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A Rational Plan of Energy Performance Contracting in an Educational Building: A Case Study

Zulhazmi Hatta Mohamad Munir, Norasikin Ahmad Ludin *, Mirratul Mukminah Junedi, Nurfarhana Alyssa Ahmad Affandi, Mohd Adib Ibrahim and Mohd Asri Mat Teridi

Solar Energy Research Institute (SERI), Universiti Kebangsaan Malaysia, Bangi 43600, Malaysia
* Correspondence: sheekeen@ukm.edu.my

Abstract: Energy performance contracting (EPC) is the best solution for an educational building to implement energy conservation measures (ECMs) because of its high capital expenditure and operational expenditure needed for retrofit and maintenance. It is also considered a win–win mechanism for organising building energy efficiency retrofit projects. It aims to assist educational buildings in acquiring new high-efficiency equipment and maximising energy use reduction, as guaranteed by energy service company (ESCO). This study developed an EPC model using regression analysis, in which the inputs are based on the data collected during the preliminary energy audit in University A. As a result, with a quantum sharing ratio of 0.95/0.5 for ESCO/University A, the forecasted energy savings from the proposed ECMs, chiller optimisation and replacement, lighting retrofit, and energy management system are estimated to save 25.6% energy use, which reduces 5,672,057 kilowatt-hour (kWh) in electricity consumption; saves RM 2,762,291.76/year; carbon dioxide (CO_2) mitigation equal to 3,771,061.22 kgCO_2/year; return of investment of 4.2 years with a 5% interest rate; and building energy intensity of 93.55 kWh/m^2/year. A sensitivity analysis of various quantum sharing ratios found that the saving value of ESCO is inversely proportional to that of University A as the client when the quantum sharing ratio for the former is increasing.

Keywords: building energy index; commercial building; energy audit; energy conservation measures; energy performance contract

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1. Introduction

Globally, the building sector consumed a significant amount of energy, accounting for 30% of the final energy usage and 28% of carbon dioxide (CO_2) emissions worldwide [1]. Commercial buildings are the major contributors to these figures because of variables such as rising energy demand for space cooling and heating as the population grows and due to the effect of the building materials, features, and functions. Various strategies, such as the establishment of energy efficiency policies, the introduction of green building tools for certification, and incentive schemes to boost motivation in achieving sustainability, have been implemented around the world to address the issue of reducing the energy consumed by the building sector. The energy efficiency aspect should be considered in the development of a building because it affects the energy demand, which influences the environmental and economic aspects. An energy efficient building with low energy consumption leads to a low environmental impact (i.e., greenhouse gas (GHG) emission). Moreover, lower cost for electricity usage can be paid considering that energy waste may be prevented. Energy efficiency can be implemented in either an existing or a new building. Thus, the benefits can be reaped at any stages of the building's use.

Energy performance contracting (EPC) has been utilised worldwide [2]. It is the concept of a profit-sharing agreement between the building owner and the energy service company (ESCO) who bears the initial cost for the energy efficiency improvement project [3], which is significantly beneficial in optimising energy use and emphasising social and economic benefits effectively [4]. In the EPC project, the profit is shared through the division of the energy-saving quantum ratio between the ESCO and the client (building owner) which is competitive and can impact the amount of energy saved in the building. Thus, both the ESCO and the client benefit from the energy savings. ESCO provides energy-saving retrofitting for customers, thereby acquiring a return on investment (ROI), and rolling development by delivering energy saving guarantees with a minimum fair share of financing and risks from energy efficiency projects [5]. Moreover, various EPC models with two dominant models, namely the share savings model (SSM) and the guaranteed saving model (GSM), are adopted to ensure that the building owner and ESCO can reap the benefits from national and tax incentives [3].

Based on the published literature searches of keywords "energy audit", and/or "energy conservation measures", "university", "campus", "energy performance contracting" from 2017 to 2022, most of the studies assessing the energy performance use of tertiary educational settings, including Malaysia, were heavily focused on the energy conservation measures (ECMs) without developing an EPC model between the building owner and ESCO in the implementation of the proposed precise ECMs [6–28]. Therefore, this study evaluates the best recommended EPC model for the commercial building of the educational institute, University A, which has been operating for more than 15 years under climatic conditions and has exceeded more that 3 million kWh/month of electricity consumption for 6 consecutive months. Regression analysis is employed in developing the EPC model based on the appropriate and ECMs proposed from the preliminary energy audit. This study presents a novel EPC model specifically developed for educational buildings in Malaysia. To the best of our knowledge, this is the first published article on this topic.

