

Zero-CAPEX Strategy for Implementing Solar Rooftop Initiatives in Malaysia: Towards a Sustainable Campus

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ABSTRACT

This study provides the first comprehensive empirical assessment of Zero Capital Expenditure (Zero-CAPEX) financing strategies for solar photovoltaic (PV) implementation in Malaysian higher education institutions, specifically addressing the critical barrier of substantial upfront investment costs that significantly impede renewable energy adoption across the sector. Using a robust mixed-methods approach that combines qualitative financing assessment with quantitative energy performance evaluation, the research examined solar PV operations across three Universiti Teknologi MARA (UiTM) campuses operating under Net Energy Metering (NEM) schemes during a four-month operational validation period from June to September 2021. The performance analysis demonstrated remarkable energy consumption reductions averaging 503,054 kWh across all campuses, substantially exceeding the initially projected 25% reduction targets, with Campus B achieving an exceptional 70% reduction in energy consumption. Detailed Net Present Value (NPV) calculations revealed consistently positive financial returns ranging from RM 2,189,850 to RM 3,403,936 over the complete 21-year contract period, demonstrating robust long-term profitability for both educational institutions and private investors. Campus-specific energy reductions of 389,500 kWh (Campus A), 514,219 kWh (Campus B), and 605,445 kWh (Campus C) effectively validated Zero-CAPEX model effectiveness under Malaysian tropical environmental conditions. The research establishes NEM as the optimal Zero-CAPEX framework for educational institutions, providing concrete empirical evidence of both technical feasibility and economic sustainability. Comprehensive sensitivity analysis incorporating varying tariff escalation scenarios (2-2.9% annually) confirmed the model's robustness, with higher utility rates further strengthening the Zero-CAPEX value proposition and financial attractiveness for stakeholders.

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INTRODUCTION

Universiti Teknologi MARA (UiTM) has demonstrated significant progress in environmental sustainability, climbing 17 positions to rank 111th in the 2023 UI GreenMetric World University Ranking. Established by Universitas Indonesia in 2010, this comprehensive global assessment framework evaluates higher education institutions through 39 indicators across six criteria, standing as the pioneering system to implement Voluntary Standards for enhancing campus infrastructure and promoting sustainable practices worldwide (IEA, 2023; Sudaryati & Raharja, 2022).

Despite UiTM's overall improvement, the UiTM Green Center has identified a critical opportunity within the energy and climate change category, one of the six assessment areas containing eight specific indicators, including campus renewable energy sources. Unlike other categories where UiTM has performed relatively well (Education and Research, Waste, Water, and Transportation), this energy criterion presents substantial room for improvement through strategic initiatives requiring either minimal or zero capital expenditure (Zero-CAPEX).

Rooftop Solar Photovoltaic (PV) systems have emerged as a leading strategy among universities seeking to enhance energy efficiency while satisfying the renewable energy indicators in the UI GreenMetric framework. The global adoption of solar PV in educational institutions has grown approximately 23% annually between 2018 - 2023, with universities worldwide installing an estimated 2.7 GW of capacity by the end of 2023, representing approximately 5% of the total institutional solar market (IEA, 2023). However, implementation rates vary significantly by region; North American and European institutions lead in adoption, while developing nations, including many in Southeast Asia, face substantial barriers despite possessing advantageous solar irradiation profiles. The consistent primary obstacle remains the substantial initial capital investment, which competes directly with core educational funding priorities (Fuentes-del-Burgo et al., 2021).

Within Malaysia, multiple Higher Education Institutions (HEIs) have successfully implemented rooftop solar energy systems, including Universiti Utara Malaysia (Shafie et al., 2022), Universiti Tun Hussein Onn (Roslan & Akasah, 2018), Universiti Sains Malaysia (Rohaisham & Salleh, 2024), and IKBN/ITBN campuses (Khairi et al., 2022). UiTM has joined this movement toward campus sustainability. Beyond reducing electricity consumption, these systems decrease greenhouse gas emissions and carbon footprints, contributing significantly to smart campus initiatives (Ayadi et al., 2025; Khairi et al., 2022; Krishna et al., 2021; Rohaisham & Salleh, 2024; Shafie et al., 2022; Yusri et al., 2023). All of these institutions are using large-scale Self-Consumption (SELCO) with collaborative strategies between solar service providers and educational institutions to support the government's agenda to achieve carbon emission reduction in Malaysia (Govindarajan et al., 2024).

The Malaysian government has introduced several supportive programs, notably the Net Energy Metering (NEM) 3.0 program for government buildings, including HEIs. However, the substantial capital expenditure (CAPEX) for solar installation, operation, and maintenance presents a significant barrier. For example, installing a 125.75 kWh system can cost up to RM 165,475.00 (Shafie et al., 2022), causing many HEIs to hesitate in adopting renewable energy approaches. This situation underscores the importance of profitable investment decisions, highlighting where Zero-CAPEX models become particularly advantageous. Financial models like Net Present Value (NPV) or Internal Rate of Return (IRR) can generate positive values for consumers, indicating profitable investments (Dahlan et al., 2013). Responding to this market needs, companies including GSPARX Sdn Bhd, GO Energy Sdn Bhd, and Ditrolc Energy now offer Zero-CAPEX initiatives (Shafie et al., 2022; Yusri et al., 2023; Zublie et al., 2023).

Malaysia's geographical position offers exceptional solar potential, with an average daily solar radiation of 5 kWh/m² and approximately 12 hours of sunlight, indicating substantial capacity for solar electricity generation (Subramani et al., 2017). The country's three major electricity generation entities, Tenaga Nasional Berhad (TNB), Sabah Electricity Sdn Bhd, and Sarawak Energy Berhad, have embraced

government energy incentives. For instance, TNB Renewables Sdn Bhd, a TNB subsidiary, offers attractive options like solar leasing that benefit both end-users and the company. These advantageous natural conditions and supportive corporate structures suggest that Solar PV implementation should be more widely adopted as a valuable energy resource, benefiting both the environment and consumers through reduced electricity consumption.

