-100KTL-M1

Table 5
Mechanical properties of inverter (SUN2000-100KTL-M1)

Efficiency	
Max. Efficiency	98.8%
Input	
Max. Input Voltage	1,100 V
Max. Current per MPPT	26 A
Max. Short Circuit Current per MPPT	40 A
Start Voltage	200 V
MPPT Operating Voltage Range	200 V ~ 1,000 V
Rated Input Voltage	600 V
Number of Inputs	20
Number of MPP Trackers	10
Output	
Rated AC Active Power	100,000 V
Rated AC Apparent Power	100,000 V
Max. AC Apparent Power	110,000 V
Max. AC Active Power (co sϕ=1)	110,000 V
Rated Output Voltage	400 V, 3W + PE
Rated AC Grid Frequency	50 Hz / 60 Hz
Rated Output Current	144.4 A
Max. Output Current	160.4 A
Adjustable Power Factor Range	0.8 LG ... 0.8 LD
Max. Total Harmonic Distortion	<3%

Normalized Production
Considers external factors like shading and soiling, allowing a realistic assessment of the system's energy output compared to expectations.
$$Normalized\ Production\ = \frac{Actual\ Energy\ Production}{Expected\ Energy\ Production}\ (1)$$

System Power
Calculates the average power production during a specific period, helping us understand the system's efficiency in distributing electricity.
$$System\ Power\ = \frac{Total\ Energy\ Output}{Time}\ (2)$$

System Production
Determines the overall energy output over a specific time frame, providing insights into the system's efficiency and power generation capabilities.
$$System\ Production\ = System\ Power\ \times\ Time\ (3)$$
Specific Production

Allows for a standardized comparison of different PV systems by calculating the energy output per unit of installed capacity.

$$Specific\ Production = \frac{Total\ Energy\ Output}{Total\ Installed\ Capacity} \quad (4)$$

Performance Ratio

It is described as the difference between the reference and final yields. Information regarding the daily impact of the system-wide losses on the rated output is available from the performance ratio. The losses include the loss of a solar panel, the loss of the angle of inclination, the loss due to dust, the loss due to shade, and the loss due to changes in the temperature of the module. Every year, it is used to analyze the effectiveness of solar power systems (Jagadale et al., 2022).

$$P_r = \frac{Y_F}{Y_R} \quad (5)$$

ii. *Detailed Economic Analysis*

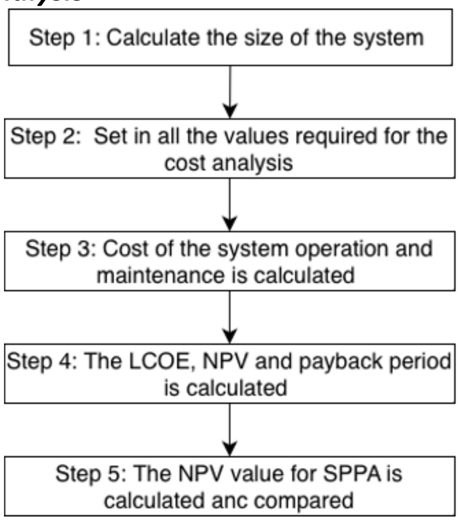
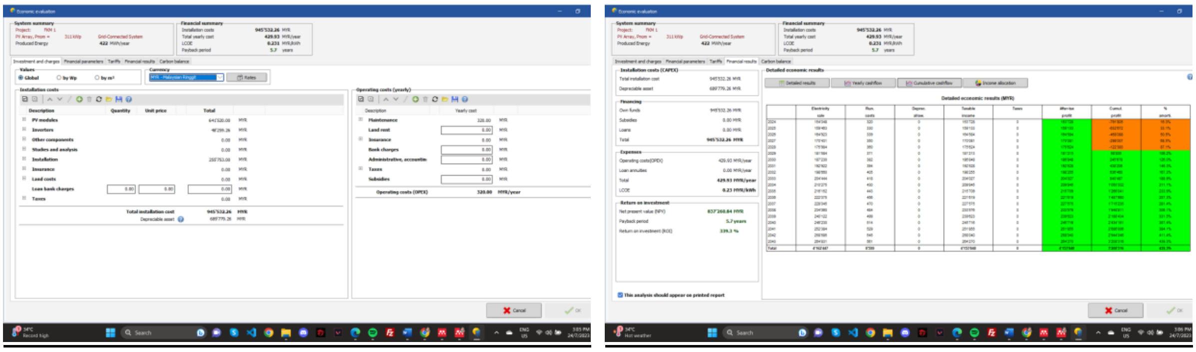