2. Context and Motivation

Malaysia, which is located near the equator and receives approximately 157 kilowatt-hour per metre square (kWh/m^2) [29] of solar irradiation annually, necessitates more energy for space cooling in buildings [30]. The total electricity consumption in Malaysia has climbed steadily over the last several years, rising from 104,523 gigawatt-hour (GWh) (2010) to 152,865 GWh (2018) [31], with the commercial sector's overall energy usage of roughly 29.0% out of the total energy consumption in 2018 [32]. Recently, Malaysia vowed to reduce the intensity of GHG emissions across its economy by 45% based on gross domestic product (GDP) in the United Nations Framework Convention on climate change conference COP26 [33]. Hence, the implementation of the energy efficiency aspect in building sectors, especially in commercial buildings, shall be reinforced to support the country's target. Malaysia has been supporting the target of reducing carbon emission through energy efficiency measures using green building tools [34,35] such as the green building index, leadership in energy and environmental design, Green Star Building Research Establishment's Environmental Assessment method, energy use intensity indicator, building energy intensity (BEI) indicator, ASEAN Energy Management Scheme-Energy Management Gold Standard, and the Malaysian Carbon Reduction and Environmental Sustainability Tool. These tools inspected elements such as the use of environmentally friendly transportation and the auxiliary, sustainable site management, water and energy efficiency elements, environmentally friendly materials and resources, good indoor environmental quality, and any innovation towards the energy-efficient building status. In promoting the efforts, the Malaysian government launched the energy performance contracting (EPC) model in 2013 by employing market-based financing and technology to improve the energy efficiency of buildings [3].

Previous studies on EPC projects in various sectors have been predominantly concentrated on its implementation, the mechanism for effective EPC projects, the behaviour and decisions made by stakeholders, the role of the energy service company (ESCO) and the risk management in EPC projects [2]. Moreover, the published studies implemented four main methodologies, namely, modelling and simulation, cost–benefit analysis, descriptive analysis, and statistical analysis, for the data analysis of EPC projects. Generally, the EPC project consists of six crucial steps that are presented in Figure 1 below.

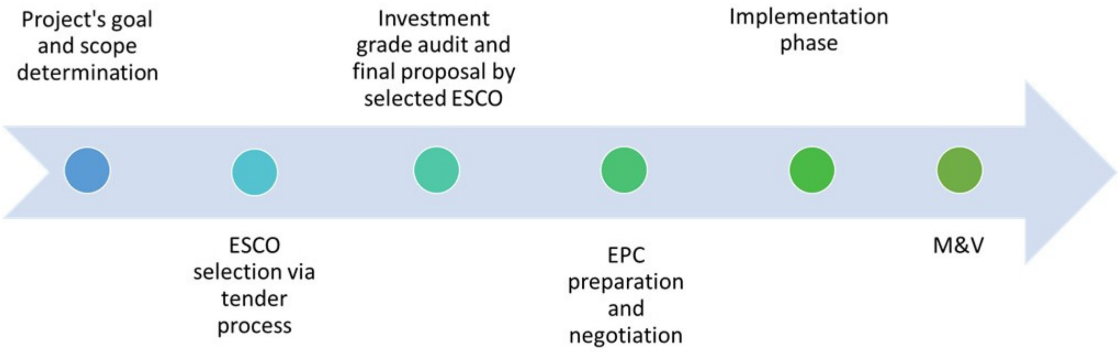

Figure 1. EPC Process.

To begin an EPC programme, an energy audit is required to determine the current load, energy usage and energy conservation measures (ECMs). Energy audit refers to a surveying technique that consists of an analysis of the energy usage of an organisation [36]. The energy audit is used to 'diagnose' the weak points in the building's energy usage system, harness the latent potential, and instil energy saving responsibilities [37]. Furthermore, reducing areas of energy waste with well-defined economic implications is the most important part of an energy management programme, which indicates the current status of an industrial facility/system in terms of energy utilisation efficiencies of different activities and the efficiency of various equipment and processes and suggests corrective measures [38]. One of the most well-known tools for developing the EPC model is by employing statistical analysis [2]; for example, employing regression analysis as a baseline for developing the EPC model. A key advantage of using regression analysis is that it can serve deeper data analysis than descriptive analysis. Based on the baseline study, then, appropriate ECMs for the EPC will be proposed such as chiller optimisation and replacement, lighting retrofitting, and energy management system.

Various chiller optimisation methods are used worldwide. The chiller plant control (CPC) system ensures that the chiller could function optimally and efficiently. The chiller optimisation in a building can be categorised into three approaches, namely chiller modelling, chiller scheduling and learning-based approaches [39]. Data-driven approaches such as multi-task learning [40], clustered [41], regression-based [42], and neural network-based online algorithm [43,44] have been applied in developing the model for chiller optimisation. The developed chiller modelling based on these approaches were aiming to improve chiller performance by utilising a separated model for each chiller, coefficient of performance (COP) prediction model, or chiller power prediction [40–43]. Meanwhile, the cooling load profile prediction is applied for chiller scheduling [39]. The approaches utilised to optimise chillers by scheduling include deep-learning techniques [43], model-based predictive control (MPC) method [45], an optimum load sharing strategy [46], time-constrained chiller sequencing method [41], robust chiller loading strategy [41], stochastic chiller sequencing [47], and rule-based scheduling [48]. The last category includes learning-based approaches, such as a machine learning-based approach [49], model the thermal properties of the building. Moreover, model-free and model-based deep reinforcement learning (DRL) are used to optimise the chillers' control [50,51]. These approaches are applied by assessing the problems within the building firstly.