Despite the recognized benefits of solar PV systems for educational institutions and the availability of various financing mechanisms, a significant knowledge gap remains regarding the practical implementation and performance of Zero-CAPEX models in university settings, particularly in developing economies like Malaysia. While theoretical models suggest the viability of such approaches, empirical research documenting actual energy performance, financial returns, and implementation challenges is limited. This research addresses this critical gap by providing a comprehensive case study analysis of three campus implementations, offering evidence-based insights for institutional decision-makers and policy frameworks. The study is particularly timely as educational institutions worldwide face increasing pressure to reduce carbon footprints while simultaneously managing budget constraints exacerbated by post-pandemic financial challenges.

This research aims to develop an optimal Zero-CAPEX strategy for implementing solar PV systems in Malaysian educational institutions that maximizes both environmental and economic benefits. To achieve this aim, this study will identify and analyze various Zero-CAPEX financing models available for solar PV implementation in educational institutions, evaluate the actual energy performance and financial returns of Zero-CAPEX solar PV systems across three university campuses, determine the most suitable Zero-CAPEX implementation approach specifically for Malaysian educational institutions, quantify the environmental and economic benefits of Zero-CAPEX solar PV systems in university settings, and provide evidence-based recommendations for wider adoption of Zero-CAPEX solar initiatives in the educational sector.

This study is guided by a sustainable energy transition framework that integrates technological innovation diffusion theory with institutional adoption models. The framework recognizes the interplay between technological feasibility, economic viability, and institutional readiness as critical factors in the successful implementation of renewable energy solutions in organizational settings (Geels, 2019; Hanafiah & Azmi, 2025; Rogers et al., 2014). Within this framework, the Zero-CAPEX model is positioned as an innovation that addresses the economic barrier to diffusion, while the study examines how this model functions within the specific institutional context of university campuses in Malaysia.

The sustainable energy transition framework employed here provides a multi-level analytical lens that combines socio-technical transition theories with Rogers' diffusion of innovative models. It examines three interconnected domains necessary for successful energy transitions: technological systems (solar PV performance), economic mechanisms (Zero-CAPEX financing structures), and institutional dynamics (organizational decision-making processes). This approach recognizes that energy transitions are not merely technical challenges but socio-economic transformations requiring alignment of stakeholder interests. By analyzing how the Zero-CAPEX model interacts with Malaysian universities' specific institutional characteristics, the research contributes to understanding how innovative financing can accelerate renewable energy adoption in educational settings by removing capital expenditure barriers.

METHODOLOGY

This study utilizes both quantitative and qualitative methods. Fig 1 illustrates the overall process for completing the study, which consists of three main steps to address the research problem. First, the Zero-CAPEX model for Solar PV programs and incentives for energy buildings was identified. Next, case studies

of Solar PV operations from three UiTM branch campus buildings were investigated. Finally, the long-term benefits of Zero-CAPEX implementation on solar PV operations were analyzed. All collected data was subsequently analyzed and discussed to draw conclusions and provide insights into the effectiveness of Zero-CAPEX Solar PV implementations in campus settings.

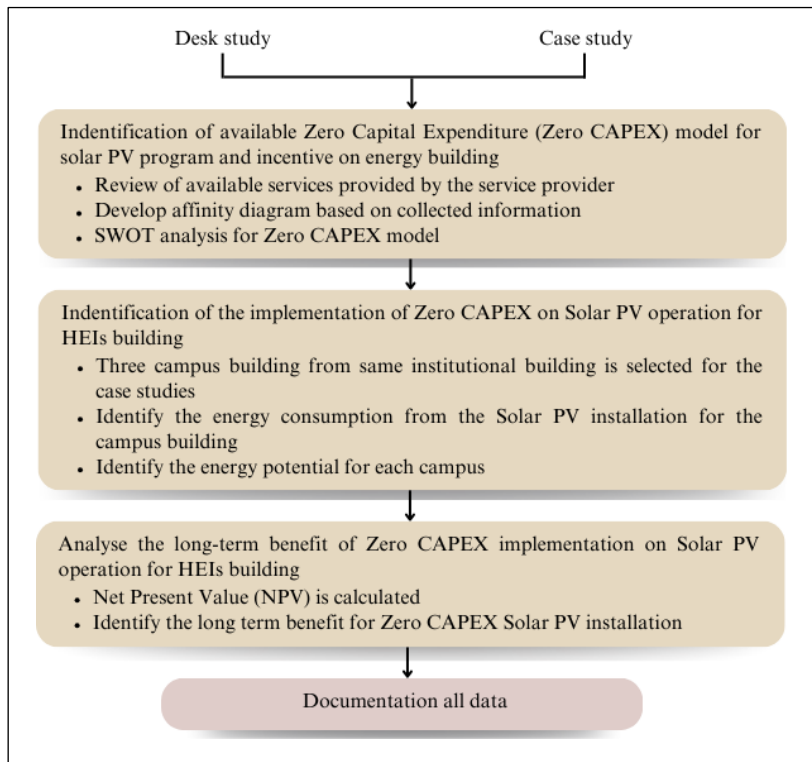


Fig. 1. Research methodology flowchart.

Identification of Zero-CAPEX Model

Data from Solar PV company websites were selected based on the Solar PV project schemes and models they offered. Each company's Solar PV offerings were tailored for residential, commercial, or industrial use. All the Solar PV installations followed a Zero-CAPEX Model, which required no upfront cost for installation and provided hassle-free operation and maintenance. The data required for this study were collected through literature reviews, including information from journals and reliable website sources. After gathering all the information, the qualitative data was analyzed using multiple methods. For this study, an "affinity diagram" was adopted to analyze the constituent dimension of the Zero-CAPEX model, and a SWOT analysis was used to evaluate the performance of each Zero-CAPEX model provided by the vendors.