Fig. 6 Flowchart for economic analysis

The economic analysis began with entering system parameters into PVsyst, such as solar PV panel specifications, system capacity, and local energy tariff rates. PVsyst simulated the performance of the solar PV system using historical meteorological data particular to UiTM Shah Alam, including solar radiation levels, temperature, and shading information.

PVsyst provided extensive analyses that included economic measures such as the levelized cost of electricity (LCOE), payback period (PP), return on investment (ROI), and Net Present Value (NPV). These indicators provided vital insights into the financial feasibility and profitability of the Solar PV project.

The duration of the initial investment was considered throughout the project's lifespan. A favourable ROI indicated the project was financially feasible. The present worth of the system's generated cash flows was calculated by considering the time value of money. A positive NPV indicates a financially sound investment.



(a) (b)

Fig. 7 (a) PVsyst Economy Evaluation system, (b) The financial result

LCOE

The formula used in PVsyst software for the LCOE calculation is (Mohamed et al., 2022)

$$LCOE = \frac{\sum_{t=1}^{n} \frac{I_t + M_t}{(1+r)^t}}{\sum_{t=1}^{n} \frac{E_t}{(1+r)^t}} \quad (6)$$

where I_t is the investment and expenditures for the year (RM/kWp), M_t is the operational and maintenance expenditures for the year (RM/kWp), E_t is electricity production for the year (kWh), r is discount rate and n is the lifetime of the system.

NPV

NPV determines the end-of-life value of a project considering discounted cash flows. The NPV is a useful determinant when comparing projects with similar lifetime and initial investment cost. Positive NPV indicates that a project generates value while negative NPV indicates losses. NPV is calculated as follows (Gönül et al., 2022).

$$NPV = \sum_{t=1}^{T} \frac{C_t}{(1+i)^t} - C_{t,0} \quad (7)$$

where C_t is net cash flow in time t, i is real interest rate and $C_{t;0}$ is the initial investment cost of the PV project.

Payback Period

Payback period is used to determine the expected time required for the project to recover its initial cost (Laajimi & Go, 2021). The payback period (PP) method does not account for the time value of money and has calculated as (Masters, n.d.).

$$Payback\ Period\ (PP) = \frac{Initial\ Capital\ Cost}{Annual\ Cash\ Flow} \quad (8)$$

Results

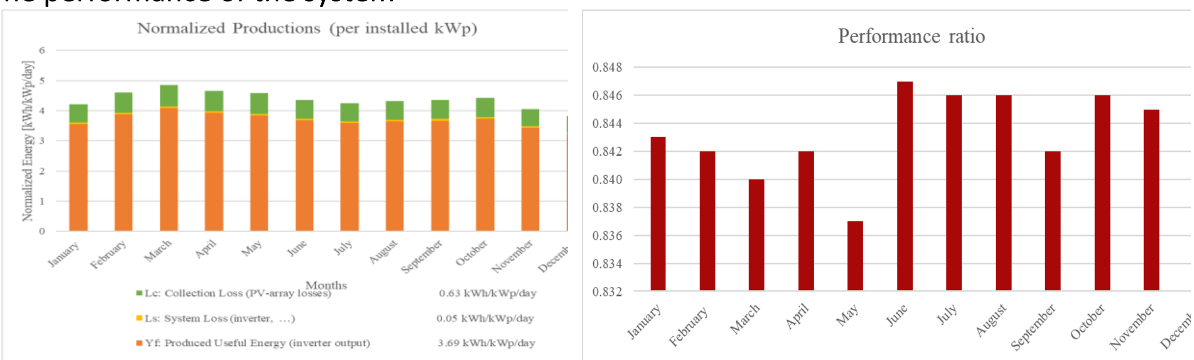
i. Technical analysis

The results acquired for each building are shown below, thoroughly analysing the system's operation and its results for specific buildings.