For lighting retrofitting, light-emitting diode (LED) technology can reduce equipment energy losses with improved lifespan and lighting quality [52]. The advantages of LED lighting is its small size, high reliability, high colour-rendering index, long life, energy-saving, and environmental protection [53]. This leads to a drop in power consumption anywhere near 15–70% [54]. ASHRAE 90.1 2013 shows that the recommended lighting power density is below 8.82 W/m^2 [55]. Moreover, a redesign of the workplace layout to optimise luminescence inside the workstation would be advantageous [10].

In a tropical climate location, such as Malaysia, published work on the energy management system (EnMS) ECM, such as the EPCert scheme, has been introduced to address the importance of the energy efficient rating and labelling in building and concern about the occupant's satisfaction and building's functionality [56]. The scheme assesses the building's BEI and characteristics and the commitment from the building's organisation towards energy efficiency. These assessments provide building owners, prospective buyers, and occupants with information on the energy performance of a building. The commitment from the top- to low-level management of the building is the main success factor in energy saving. For a building organisation that consists of more than 10 staff and a gross building area of 500 m^2, EPCert outlines the best criteria for the building's organisation to ensure the success of the EnMS strategies. These criteria include:

- The committee responsible for the energy efficiency aspects of the building;
- Energy performance certificates awarding internal meeting;
- Internal energy audit;
- Energy efficiency-related activities;
- Energy efficiency-related goals and policies.

Malaysia is still new in terms of the implementation of EPC. Hence, published information on this topic is limited [3,5,56]. A search of the literature revealed a few studies on the EPC in Malaysia such as a discussion on the limitation and room for improvement of the EPC model in the country [3], a report of the EPC model adopted by the Ministry of Health in public hospitals [5] and a proposed EPC scheme for local state of Melaka, namely EPCert [56]. Therefore, this study provides a developed EPC model in an educational institution under the tropical climate settings which address the appropriate ECMs to be implemented with the evaluation of energy use performance including BEI, energy saving, carbon dioxide (CO_2) emission mitigation, and the return of investment (ROI). Furthermore, a sensitivity analysis of quantum sharing ratio between the ESCO and building owner (University A) are presented for the developed EPC model.

3. Methodology

Three main types of study, namely, theoretical analysis, empirical survey, and case study, are used to evaluate the robustness of the research outcomes and enhance the body of knowledge of energy performance contracting (EPC) topics [2]. This study utilises a case study approach to determine the factors that affect the EPC model when used for developing commercial buildings under tropical climates with various profit-sharing and ROI scenarios. A preliminary energy audit is conducted to develop the EPC model for the selected case study. Before the implementation of EPC, the measurement and verification (M&V) process, wherein the regression analysis will be conducted, is performed, as shown in Figure 2 below.

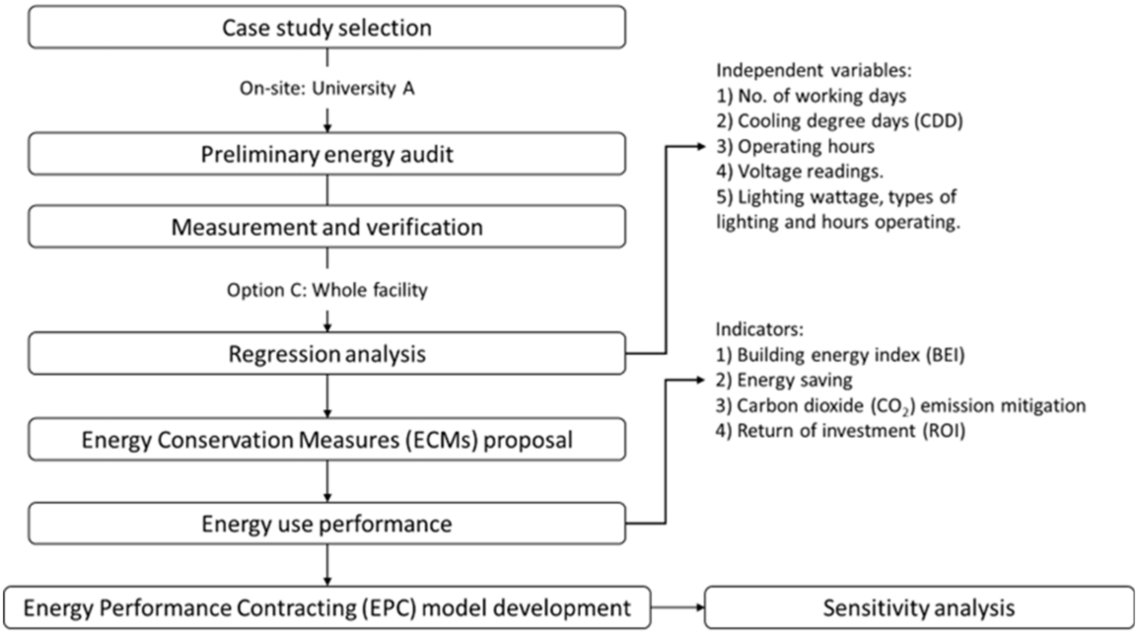

Figure 2. Scheme of the research.