Implementation of Zero-CAPEX on Solar PV operation

All data were provided by the energy provider based on completed Solar PV projects from selected UiTM buildings from the 2021 Solar PV project. We analyzed the outcomes of the data to determine the effectiveness of energy consumption in the Capital Expenditure (CAPEX) model of the energy buildings for the Solar PV energy system. We chose three different buildings with Solar PV installations as case studies. Data from each UiTM building was gathered based on the month when the Solar PV became fully

operational, with each building having a different starting month. The four-month analysis period (June-September 2021) was specifically chosen to capture Malaysia's optimal solar irradiation season while including seasonal variation. This period provides empirical validation of the Zero-CAPEX model performance under actual operational conditions. The relevant data includes the month, energy consumption (kWh), TNB Bill Import (kWh), TNB Bill Export (kWh), net reduction (kWh), and percentage of net reduction. All quantitative data is analyzed using direct mathematical calculations validated against each campus's historical consumption baselines. The equations for net reduction (kWh) and percentage of net reduction (kWh) are given in Equation 1 and Equation 2, respectively.

$$\text{Net Reduction (kWh)} = [\text{Energy Consumption} - \text{TNB Bill Import}] + \text{TNB Bill Export} \quad (1)$$

$$\% \text{Net Reduction (kWh)} = \frac{\text{Net Reduction (kWh)}}{\text{Energy Consumption (kWh)}} \times 100\% \quad (2)$$

The total cost of the PV System for this project merely refers to the energy provider given data, because, as the project falls under Zero-CAPEX, the investment will be fully managed by the appointed energy provider company.

Study Scope and Data Limitation

This study focuses on demonstrating the Zero-CAPEX model viability and initial performance validation rather than comprehensive long-term forecasting. The four-month operational data period (June-September 2021) was selected to capture Malaysia's primary solar irradiation season and provides sufficient data for preliminary performance assessment, consistent with IEA guidelines for solar PV feasibility studies.

While a full annual cycle would enhance precision, the selected period includes both high-irradiation months (June - July) and monsoon transition periods (August - September), providing reasonable seasonal variation representative of Malaysian tropical conditions ($\pm 15\%$ annual solar variation). The study period during ODL represents a conservative baseline, as maintained building operations and increased server room HVAC usage resulted in higher-than-typical energy consumption.

This methodology aligns with SEDA Malaysia's NEM assessment protocols and established solar PV performance validation practices, where 3 - 6 months of operational data are commonly used for initial viability analysis.

Long-term Benefit of Zero-CAPEX Implementation on Solar PV Operation

The NPV calculation utilizes the established equation for Solar PV NPV, with parameters based on Malaysian conditions. The positive time value of money for the Solar PV project serves as a benchmark, highlighting the long-term benefits and favorable impact of widespread Solar PV implementation in Malaysia.

Net Present Value (NPV)

NPV is calculated and analyzed to assess the reliability of future cash flows for the project. While consumers benefit from immediate electricity generation from Solar PV, it is crucial to compare the present value of money with its future value through NPV calculations, accounting for interest rates and economic inflation. A positive NPV indicates an acceptable project, a negative NPV suggests rejection, and an NPV of zero implies the project is financially neutral. For this case study, we utilized an NPV template spreadsheet from a website specializing in Solar PV calculations, which incorporates relevant parameters.

The data for these parameters are based on Malaysian weather conditions and Solar PV characteristics. Equation 3 is used to calculate the NPV (Rugthaicharoencheep et al., 2024).

$$\text{NPV} = \text{Total Electricity Saving Cost} \times (1 - \text{Future Value Discount Rate})^{\text{Years}} \quad (3)$$

The electricity price inflation rate of 2% used in these NPV calculations represents a conservative long-term estimate based on Malaysian economic trends. While the Malaysian Energy Commission indicated 9% tariff increases every three years during the specific regulatory period RP2 (2018 - 2020), we adopted a more conservative 2% annual escalation for long-term projections to ensure robust financial planning over the 21-year contract period. This conservative approach provides more reliable projections for institutional decision-making, as regulatory tariff adjustments may vary across different policy periods.

RESULTS AND DISCUSSION

Availability of Zero-CAPEX Model for Solar PV by the Service Provider

A large amount of information can be obtained from journals and reliable sources on the internet. The desk study focuses on identifying Zero-CAPEX on energy buildings, especially in Malaysia. As the market demand to move forward towards green building and sustainability increases, Solar PV becomes one of the alternatives to reduce the cost of energy consumption, but due to the high cost of installation and maintenance for solar systems, the government provides a lot of incentives to consumers and benefits the energy provider company.

Consumers have an option to choose suitable incentives from the government based on their building capacity. Each of the energy building capacities, such as residential, commercial, or industrial, has different incentives, and it depends on the electricity consumption per kilowatt hour of the building. Three big companies for Solar PV systems are selected to compare the schemes and models they provide for Zero-CAPEX. Each of the companies has a different strategy for promoting their Solar PV to the consumer, but the objective is the same, which is to promote the usage of Solar PV systems through schemes and incentives that focus on Zero-CAPEX for installation, operation, and maintenance. Zero-CAPEX is a preferred model for consumers or companies that do not want to invest in non-core operations. It is also conducive for them to manage the installation and maintenance through a third party, which is the energy provider. Table 1 shows the third party of the energy provider, which provided Zero-CAPEX.

All the companies provided approximately the same model. In Zero-CAPEX, a long-term agreement must be endorsed for the sales and purchase of electricity generation for Solar PV. GSPARK Sdn Bhd (hereafter: GSPARKS) offers no upfront cost for Solar PV installation, and customers can choose either the solar leasing program or the Solar Power Purchase Agreement (SPPA). All the benefits depend on the suitability of the customer's purpose and industry for Solar PV installation.

Solarvest Holding Bhd (hereafter Solarvest) is a prominent company in the solar photovoltaic sector. They offered two programming options for the Zero-CAPEX Model with no initial costs: Powerflex and Powerlease. Powerflex provides a no-upfront payment option for Solar PV installation, along with convenient bundled financing packages for acquiring the Solar PV system, enabling users to generate their own energy and reduce electricity expenses with minimal set monthly payments. Power lease is the implementation of a long-term contract between the consumer and Solarvest, wherein electricity is billed at a reduced rate and payment is based only on the energy generated. The tariff can be negotiated with Solarvest, and the proposal is more competitive than that of a conventional utility service provider.