Table 6
Technical Detail Analysis

Location	System Production (MWh/Yr)	Specific Production (kWh/kWp/Yr)	Normalized Production (kWh/kWP/day)	System Power (kWp)
AA	298	2740	7.51	218
DA	142	1369	3.75	104
DATC	850	1368	3.75	621
DB	283	1367	3.74	207
DKML	285	1364	3.74	207
DKMW	283	1365	3.74	207
DSB	141	1362	3.73	104
FKA	422	1359	3.72	311
FKE	281	1356	3.72	207
FKK	422	1360	3.73	310
FKM	422	1359	3.72	311
FSG	992.1	8179	22.4	828.4
FSKM	970	5417	14.84	712.2
FSPU	731	4077	11.16	538
IDO	466.3	5459	14.96	340.6
KA	834	8070	22.14	624
KPS	821	4099	11.23	600
MC	691.4	6825	18.7	507.7
MOU	285	1356	3.71	210
MSAAS	255	1369	3.75	186
MTDC	141	1361	3.73	104
PI	284	1372	3.76	207
PS	142	1372	3.76	104
PTAR	412	1372	3.76	300
TOTAL	10853.8	66697	182.75	8068.9

The performance of the system



(a) (b)

Fig. 8 (a) Normalized Production of Kolej Anggerik 1, (b) Performance Ratio of Kolej Anggerik 1

Figure 8 (a) in the report shows Kolej Anggerik 1's normalised production, representing the energy produced over the month based on inverter output. This graph gives a thorough overview of the system's energy production patterns and enables a thorough evaluation of its operation. Notably, the performance ratio shown in Figure 7 (b), which shows the solar system's outstanding efficiency at 84.3%, is displayed. This high percentage demonstrates the efficient and effective solar system design at Kolej Anggerik 1 by demonstrating the successful conversion of solar energy into usable power with minimum losses or inefficiencies. The information shown in Figure 8 supports the system's capacity to produce a sizable amount of clean energy, greatly enhancing the facility's overall energy sustainability.

	GlobHor kWh/m²	DiffHor kWh/m²	T_Amb °C	GlobInc kWh/m²	GlobEff kWh/m²	EArray MWh	E_Grid MWh	PR ratio
January	133.5	77.63	27.33	130.8	126.8	11.77	11.61	0.843
February	131.4	78.85	27.91	128.8	125.2	11.58	11.41	0.842
March	153.7	93.45	28.26	150.4	146.4	13.50	13.31	0.840
April	142.6	83.79	27.87	139.7	136.0	12.57	12.39	0.842
May	145.0	74.74	28.72	142.1	138.4	12.71	12.52	0.837
June	133.2	82.35	28.18	130.5	126.9	11.80	11.64	0.847
July	134.5	81.73	28.19	131.7	128.1	11.90	11.73	0.846
August	136.6	87.30	28.19	133.8	130.2	12.09	11.92	0.846
September	133.3	75.13	27.38	130.6	127.1	11.76	11.59	0.842
October	139.8	86.56	27.66	137.0	133.4	12.38	12.20	0.846
November	124.4	73.50	26.85	121.8	118.4	11.00	10.84	0.845
December	121.1	76.43	27.25	118.5	114.8	10.70	10.54	0.845
Year	1629.3	971.48	27.82	1595.6	1551.7	143.74	141.71	0.843

Fig. 9 Balance and Main Result

Figure 9 shows the list of balanced energy power throughout the 12 months during the first year of the system being implemented. The table summarizes the global horizontal irradiation, horizontal diffuse irradiation, temperature, global incident, effective global IAM or shadings, effective energy output from the PV Array, energy injected in the grid performance ratio from the designated system. Throughout the year, the performance ratio shows a good performance, and this is a good indication on the lifetime of the system could last as well as the efficiency of the system.