3.1. Case Study Background

University A is an educational institute which is located in Malaysia. The university consists of 15 identified saving potential areas. Based on the walk-through energy audit, we categorised these areas into three zones when implementing the proposed energy conservation measures (ECMs). Table 1 shows the building description. In term of climatic condition, this study considered the country's climate and as such Malaysia has a humid climate all year round, with an average daily temperature ranging from 21 °C to 32 °C. The winds that influence the country's climate come from the Indian Ocean (southwest monsoon, May to September) and the South China Sea (north-eastern monsoon, November to March). The annual rainfall in Malaysia is typically around 80% of the year, with a range of 2000 mm to 2500 mm [57].

Table 1. University A description.

Building Name	University A
Sector	Education—University
Total zones	3 zones (refer Figure 3)
Floor Area	180,408 m^2
Electricity Tariff	Tariff C2—Thermal Energy Storage Unit Rate: Maximum Demand—RM45.10 All kWh (Peak)—RM0.365 All kWh (Off-peak)—RM0.186
	Tariff C1—Medium Voltage General Unit Rate: Maximum Demand—RM30.30 All kWh—RM0.365
Operation Time	7.30 am–11.00 pm
Electrical Consumption (2019)	22,688,226 kWh/year RM 11,051,414.66
Building Energy Index (BEI)	125.76 kWh/m^2

Figure 3. Audited zones in University A.

A total of 3 zones in University A are audited as where the district cooling systems are located. Zone 1 consists of six buildings, Zone 2 consists of eight buildings and Zone 3 consists of a building with total floor area of 180,408 m^2. Most of the audited area located the faculty buildings. Table 2 tabulated the audited zones in respective to the buildings, area, and energy consumption.

Table 2. Audited zones in respective to the buildings, area, and energy consumption.

Zone	Area	Area (m^2)	Energy Consumption (kWh/year)	Audit Scope
Zone 1 and 3	CCS1	481	4,012,703	Lighting
	Administration building 1	13,589	617,166	
	Library	11,198	749,933	
	Administration building 2	5801	386,740	
	Faculty building 1	13,668	458,515	
	Main hall	13,000	752,142	
	Faculty building 2	13,796	838,901	
Zone 2	Centralized utility building	971.0	4,088,774.0	Lighting and chiller plant
	Faculty building 3	14,776.0	496,057.0	
	Faculty building 4	15,616.0	544,226.0	
	Lecture hall 1 and 2	3157.0	242,233.0	
	Faculty building 5	9711.0	543,505.0	
	General laboratory	8145.0	491,705.0	
	Faculty building 6	13,885.0	728,600.0	
	Faculty building 7	2125.0	145,703.0	

3.2. Preliminary Energy Audit

This study conducted the preliminary energy audit in University A which follows the three levels of energy audit defined by The American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) as illustrated in Figure 4 [58]. Firstly, a walk-through audit or preliminary audit (Level 1), which aims to provide low/no-cost recommendations and instantaneous results. Secondly, during the energy survey and analysis (Level 2), the energy audit team conducts a thorough analysis of all equipment and installed devices and then provides a detailed report on the equipment's condition, as well as long-term recommendations to improve the efficiency of the said equipment. Thirdly, the final stage refers to the implementation of the detailed analysis of capital intensive modifications (Level 3) [59]. Generally, energy auditors follow the methods listed by ASHRAE in performing a building energy audit [54]. ASHRAE, a global energy conservation and development society, was established in 1894 to provide newer ideas and technologies for a much more sustainable built environment.

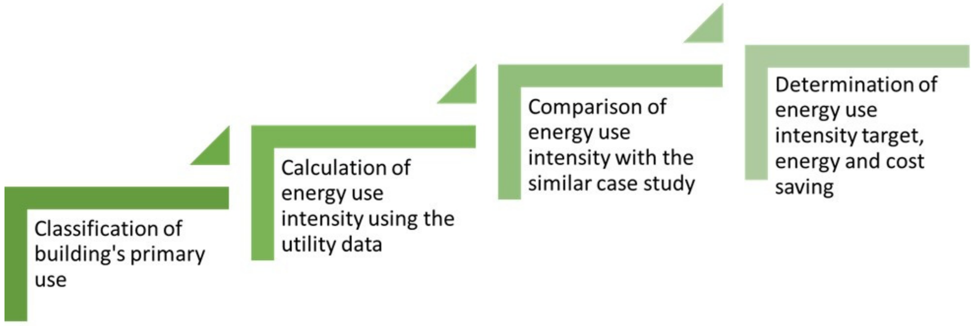

Figure 4. Preliminary energy audit steps.