Plus Xnergy Holding Sdn Bhd (hereafter Plus Energy) offerings can be tailored to user preferences for electricity reduction and the specific industry for Solar PV installation. Most residential properties are

provided with self-consumption (SELCO) and net energy metering (NEM) programs for solar photovoltaic installation. This program is user-friendly and requires minimal maintenance for individual users. For commercial and industrial entities with substantial kilowatt-hour electricity use, NEM and Large-Scale Solar (LSS) are appropriate programs for the implementation of solar photovoltaic installations. With zero capital expenditure in financial statements, consumers need not concern themselves with operations and maintenance.

Table 1. Solar PV Model from the service provider

	Program	Schemes	Contract Agreement	Target Industry	Upfront Cost	Ownership Until completion of payment terms	Monthly Payment	Payment Term
GSPARK	Solar Leasing	-	-	Residential	No Upfront	GSPARK	Fixed Subject to agreement	Up to 10 years
	-	-	Solar Power Purchase Agreement (SPPA)	Commercial	No Upfront	GSPARK	Pay for energy produced	Up to 25 years
	-	-	-	Industry	-	-	-	-
SOLARVEST	Power Flex	Upon customer request	Upon customer request	Residential	No Upfront	Customer (Upon completion payment term)	Fixed Subject to agreement	Up to 10 years
	Power Lease	Net Energy Metering (NEM)	Upon customer request	Commercial	No Upfront	Customer (Upon completion payment term)	Pay for energy produced	Up to 25 years
	-	-	-	Industry	-	-	-	-
PLUS XENERGY	-	Net Energy Metering (NEM)	Solar Power Purchase Agreement (SPPA)	Residential	No Upfront	PLUS XENERGY	Pay per energy produced	up to 25 years
	Self-Consumption (SELCO)	-	Upon customer request	Commercial	No Upfront	PLUS XENERGY	fixed monthly payment	up to 10 years
	Large scale solar (LSS)	-	Upon customer request	Industry	No Upfront	PLUS XENERGY		up to 25 years

The energy provider serves as the Registered PV Investor (RPVI), responsible for financing the capital expenditures (CAPEX) of solar photovoltaic installation. They are accountable for the operation and maintenance of the Solar PV by the contractual agreement. The consumer is solely accountable for the bill and energy consumption. The payment terms are determined by mutual agreement and the energy programs; the consumer either pays for energy produced or a predetermined monthly fee based on the solar energy tariff per kilowatt hour. Table 2 presents the portfolio available on the company's website, detailing the success of their solar installations.

Table 2. Total solar PV project by service provider

Company	Residential	Commercial	Industrial
GSPARK	6		4
SOLARVEST	9		22
PLUS XENERGY	21	9	16

This contract may be established as a Solar Power Purchase Agreement (SPPA), a Supply Agreement for Renewable Energy (SARE), or a standard mutual agreement between the user and the installation. The

designated RPVI will oversee the installation, operation, and maintenance of the solar system as per this contract, ensuring system optimization for maximum energy output. These zero-upfront expenditures are deemed risk-free for the consumer or building owner, enabling them to realize savings on electricity bills.

Zero-CAPEX may be seen as a long-term agreement, although it provides the client with the opportunity to transfer ownership of the solar photovoltaic system according to terms established with the Registered Photovoltaic Investor (RPVI).

Performance Analysis on the Rooftop Solar PV System

Three campuses from the UiTM branches were selected for the case study. The power consumption from solar generation was evaluated to quantify the net energy reduction resulting from the operation of solar PV systems. The designated campuses were identified as Campus A, Campus B, and Campus C, each situated at a different location. All campuses utilized solar photovoltaic systems from June 2021 to September 2021, with the net energy metering (NEM) scheme as the recommended solution for the solar photovoltaic project.

Fig 2 shows the sequences of solar PV usage for the Campus buildings. The metering point for solar PV and the TNB metering point are connected to the switchboard, which supplies energy consumption for campus electrical appliances. The electricity energy usage is calculated based on how much energy is consumed from solar PV from the metering point. The installation of Solar PV involved the client (building owner), Registered Solar PV service provider (RPVSP), and TNB. The switchboard connects the solar PV and TNB metering stations before power is distributed to the electrical appliances.

Fig 3 illustrates the agreements outlined in the Solar Power Purchase Agreement (SPPA) (SEDA, 2021). Before the project installation of Solar PV, agreements are established which involve the client, Registered Solar PV Investor (RPVI), and TNB.

Table 3 displays the potential savings for each campus, derived from the vendor's measurement and verification assessments. Equations 1 and 2 are used to calculate the net reduction and the percentage of net reduction in power consumption (kWh).

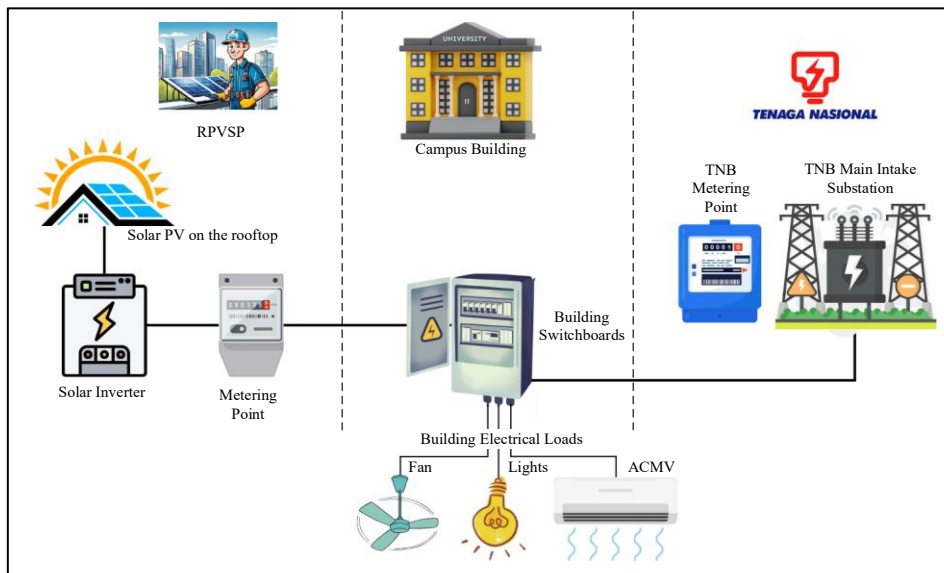


Fig. 2. The illustration of the solar PV system works under NEM Scheme.