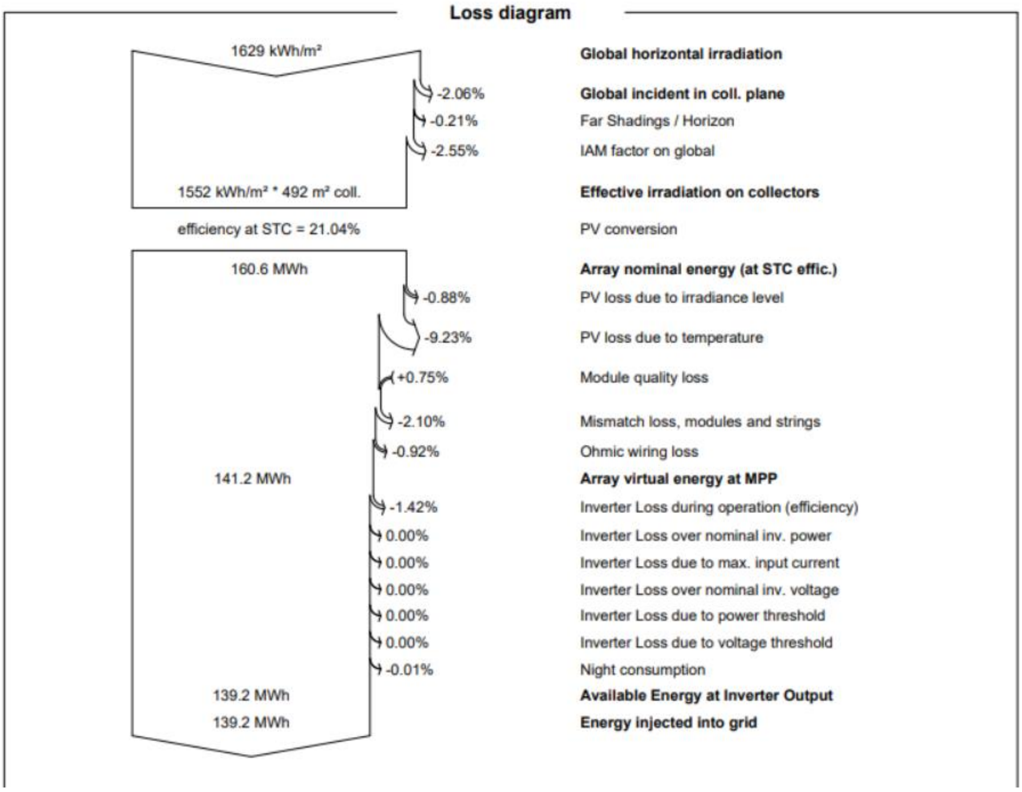


Fig. 10 Loss Diagram

Figure 10 shows the loss diagram for a solar photovoltaic (PV) system, illuminating the system losses' increasing breakdown. The loss diagram illustrates the different elements affecting the PV module and array's overall losses. These losses include ohmic wiring losses, module mismatch losses, module quality losses, converter operation losses, converter threshold power losses, battery efficiency losses, charge/discharge current efficiency losses, and inverter threshold power losses. The grid input can be precisely determined by correcting the losses the inverter suffered.

iii. Economic Evaluation

The economic parameters used in the analysis are shown.