3.3. Measurement and Verification (M&V)

A plan for M&V must be designed before the implementation of the EPC [60]. The baseline and M&V plan are crucial in the implementation of the energy saving project. These energy saving targets must be measured and verified, and in many countries, such M&V activity is guided by the International Performance Measurement and Verification Protocol (IPMVP) [61]. The baseline is often the first place parties revisit in the case of under-performance [62].

The IPMVP is an international standard for M&V of EPC projects. It offers four options for measuring and verifying performance, namely:

1. Option A—Retrofit Isolation: Key Parameter Measurement;
2. Option B—Retrofit Isolation: All Parameter Measurement;
3. Option C—Whole Facility;
4. Option D—Calibrated Simulation [63].

This study employed Option C, in which the whole facility of University A is audited with multiple suggested ECMs. Option C is selected out of four M&V options because the expected saving is more than 10%, and each electrical metre data in University A need not be assessed to determine the energy use. Hence, only the main metre data will be assessed (refer to Figure 5).

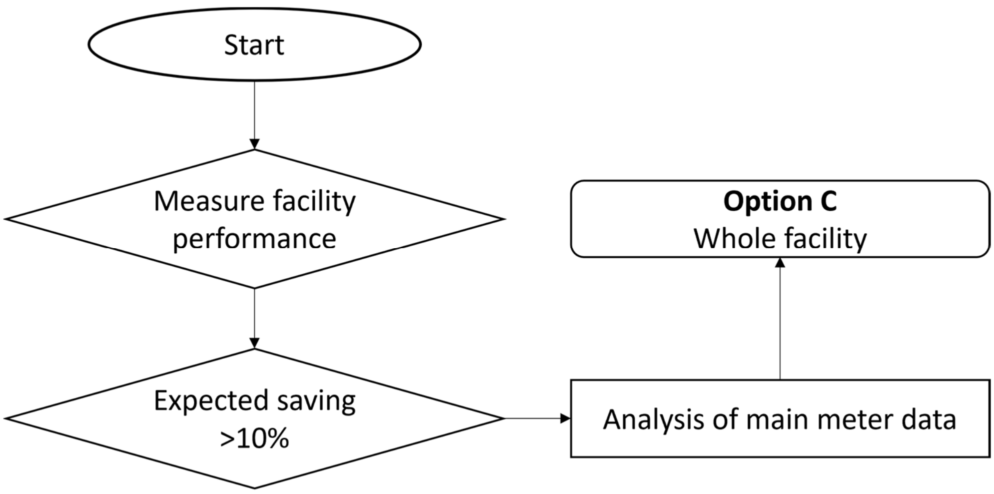

Figure 5. M&V plan.

Then, the M&V plan used to evaluate the performance of all installed energy saving measures includes the calculation of energy savings (i.e., individual measures and the total savings), the assessment of any shortfalls and adjustment of the baseline, the identification of any internal or external factors that may affect the baseline and the savings and lastly, reporting on the basis of the format for the energy savings report and its verification procedure [60].

3.4. Energy Use Performance from the Implementation of Energy Conservation Measures (ECMs)

Three indicators, namely, building energy index (BEI), energy- and cost-saving, and return of investment (ROI), are used to evaluate the energy use performance of University A. Meanwhile, the carbon dioxide (CO_2) emission mitigation indicator is used to assess the environmental impact.

(a) Building energy index (BEI)

BEI is the ratio of a building's total annual energy consumption to its total floor area in kWh/m^2/year, as calculated in Equation (1) [64]. A building with a lower BEI rating indicates that the building is more efficient in terms of energy consumption.

$$\text{BEI} = \frac{\text{Total Annual Energy Consumption, kWh/year}}{\text{The total floor area of the building, m}^2} \quad (1)$$

(b) Energy-saving, α

Energy saving is calculated on the basis of the energy reduced after the proposed implementation of ECMs in University A based on Equation (2) [65]. The baseline energy use is obtained from the monthly electricity use in 2019. The baseline energy use and the energy use after the implementation of ECMs are analysed using the regression analysis, which is explained in Section 3.5.

$$\alpha = \text{Baseline Energy Use} - \text{Energy Use during Reporting Period} \quad (2)$$

(c) Carbon dioxide (CO_2) emission mitigation, γ

CO_2 emission mitigation is an indicator used to determine the avoidance of CO_2 emission from energy use reduction based on the baseline energy use, which is connected to the grid and calculated as Equation (3) [66]. The emission factor of University A is 0.649 kgCO_2/kWh [67].

$$\gamma = \alpha \times \text{emission factor} \quad (3)$$

(d) Return of investment (ROI)

ROI is an indicator used to assess how well an investment performed by dividing the cost of the investment by the return of the investment as follows:

$$\text{ROI} = \frac{\text{Annual retrofit savings} - \text{Project cos t}}{\text{Cost of investment}} \quad (4)$$

3.5. Regression Analysis

This study adopted the share savings model (SSM) of energy performance contracting (EPC) project model and use multilinear regression to forecast future revenue and expenses. To develop the baseline model, the electrical energy usage of the building must be presented before the implementation begins. The energy and cost consumption for the year 2019 (refer to Figure 6) is used as a baseline that acts as a dependent variable that collects the utility bill. Meanwhile, independent variables such as the number of working days are taken from the calendar, and the number of cooling degree days (CDD) are calculated on the basis of the temperature data obtained from the Malaysian Meteorological Department. The occupancy data were collected by the energy accounting centre of each department in University A. These data will be utilised to model the baseline energy and post-retrofit energy use. Subsequently, the savings are quantified by subtracting post-retrofit usage, including adjustment.