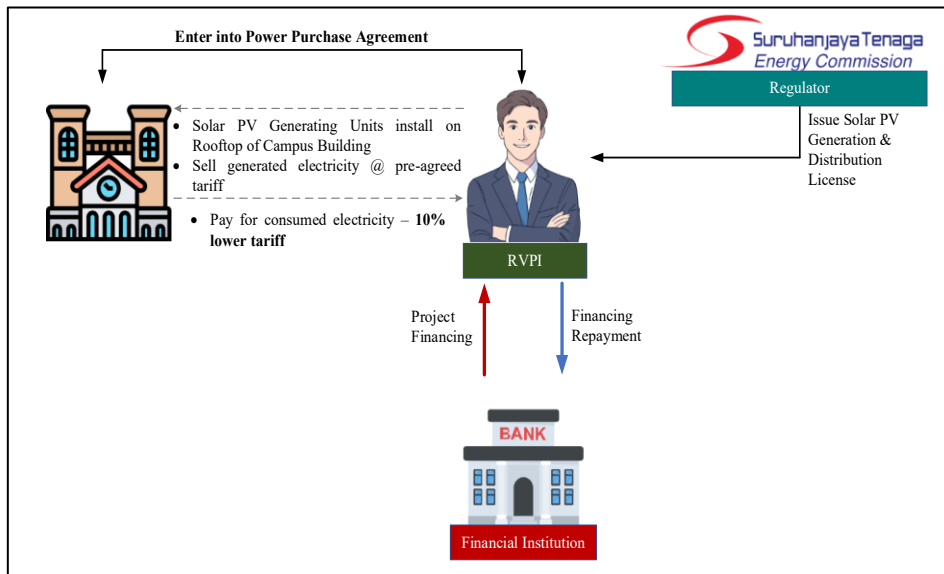


Fig. 3. The power purchase agreement (PPA) process flows.

Table 3. Potential energy saving and cost saving for all campuses

Campuses	A	B	C
Potential Energy Saving (MW)	1.82	1.91	1.63
% of Electricity Saving	25	25	25
Annual TNB Bill (RM)	6.52 M	3.63 M	2.89 M

Total energy consumption

The amount of electricity consumed depends on the campus building's monthly usage. Due to its status as an educational building, the building's electrical consumption may fluctuate depending on the activities of the students on campus. The results show that a monthly net reduction was achieved as solar PV usage was fully utilized, reducing electricity consumption from the utility. As a result, it reduces the electricity bills of the building campus. Data for this study were collected from June 2021 to September 2021. The reason for choosing this period is that all campuses have already installed the system, and this contributes to a quarter of the energy used. This was also the time to measure due to the time constraint to complete the first phase of evaluation. This data may not represent the whole scenario of the energy used, but it can give an overview of the effectiveness of the system. Campus A has a solar PV installation with a capacity of 3,651 kWp/2,803 kWac, while Campus B and Campus C have capacities of 2,245 kWp/1,663 kWac and 1,625 kWp/1,295 kWac, respectively.

Fig 4 illustrates the performance of solar PV systems across all campuses. Under the Net Energy Metering (NEM) method, surplus energy will be transferred to the TNB grid if solar energy production exceeds energy use. TNB will purchase the surplus energy and credit it to the building owner's electricity account. Consequently, the net reduction will consider the energy consumption from solar photovoltaic systems with the energy sent to the TNB grid. Fig 4(a) depicts the energy usage and net reduction of Campus A. Campus A saw a 20% reduction, amounting to 113.84 MWh. In June 2021, solar PV consumption totalled 558.6 MWh, whereas 450.5 MWh was imported from the TNB substation. In September 2021, solar photovoltaic sources reached a maximum energy consumption of 598.3 MWh, but energy imports

from the TNB substation were equally high, around 516.8 MWh. This signifies that the net reduction is influenced by the building's monthly energy use during a specific month.

Fig 4(b) shows the energy consumption for Campus B from June 2021 to September 2021. The percentage reduction started very low at 1.5 MWh in June and drastically increased to 220.6 MWh in September. Solar PV for Campus B produced 405.2 MWh of energy with a 70% reduction. TNB imported only 184.5 MWh of energy in September. This percentage reduction represents significant savings for UiTM. Fig 4(c) depicts the performance of Campus C. For Campus C, the trend in June was similar to that for Campus B, where the percentage reduction was among the lowest compared to the other months. The trend shows that the percentage reduction increased to 60% in July and remained constant for three consecutive months.