Table 7

Economic Parameters

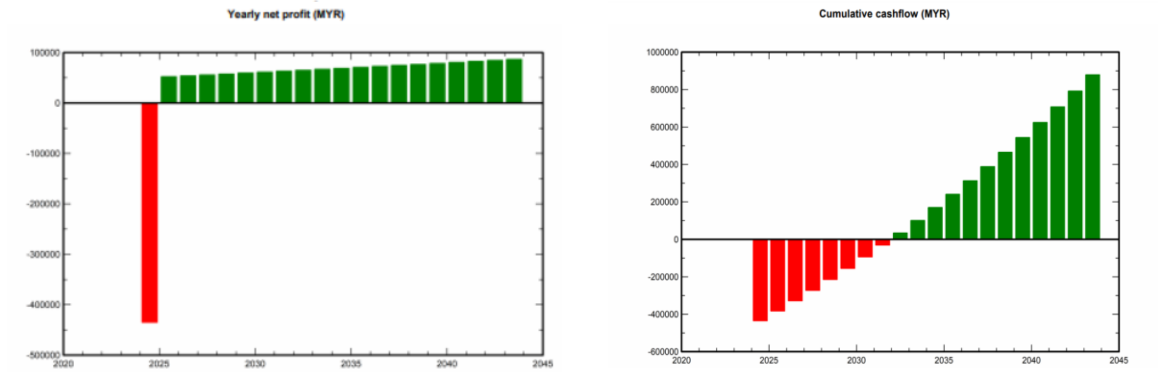
Parameters	Value
PV Module	RM 950/Unit
Inverter	RM 16086.42/Unit
Installation Cost	RM 2826/Unit
Maintenance Cost	RM 320/Year
Feed-in-tariff	RM 0.365/kWh
Installer	RM 238/Unit
Inflation Rate	3 %
Discount Rate	10 %
System Expected Lifetime	20 years

Table 8
Detailed Economy Result

Location	Installation Cost (MYR)	Total yearly cost (MYR)	Levelized Cost of Electricity (MYR/kWh)	Net Present Value (MWR)	Return of Investment (Years)
AA 1	281077	429.93	0.206	316191.6	5
AA 2	610917.9	429.93	0.406	44820.73	9
DA	383378.2	429.93	0.281	212757.3	7
DATC	1788763	429.93	0.217	1805102	5
DB	920208.2	429.93	0.336	273845.8	8
DKML	562154	429.93	0.206	630398.7	5
DKMW	869057.6	429.93	0.318	322410.6	8
DSB	434528.8	429.93	0.32	158506.4	8
FKA	945532.3	429.93	0.231	837341.7	6
FKE	715605.8	429.93	0.264	469240.9	6
FKK	945532.3	429.93	0.231	838308.3	6
FKM	945532.3	429.93	0.231	837260.8	6
FSG 1	217264.4	429.93	0.324	75984.99	8
FSG 3	766756.4	429.93	0.28	429336.5	7
FSG 4	996682.9	429.93	0.242	803604.2	6
FSG 5	447190.8	429.93	0.218	450830.6	5
FSKM 1	1351903	429.93	0.241	1092244	6
FSKM 2 (1)	332227.6	429.93	0.247	255826.9	6
FSKM 2 (2)	337392.9	429.93	0.313	133485.6	7
FSKM 2 (3)	383378.2	429.93	0.285	204065.3	7
FSPU 1	613304.6	429.93	0.226	573845.1	6
FSPU 2	636297.3	429.93	0.223	610035.5	6
FSPU 3	304069.7	429.93	0.205	347442.7	5
IDO 1	462686.8	429.93	0.375	74794.01	9
IDO 2	434528.8	429.93	0.318	162878.9	8
IDO 3	194271.8	429.93	0.362	40453.2	9
IDO 4	485679.4	429.93	0.359	104181.2	8
KA 1	485679.4	429.93	0.362	100040.2	9
KA 2	485679.4	429.93	0.355	110551	8
KA 3	485679.4	429.93	0.355	110551	8
KA 4	485679.4	429.93	0.355	110590.4	8
KA 5	485679.4	429.93	0.355	110590.4	8
KA 6	485679.4	429.93	0.355	110590.4	8
KPS 1	613304.6	429.93	0.224	581233.1	6
KPS 2	664455.2	429.93	0.243	532190.8	6
KPS 3	516168.8	429.93	0.211	554344	5
MC 1	434528.8	429.93	0.319	159633.5	8
MC 2	286242.3	429.93	0.264	189024.2	6
MC 3	715605.8	429.93	0.262	476537	6
MC 4	166113.8	429.93	0.247	129461.6	6
MC 6	189106.5	429.93	0.234	165842.8	6