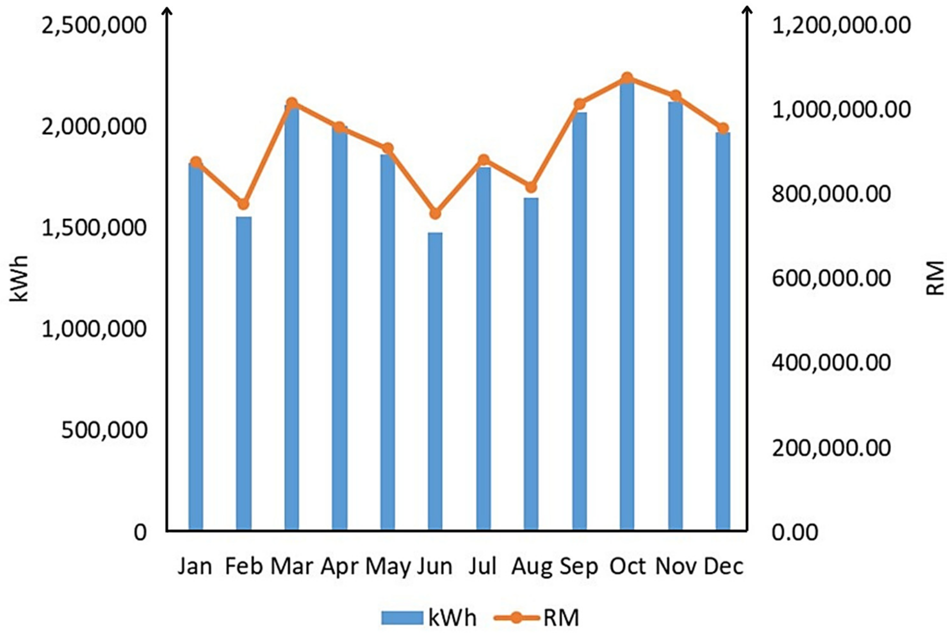

Figure 6. Energy and cost consumption of University A in 2019.

For further analysis and adjusted baseline setup, regression analysis is used to identify the strength of the effect that the independent variables have on the dependent variable. Based on Equation (5), Y indicates the dependent variable affected by the independent variables X_1, X_2, and X_3. The three independent variables, namely, X_1: the number of working days, X_2: CDD and X_3: occupancy, have a coefficient of 22,823, 448 and 8.42, respectively. Meanwhile, Equation (6) calculates the y-intercept, a with the coefficient of $-37,625$. Next, b, c, and d are the slopes that are calculated using Equation (7); and $\in$ is the error. In addition, x, y, and n indicate the values of the independent variable, dependent variable value, and number of values generated, respectively. Hence, the EPC model is developed from the regression analysis based on Equation (8) to analyse and forecast future revenues and expenses.

$$Y = a + bX_1 + cX_2 + dX_3 + \in \tag{5}$$

$$a = \frac{\sum y \sum x^2 - \sum x \sum xy}{n \sum x^2 - \left(\sum x\right)^2} \tag{6}$$

$$b,\ c,\ d = \frac{n \sum xy - \sum x \sum xy}{n \sum x^2 - \left(\sum x\right)^2} \tag{7}$$

$$Y = -37,625 + 22,823X_1 + 448X_2 + 8.42X_3 + \in \tag{8}$$

4. Results and Discussion

This section discussed the results based on the preliminary energy audit in University A. The suitable energy conservation measures (ECMs) to be implemented and the respective savings are discussed. Then, whether the energy performance contracting (EPC) agreement between the energy service company (ESCO) and the building owner settled with the agreement on the saving share percentage will be addressed. Next, the results based on the regression analysis before and after the implementation of the ECMs will be discussed. Lastly, the sensitivity analysis of different scenarios involving EPC models with various profit sharing and return of investment (ROI) will be presented.

4.1. Energy Conservation Measures (ECMs) Suggestion and the Saving Analysis

ECM is a collection of certain implementation of equipment installation that intends to reduce the facilities' on-site energy consumption [54]. It is implemented to achieve reductions in energy consumption (kWh) and ultimately cost savings for the stakeholders [62].

For instance, the operation of an energy efficiency management for air-conditioning and mechanical ventilation (ACMV) system in commercial buildings has contributed to about 57% of the country's total electricity consumption [68]. The lighting system consumes approximately 25% of the electrical energy utilisation in buildings [69]. Therefore, this section discussed the suggested ECMs of the energy performance contracting (EPC) project, which will be implemented in University A.