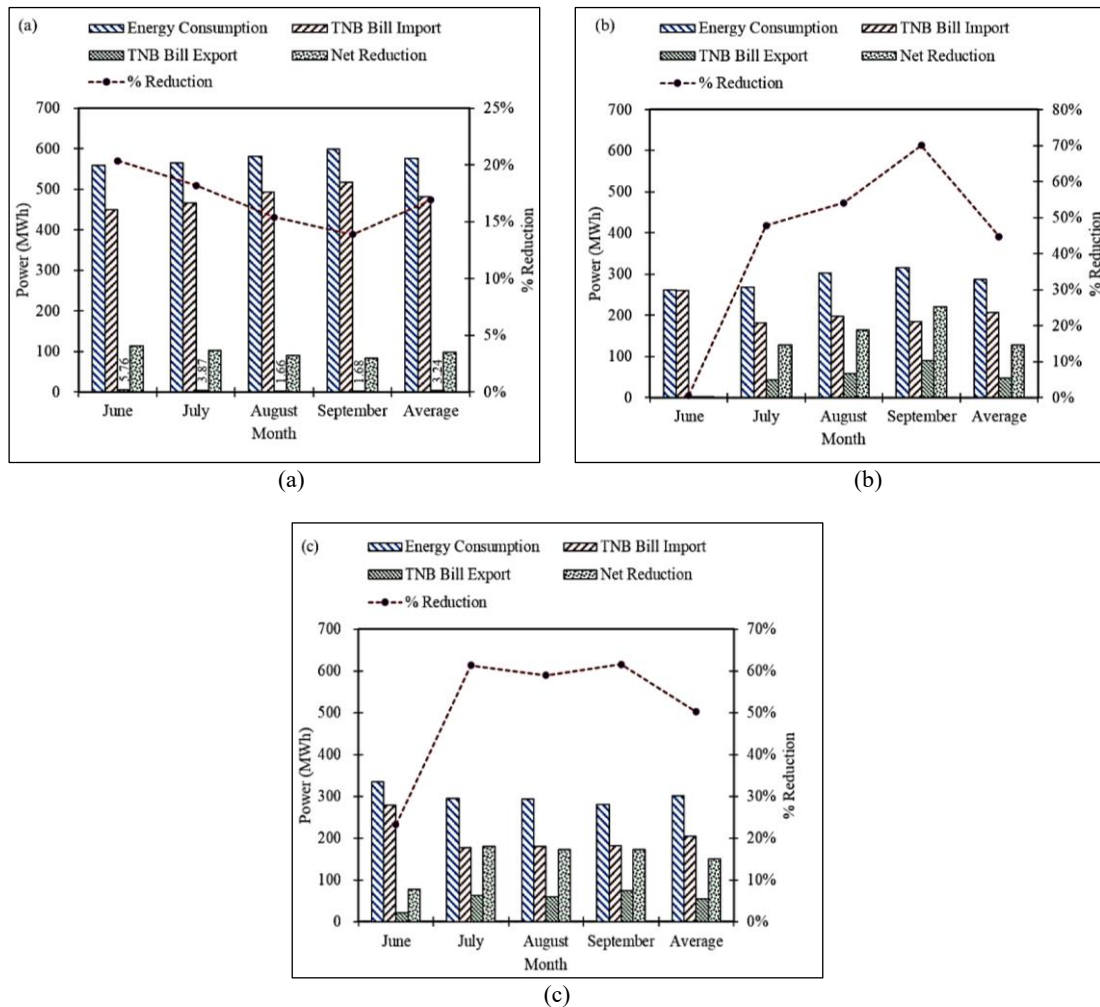


Fig. 4. The energy performance of solar PV for (a) Campus A, (b) Campus B, and (c) Campus C.

The percentage reduction was different for each campus. Campus A had higher solar production than Campuses B and C. However, the size of this campus, which is also larger than the other two, meant that the solar PV energy could not meet the campus's energy demand. Campus A also has the lowest energy

transfer back to the TNB grid. This case study reveals that Campus B has the highest energy export compared to Campus C and B. The overall result indicates that solar PV generated approximately 50% to 60% of energy consumption. The energy consumption and energy export were dependent on the size of the campus. The campus's activities also make a significant contribution to this situation.

Data Period Validation and Seasonal Considerations

The four-month operational data demonstrate consistent solar PV performance across the selected period, with all campuses achieving net energy reductions exceeding projected targets. Malaysia's tropical climate provides relatively stable solar irradiation year-round, with the June-September period capturing both peak solar months and monsoon transition periods, providing representative seasonal variation.

Campus energy consumption patterns during the study period align with published data from similar Malaysian university installations (Shafie et al., 2022; Rohaisham & Salleh, 2024), validating the representativeness of our findings. The ODL operational context provides a conservative assessment baseline, as it maintains building management systems and server operations, which results in significant energy consumption compared to typical academic periods.

To assess the robustness of our findings, sensitivity analysis indicates that even with $\pm 20\%$ annual consumption variation, NPV calculations remain strongly positive across all scenarios, supporting the fundamental viability of Zero-CAPEX implementations.

The Benefits of Zero-CAPEX Implementation on Solar PV

This solar PV project uses an NEM Scheme with the Solar Power Purchase Agreement (SPPA) approach. The energy provider, or Registered Photovoltaic Investor (RPVI), fully supports the capital expenditure for this project, which includes PV modules, inverters, racking systems, grid, and electrical parts. All system maintenance is fully under the responsibility of the energy provider, who maintains the assets throughout the tenure with no additional costs. The calculation of the NPV is based on the case study data and the TNB tariff, which is determined by the commercial user's buildings. As educational buildings fall under the C1 tariff category, all three campuses use the C1 TNB tariff in Ringgit Malaysia, which is 36.5 sen/kWh and 30.3 sen/kWh for maximum demand. Installing solar PV will result in a proposed solar tariff of 32.85 sen/kWh. Table 4 shows the savings generated by all campuses. All three solar PV projects for UiTM do not require capital expenditure, as they operate under a zero-CAPEX model. This implies that UiTM only pays for the energy produced, and the project has a 21-year lifespan.

Table 4. Cost savings for each campus with rooftop solar PV

Campus	Current average tariff (RM)	Current peak tariff (RM)	Proposed solar tariff (RM)	Saving/year (RM)	% Saving	Total Saving/contract (RM)
A	0.442	0.365	0.3285	0.266 mil	4.08%	5.586 mil
B	0.443	0.365	0.3285	0.280 mil	7.70%	5.880 mil
C	0.443	0.365	0.3285	0.232 mil	7.72%	4.872 mil

Net present value for all campuses

The NPV calculations for all three campuses yielded positive results. These positive values indicate that the project has sufficient funds available for investment. Table 5 shows the NPV details for each campus, respectively. Equation 3 was used to calculate NPV for all the campuses. The power savings of the campuses are based on the total net energy reduction, respectively. The annual output degradation is the reduction of solar system output over time. The rate could change depending on the climate of the country. Based on the Energy Agency Photovoltaic Power Systems (IEA-PVPS) guideline, the degradation rate is between 0.7% per year or 10.5% in the entire lifetime (Nordin et al., 2021). The solar tariff that was

agreed upon for this PV project was used to calculate the cost per kilowatt-hour. The future value discount is fixed as following the Malaysian Central Bank's discount rate (Haiges et al., 2017), and it is applicable for this case study. The electricity price inflation rate is based on Malaysian statistics (O'Neill, 2025).