MOU	874997.6	429.93	0.318	325929.6	8
MSAAS	874223	429.93	0.354	201541	8
MTDC	536830	429.93	0.395	55800.12	9
PI	1022509	429.93	0.372	176376.2	9
PS	485679.4	429.93	0.355	111842.9	8
PTAR	1127142	429.93	0.283	612565.5	7
TOTAL	28786907	429.93	0.297979	16209149	8

Based on the thorough analysis of the data presented in Table 8, key financial aspects of the project are revealed. The overall installation cost, totalling MYR 28,786,907 covers all expenses associated with deploying the solar energy system. Additionally, the anticipated operating cost of MYR 429.93 per year of energy produced emphasizes the long-term expenses required for the system's maintenance and operational efficiency. The Levelized Cost of Energy (LCOE) is estimated to be MYR 0.297979 per kilowatt-hour (kWh), serving as a crucial measure for evaluating the economic viability and competitiveness of the solar energy project. Moreover, with a net present value (NPV) cost of RM 16209148.98, considering the entire project cost, ongoing expenses, and expected energy production over a 20-year lifespan, starting in 2024, the project demonstrates financial feasibility and substantiates its potential for long-term profitability.



(a) *(b)*

Fig. 11 (a) Yearly Net Profit of Kolej Anggerik 1, (b) Cumulative Cashflow of Kolej Anggerik 1

The figure above displays an example output of Kolej Anggerik 1. From figure 11 (b), it can be observed that from the ninth year, the project will be in the positive y-axis, beginning to generate profit from the initial investment. All the costs were equalized for a lifespan of 20 years. For the first 8.5 years, the investment cost is greater than the profit amount; then, the breakeven point is reached, and positive values result in annual profits from the PV system.

iii. Carbon Emission

About 149194.9 tonnes of CO_2 emissions can be avoided by installing PV solar panels at UiTM Shah Alam. The need for electricity produced from fossil fuels is decreased by these solar panels, which transform sunlight into electricity. Carbon emissions (CO_2) from fuel-burning are used as an indicator for pollution in the environment (Rehman et al., 2022). The carbon emission savings represent the amount of CO_2 that would have been produced if fossil fuels had been used to generate electricity rather than solar energy. By using solar energy, UiTM Shah Alam aids in reducing climate change, encourages sustainability, and works towards a better future.

The projected reductions in carbon emissions demonstrate the PV solar panel installation at UiTM Shah Alam's considerable environmental impact. The campus increases energy independence and decreases its dependency on fossil fuel-powered electricity. In addition to reducing carbon emissions, this switch to solar energy is an example for other organizations and the community, proving the viability and advantages of adopting renewable energy sources.

Comparison between Solar Power Purchase Agreement (SPPA) Scheme with Own Funding

Table 9
Assumptions for Tariff rate for SPPA

Fixed tariff Rate	10% lower than TNB Rate	RM 0.3285

Table 10
Specific Data for SPPA Scheme

Capital Cost	RM 0
Cost of Maintenance	RM 0
Carbon Emission	0.78kg/kWh (*Grid Emission Factor (GEF) in Malaysia*, n.d.)
System Generation	10853.8 MWh

Table 11
NPV Rate

Year	Annual Cash Flow (without depreciation)
1 - 20	MYR 3,265,654.41

According to the table 11, the Solar Power Purchase Agreement (SPPA) has an NPV value of MYR 3,265,654.41, whereas using UiTM cash yields gives an NPV of MYR 16,725,250.79. In general, a greater NPV value indicates a better financial outcome.