4.1.1. Chiller Optimisation and Replacement

Based on the preliminary energy audit, only two chillers which are Chiller Plants 1 and 3 at University A were optimised because both chiller plants have less than 10 years of operation. A CPC system will be implemented to optimise [70] as a dependable and efficient CPC system that can help increase plant system efficiency by reducing electric power consumption and avoiding the use of excessive energy to operate the existing chiller plant [39,70,71]. This study measures the saving potential of the chiller optimisation using a chiller optimiser system. The system will collect the data on the chiller operation and execute the optimisation either automatically or manually. This study shows that the chiller optimisation in University A saves up to 5.8% of energy and cost per annum. Based on the recently published works conducted on the commercial building, the chiller optimisation can save up to 15.4% of energy use [44,70–72].

Meanwhile, for chiller replacement, University A installed chillers with ice storage that can be used to transfer the cooling demand of a building to off-peak hours. Ice is used to store thermal energy as the system generates ice to store cooling at night and then discharges it throughout the day to fulfil peak electrical demands [73]. The ice storage falls under the cool thermal energy storage, together with chilled water storage and phase change storage systems. The system has the potential to save up to 68.5% more energy and cost under the tropical climate [74] compared with the conventional storage system with a payback period of up to 6 years [75] and are affected by the climatic condition, electricity tariff and energy storage strategies [76]. In University A's case study, the present chiller storage system is already an ice storage system; however, it requires greater efficiency and capacity to increase its performance, and the overall coefficient of performance (COP) should be reduced. Therefore, retrofitting two existing chillers from 350RT (day mode)/243RT (ice mode) to higher efficiency and greater capacity system with 700RT (day mode)/469RT (ice mode) saves up to 5.4% in energy consumption and its cost1. Previous studies in Malaysia had also shown that installing an energy-efficient chiller in a commercial building reduces energy consumption by up to 40% [5,34].

4.1.2. Lighting Retrofitting

Based on the preliminary energy audit in University A, retrofitting lighting by replacing the current lighting with light-emitting diode (LED) lighting saves 9.4% of the total energy consumption and cost. Previous research has established that retrofitting lighting to LED-type lighting reduces the total energy consumption of a university building [10,11,22,26]. In comparison, Figure 7 presents the energy saving percentage by replacing the existing lighting in university buildings with LED based on recently published articles [17,20,24,26,27,77].

Another study conducted in a university building in Malaysia also shows similar trends, in which they save up to 36–50% in energy consumption by installing LED lighting compared with the conventional type of lighting [78,79]. These findings indicate that the replacement of existing lighting (i.e., fluorescent or CFL lighting) to LED-type lighting reduces the total energy consumption of a commercial building, especially a university building, and its cost.

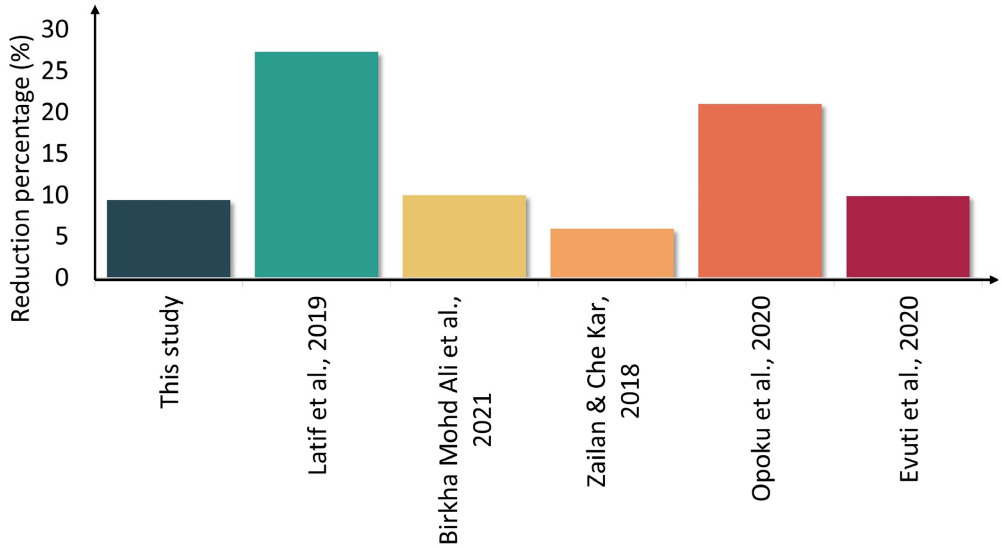

Figure 7. Saving from lighting replacement to LED in university buildings—comparison of this study with others [17,20,24,26,77].