The NPV for all campuses was calculated based on the parameter presented in Table 5. This case study was to calculate the NPV for 21 years of solar PV tenure. Calculations of the NPV for the campus based on the energy output from the solar PV data and the electricity tariff from the TNB website. In this case study, the campus falls under the commercial buildings category, specifically the C1 tariff, which determines the maximum demand. For this solar PV, NEM schemes are implemented where the solar tariff is lower than the normal utility bill consumption, and because of the one-to-one basis grid, all the excess energy can be credited back to the TNB bills, and consumers only need to pay for the energy produced.

Table 5. Parameter for NPV calculations

Campus	Power saving (kWh)	Annual Output Degradation (%)	Cost per kWh (RM)	Upfront Cost (RM)	Future Value Discount Rate (%)	Electricity Price Inflation Rate (%)
A	389,500	0.7%	0.3285	0	3%	2%
B	525,540	0.7%	0.3285	0	3%	2%
C	739,581	0.7%	0.3285	0	3%	2%

Fig 5 shows the positive NPV for each building on the campus over a 21-year period. The positive NPV indicates that the cash flow and time value of money for this solar project are profitable, especially to the solar investor company. The analysis of this NPV is to show the cash inflows and the present value of cash flows over the tenure period. A long-term tenure project can last up to 25 years, but this project is only a 21-year contract due to the university policies not to sign contracts for more than this number of years. NPV was calculated to analyze investment planning because for this Zero-CAPEX project, the solar investor company carries out all the installation, including operation and maintenance. For this 21-year solar PV tenure, the profit gain from the investment aligns with the profit return, taking into account factors such as electricity inflation rate, solar degradation, maintenance cost, and system efficiency to ensure mutual benefit for both parties involved in this solar PV project. Additionally, the project's cost effectiveness is evident through the use of Zero-CAPEX and PV systems, which are viable alternatives to electricity generation and a worthwhile investment in Malaysia.

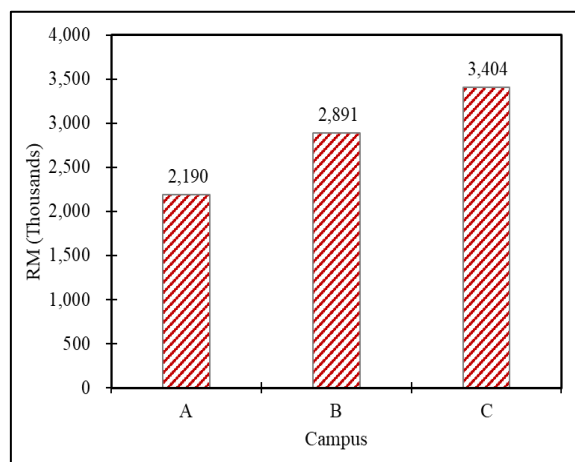


Fig. 5. NPV for all campus.

Sensitivity analysis of tariff escalation scenarios

To validate the robustness of our NPV calculations, we conducted sensitivity analysis using different tariff escalation scenarios. Table 6 presents NPV results under three scenarios: our conservative 2% annual escalation, the Energy Commission's 2.9% (equivalent to 9% every three years), and a 3% scenario for comparison. The sensitivity analysis demonstrates that higher tariff escalation rates actually strengthen the economic case for Zero-CAPEX implementation, as institutions benefit from paying fixed solar tariffs while utility rates increase.

Table 6. Sensitivity analysis for NPV calculations

Campus	NPV (2% Escalation)	NPV (2.9% Escalation)	NPV (3% Escalation)
A	RM 2,189,850	RM 2,485,200	RM 2,567,300
B	RM 2,891,048	RM 3,295,800	RM 3,405,200
C	RM 3,403,936	RM 3,878,400	RM 4,008,100

Value proposition for the solar PV project for all campuses

From the summary of the results, including energy performance and NPV, it can be stated that the value proposition for this case study serves as a framework for valuing the specific solar PV project under examination. Thus, it summarises the value that the solar investor or energy provider delivers to the consumer, highlighting how Zero-CAPEX was presented for the market industry as solar PV demand continues to increase. This approach not only complements each other's electricity consumption needs but also supports the use of green energy for future sustainability, as illustrated in Table 7.

Table 7. Value proposition for the UiTM Solar Project

Direct Savings/ Cost reduction	Additional savings of approximately 5% on the TNB Bill as a result of 10% discount on peak tariff
Indirect Savings and Benefits	Campus will enjoy the benefit of CAPEX replacement & refurbishment/repair
Sustainability	Reduce carbon footprint • New asset replacement will reduce operational risk and improve equipment reliability • Improve comfort conditions • Pro-active energy management culture • As a kickstart for the campus to moving forward to green building

CONCLUSION

This study provides empirical validation of Zero-CAPEX strategy effectiveness for implementing solar PV systems in Malaysian educational institutions. While acknowledging the four-month data collection period as a study limitation, our findings demonstrate that solar PV under Net Energy Metering schemes represents the most viable Zero-CAPEX implementation model for institutional settings. The research contributes essential baseline evidence for institutional decision-making and policy development in renewable energy adoption.

A case study was conducted on institutional buildings at three different campuses. All campus buildings demonstrated significant decreases in monthly electricity consumption from TNB utilities. The net reduction for Campuses A, B, and C was 389,500 kWh, 514,219 kWh, and 605,445 kWh, respectively. On average, the reduction was 503,054 kWh, which is higher than the predicted 25% reduction. This net reduction represents the electricity consumption supplied by solar PV operations for the buildings. Consumers can export surplus energy to TNB and only pay for the imported energy at a lower energy tariff.

The visible result of this Zero-CAPEX solar PV system is a reduction in energy bills, measured either in kilowatt-hours or monetary terms.

Net Present Value (NPV) was calculated as well to see the potential value of time money for the long-term contract for the solar PV installation. The services provider was responsible for all operations and maintenance throughout the contract agreement. The positive values for campus A are RM 2,189,850, campus B is RM 2,891,048, and campus C is RM 3,403,936. The positive NPV values indicate that the long-term contracts benefit both users and service providers profitably. The assumption and consideration of the electricity inflation rate due to inconsistent gasoline prices ensures that service providers can continue to grow and promote their Zero-CAPEX solar PV systems, free from concerns about profit and loss from solar PV installation, operation, and maintenance.