In this case, using own funds yields a larger NPV than using SPPA. Investing one's own money will result in bigger financial gains over the project. By deciding to finance the PV solar installation with its own money, UiTM Shah Alam can keep ownership of the system and reap the benefits of all the financial gains it produces.

Conclusions

This study concludes by emphasising the importance of universities reaching sustainability targets, focusing on sustainable energy used and contribute to the Sustainable Development Goal, SDG. Universities must strive to reduce its dependency on fossil fuels and embrace the promise of solar energy. This article gives thorough techno-financial investigation on installing solar rooftops and evaluates the viability of such investment, focusing on UiTM Shah Alam. A financial model was created to assess the system's profitability, accounting for numerous features and inputs. The analysis measured the Project Payback, Net Present Value (NPV), and Internal Rate of Return (IRR) to assess the financial performance and the resulting carbon avoidance. The findings showed that, on average, it would take 8 years to repay the initial investment in 49 buildings, with a large positive NPV signifying project profitability and offsetting scope 2 electricity emissions with the installation of the rooftop PV system. It is important to acknowledge that data limitations and the requirement for additional, comprehensive studies have limited the accuracy of this project's findings. Even so, the knowledge gathered from this study can be a useful resource and a starting point for future investigations that strive for a more detailed and thorough examination.

Acknowledgement
Authors are grateful for the support and assistance provided by Pejabat Pembangunan Infrastruktur dan Infostruktur(PPII), Universiti Teknologi MARA Shah Alam.

References

Abdeen, E., Orabi, M., & Hasaneen, E. S. (2017). Optimum tilt angle for photovoltaic system in desert environment. *Solar Energy*, *155*, 267–280. https://doi.org/10.1016/j.solener.2017.06.031

Alnoosani, A., Oreijah, M., Alhazmi, M. W., Samkari, Y., Alnoosani1, A., Oreijah2, M., Alhazmi3, M., Samkari4, Y., & Faqeha5, H. (2019). Design of 100MW Solar PV on-Grid Connected Power Plant Using (PVsyst) in Umm Al-Qura University Smart Firefighting Device System (LAHEEB) View project Dye-sensitized solar cells (DSSC) and Nano-technologies. View project Design of 100MW Solar PV on-Grid Connected Power Plant Using (PVsyst) in Umm Al-Qura University. *Article in International Journal of Science and Research*. https://doi.org/10.21275/30101901

Baitule, A. S., & Sudhakar, K. (2017). Solar powered green campus: A simulation study. *International Journal of Low-Carbon Technologies*, *12*(4), 400–410. https://doi.org/10.1093/ijlct/ctx011

Bozikova, M., Bilcik, M., Madola, V., Szaboova, T., Kubik, L., Lendelova, J., & Cviklovic, V. (2021). The effect of azimuth and tilt angle changes on the energy balance of photovoltaic system installed in the southern slovakia region. *Applied Sciences (Switzerland)*, *11*(19). https://doi.org/10.3390/app11198998

Gonul, O., Duman, A. C., Barutcu, B., & Guler, O. (2022). Techno-economic analysis of PV systems with manually adjustable tilt mechanisms. *Engineering Science and Technology, an International Journal*, *35*. https://doi.org/10.1016/j.jestch.2022.101116

Grid Emission Factor (GEF) in Malaysia. (n.d.).

Husain, A. A. F., Phesal, M. H. A., Ab Kadir, M. Z. A., & Ungku Amirulddin, U. A. (2021). Techno-economic analysis of commercial size grid-connected rooftop solar pv systems in malaysia under the nem 3.0 scheme. *Applied Sciences (Switzerland)*, *11*(21). https://doi.org/10.3390/app112110118

Jagadale, P. R., Choudhari, A. B., & Jadhav, S. S. (2022). *Design and Simulation of Grid Connected Solar Si-Poly Photovoltaic Plant using PVsyst for Pune, India Location*. *3*(1), 41–49. https://doi.org/10.22044/rera.2021.11057.1069

Jalil, A. (2021). *Malaysia aims 31% RE capacity by 2025*. The Malaysian Reserve.