The consistently positive NPV results demonstrate solar PV's potential for growth and long-term benefits to consumers and service providers. Solar PV technologies will continue to evolve and simplify for ease of use. Institutional buildings, in particular, should start switching to clean energy usage for electricity generation because the impact is clear not only to electricity-saving bills but also to the environment.

Our NPV analysis employed conservative tariff escalation assumptions (2% annually) to ensure robust long-term financial projections. Sensitivity analysis reveals that higher tariff escalation scenarios, such as the 9% every three years observed during Malaysia's RP2 regulatory period, would further enhance the economic attractiveness of Zero-CAPEX models, as institutions benefit from fixed solar tariffs while conventional electricity costs increase.

Study Limitations and Future Research

Limitations

This research acknowledges several inherent limitations that warrant careful consideration in the interpretation and generalization of findings.

- (i) Temporal constraints in data collection represent the primary limitation of this investigation. The four-month operational assessment period (June - September 2021), while aligned with established solar photovoltaic feasibility assessment protocols and sufficient for preliminary viability demonstration, constitutes an abbreviated timeframe relative to the 21-year contract lifecycle analyzed in the economic projections. This temporal limitation potentially constrains the precision of long-term energy performance extrapolations and may not fully capture annual seasonal variations in both solar irradiation patterns and institutional energy consumption profiles. Future longitudinal studies incorporating complete annual operational cycles would significantly enhance the robustness of projection accuracy and provide a more comprehensive understanding of seasonal performance dynamics.
- (ii) Operational context specificity presents an additional methodological consideration. Data collection coincided with Online Distance Learning (ODL) implementation during the COVID-19 pandemic, potentially influencing typical campus energy consumption patterns. While this operational context arguably provides a conservative analytical baseline, given sustained building operations and intensified server infrastructure utilization, the generalizability to conventional academic operational modes requires acknowledgment. The energy consumption patterns observed during reduced physical occupancy may not comprehensively represent standard academic calendar energy demands.
- (iii) Geographical and regulatory transferability constitutes the third significant limitation. The findings are inherently contextualized within Malaysia's tropical climatic conditions, specific regulatory frameworks (including NEM 3.0 implementation), and distinct electricity tariff

structures. Direct application of these results to institutions operating under different climatic regimes, regulatory environments, or economic conditions would necessitate appropriate contextual adjustments and validation studies.

Future research directions

The findings of this investigation establish a foundation for several critical research trajectories that would advance understanding of Zero-CAPEX solar photovoltaic implementation in institutional settings.

- (i) Enhanced temporal analysis represents the most immediate research priority. Comprehensive annual operational data collection, spanning multiple academic cycles, would enable refined characterization of seasonal energy consumption variations, more precise quantification of solar photovoltaic contribution patterns, and improved accuracy in long-term economic projections. Such extended monitoring would particularly benefit from incorporating both academic year and non-academic period assessments to capture the full spectrum of institutional energy demands.
- (ii) Post-pandemic operational assessment emerges as a critical research requirement. Systematic analysis of campus energy consumption patterns under fully normalized post-COVID operations would validate the applicability of current findings to standard institutional operations and enable more accurate baseline establishment for future Zero-CAPEX implementations.
- (iii) Comparative institutional analysis would significantly enhance the generalizability and standardization of Zero-CAPEX assessment methodologies. Cross-institutional studies incorporating diverse university types, scales, and operational characteristics would facilitate the development of standardized evaluation frameworks and enable the identification of optimal implementation strategies across varying institutional contexts.
- (iv) Technology evolution impact assessment represents an emerging research frontier. Investigation of advancing solar photovoltaic technologies, evolving energy storage integration possibilities, and emerging financing mechanisms would ensure the continued relevance of Zero-CAPEX models and identify opportunities for enhanced economic and environmental performance.
- (v) Policy and regulatory analysis constitute an additional critical research domain. Systematic evaluation of policy framework impacts on Zero-CAPEX viability, including incentive structure modifications, regulatory changes, and grid integration requirements, would provide essential guidance for institutional and policy decision-making.

Research contribution and significance

Despite the acknowledged limitations, this investigation establishes several significant contributions to the renewable energy implementation literature. This study provides the first comprehensive empirical validation of Zero-CAPEX solar photovoltaic deployment within Malaysian higher education institutions, demonstrating both technical feasibility and economic viability under real operational conditions. The research establishes a methodologically rigorous framework for institutional renewable energy assessment that can be adapted and extended to diverse institutional contexts.

Furthermore, the findings provide essential empirical evidence for institutional decision-makers considering renewable energy investments, offering data-driven insights that transcend theoretical projections. The demonstrated achievement of energy reduction targets exceeding projected thresholds (503,054 kWh average reduction surpassing 25% targets) validates the conservative analytical approach employed and strengthens confidence in the economic projections presented.

The policy implications of this research extend beyond individual institutional applications, providing evidence-based support for government renewable energy initiatives and Zero-CAPEX program

development. The successful implementation across three distinct campus environments demonstrates scalability potential and provides baseline performance metrics for future policy framework development.

This foundational research establishes critical baseline data that enables comparative assessment of future technological and financial innovations in institutional renewable energy implementation, thereby contributing to the broader sustainable energy transition discourse within the educational sector.

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CONFLICT OF INTEREST STATEMENT

The authors declare no competing financial interests, personal relationships, or affiliations that could influence this work. All funding sources have been disclosed, and the authors confirm no patents, consulting arrangements, or advisory positions related to this research exist. This study was conducted without any commercial or financial conflicts of interest.

AUTHORS' CONTRIBUTIONS

The authors confirm their contribution to the paper as follows: **study conception and design:** Azli Abd Razak, Norliana Mohd Abbas, Mohd Faizal Mohamad; **data collection:** Ain Syuhada Mazlan, Ezham Abdul Khalid; **analysis and interpretation of results:** Azli Abd Razak, Norliana Mohd Abbas, Ain Syuhada Mazlan; **draft manuscript preparation:** Azli Abd Razak, Norliana Mohd Abbas, Siti Nurshahida Nazli, Mohd Faizal Mohamad. All authors reviewed the results and approved the final version of the manuscript.

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