Kamanja, L., Komarala, V., Dutta, V., Waita, S., & Wachira, K. (2022). Techno-Economic Analysis of a Rooftop Grid-connected Photovoltaic Solar System: A case study of Jomo Kenyatta University of Agriculture and Technology (SAJOREC). *2022 IEEE PES/IAS PowerAfrica, PowerAfrica 2022*. https://doi.org/10.1109/PowerAfrica53997.2022.9905282

Khezri, M., Heshmati, A., & Khodaei, M. (2022). Environmental implications of economic complexity and its role in determining how renewable energies affect CO2 emissions. *Applied Energy*, *306*. https://doi.org/10.1016/j.apenergy.2021.117948

Laajimi, M., & Go, Y. I. (2021). Energy storage system design for large-scale solar PV in Malaysia: techno-economic analysis. *Renewables: Wind, Water, and Solar*, *8*(1). https://doi.org/10.1186/s40807-020-00064-5

Masters, G. M. (n.d.). *Renewable and Efficient Electric Power Systems*.

Mohamed, N. S. S., Sulaiman, S. I., & Rahim, S. R. A. (2022). Design of ground-mounted grid-connected photovoltaic system with bifacial modules using PVsyst software. *Journal of Physics: Conference Series*, *2312*(1). https://doi.org/10.1088/1742-6596/2312/1/012058

Mohammad, S. T., Al-Kayiem, H. H., Aurybi, M. A., & Khlief, A. K. (2020). Measurement of global and direct normal solar energy radiation in Seri Iskandar and comparison with other cities of Malaysia. *Case Studies in Thermal Engineering*, *18*, 100591. https://doi.org/10.1016/J.CSITE.2020.100591

Qazi, A., Bhowmik, C., Hussain, F., Yang, S., Naseem, U., Adebayo, A. A., Gumaei, A., & Al-Rakhami, M. (2023). Analyzing the Public Opinion as a Guide for Renewable-Energy Status in Malaysia: A Case Study. *IEEE Transactions on Engineering Management*, *70*(2), 371–385. https://doi.org/10.1109/TEM.2020.3046749

Rehman, S., Rehman, E., Mumtaz, A., & Jianglin, Z. (2022). A Multicriteria Decision-Making Approach in Exploring the Nexus Between Wind and Solar Energy Generation, Economic Development, Fossil Fuel Consumption, and CO2 Emissions. *Frontiers in Environmental Science*, *9*. https://doi.org/10.3389/fenvs.2021.819384

Wilberforce, T., Baroutaji, A., El Hassan, Z., Thompson, J., Soudan, B., & Olabi, A. G. (2019). Prospects and challenges of concentrated solar photovoltaics and enhanced geothermal energy technologies. *Science of The Total Environment*, *659*, 851–861. https://doi.org/10.1016/J.SCITOTENV.2018.12.257

Yu, J., Tang, Y. M., Chau, K. Y., Nazar, R., Ali, S., & Iqbal, W. (2022). Role of solar-based renewable energy in mitigating CO2 emissions: Evidence from quantile-on-quantile estimation. *Renewable Energy*, *182*, 216–226. https://doi.org/10.1016/j.renene.2021.10.002

Zaheb, H., Amiry, H., Ahmadi, M., Fedayi, H., Amiry, S., & Yona, A. (2023). Maximizing Annual Energy Yield in a Grid-Connected PV Solar Power Plant: Analysis of Seasonal Tilt Angle and Solar Tracking Strategies. *Sustainability*, *15*(14), 11053. https://doi.org/10.3390/su151411053

Zambri, M. F., Othman, M. M., Hasan, K., Hidayat, M. N., Ismail, A. K., & Musirin, I. (2022). Comparative study of net energy metering and feed-in tariff for the 496kWp UiTM segamat solar photovoltaic system. *Indonesian Journal of Electrical Engineering and Computer Science*, *27*(2), 601–610. https://doi.org/10.11591/ijeecs.v27.i2.pp601-610