4.1.3. Energy Management System (EnMS)

This study applied the EnMS strategies adopted from the ISO50001 standard based on the management system model implemented by organisations worldwide. Despite the fact that the building has exceeded the limit of 3 million kWh per month for six consecutive months, there is no energy committee in place to address this issue. Therefore, the implementation of EnMS in University A resulted in 5% energy saving annually. The knowledge on energy efficiency throughout the organisation is critical to the success of these energy conservation measures (ECMs). Energy efficiency can be promoted using three instruments, namely, regulation, technical assistance and, recognition or incentives, to encourage individuals to utilise energy efficiently [69,80]. Electricity saving of 30% can be achieved from the implementation of indoor environment and energy management. Hence, awareness on these aspects should be addressed [81]. Table 3 shows the EnMS strategies to be implemented and trained for the targeted groups in University A.

Table 3. Group targeted EnMS strategies.

Group Target	EnMS Strategies for Training
Management • Top Management • Middle Management	Awareness of Economic Potentials of Implementing EnMS
	General Awareness and Implementation of EnMS based on Recognised Standards
	Energy Auditing in Practice
Technical • Facility Manager • Operation and Maintenance Crew	ACMV System
	Chiller: Component Overview, Operating Principle and Maintenance Service, Plant Room Exercise
	Ice Chiller: Operating System and Maintenance Service
	Energy Efficient Building Design and Planning
	Energy Performance and Verification
Operational and Support • Operators, Clerical Personnel, Cleaners, Security • Lecturers and Students	Introduction to Energy Management
	Energy Efficient Practice within Building Facilities

In addition to the electrical efficiency in a building, water efficiency and indoor air quality should also be emphasised in the EnMS to reduce the life cycle energy consumption based on these aspects [66]. Another EnMS strategy implemented on the Universiti Teknikal Malaysia Melaka (UTeM) campus is the development of Internet of Things (IoT) to the digital energy metre to monitor the energy use of the campus [67]. With the collected data, the created IoT-digital meter simplifies the energy saving measures. Meanwhile, the energy consumption in the residential college of Universiti Teknologi Malaysia, another big campus in Malaysia, decreased for four consecutive years under the implementation of energy awareness on the campus [68]. The result of this study and previous works on EnMS shows that the implementation of the ECM is significant in reducing energy consumption, thereby saving more on cost and energy use.

4.2. Energy Use Performance

This section discussed the energy use performance in terms of energy-saving, avoidance of energy used, the building energy index (BEI) of the building, and return of investment (ROI) based on the calculation in Equations (1) to (4) after the implementation of energy conservation measures (ECMs). Table 4 tabulated the results of these energy use performance indicators.

Table 4. Energy use performance from the proposed ECMs.

No	ECMs	Estimate Saving			Carbon Dioxide (CO_2) Emission Mitigation/Year
		kWh	RM	%	
1.	Chiller optimisation	1,321,306	643,476.02	5.8%	857,527.59
2.	Chiller retrofit—upgrade chiller	1,215,899	592,142.81	5.4%	789,118.45
3.	Lighting retrofit	2,138,956	1,041,671.57	9.4%	1,388,182.44
4.	EnMS	1,134,411	552,458.16	5.0%	736,232.74
	Total	5,810,572	2,829,749	25.6%	3,771,061.22

Based on the discussion on each proposed ECM to University A in Section 4.1, Table 4 summarised the implementation results of energy and cost-saving and CO_2 mitigation. The implementation of ECMs is expected to generate an estimated energy saving of 25.6% in energy use to save 5 million kWh/year, RM 2 million per year, CO_2 mitigation equal to 3,771,061.22 kgCO_2/year, and ROI of 4.2 years with 5% of interest rate.

In comparison, Table 5 shows the recently published works from 2017 to 2021 on the implementation of ECMs in university buildings with the indicators used to evaluate energy use. As a result, most of the studies conducted low-cost ECMs (i.e., replacement with LED lighting, air-conditioning maintenance, and EnMS). For studies conducted under Malaysian conditions, the proposed/implemented ECMs have the potential to save up to 30% of energy use and cost. Meanwhile, the values of the BEI indicator for the studied university in Malaysia after the implementation of ECMs are lower than or slightly higher than those of the national standard (i.e., MS1525:2007) with a range of 76 to 135.31 kWh/m^2. This finding indicates that a university, as a commercial building, has a high potential to save up energy use through the implementation of ECMs. Furthermore, appointing ESCO through the EPC is commendable.

Table 5. Comparison of ECMs implementation in recently published works.

Location	Proposed/Implemented ECMs	Energy Use Performance Indicators	Energy and Cost Reduction (%)	BEI after ECMs (kWh/m^2)	Ref.
Malaysia	• Chiller optimisation • Chiller retrofit—upgrading • Lighting retrofit • EnMS	• Energy saving • Cost-saving • CO_2 mitigation	25.6	93.55	This study
Malaysia	• EnMS • Air-conditioning maintenance • Lighting retrofitting to LED type	• Energy saving • Cost-saving • CO_2 mitigation • ROI	30	76.12	[20]
Malaysia	• Replacement into LED lighting	• Energy saving • Cost saving • ROI	4	X	[28]
Malaysia	• Replacement into LED lighting • Maintenance and optimisation of the air-conditioning system • Sun-shading and double-glazed windows instalment	• Energy saving • Cost-saving	10.2	135.31	[72,82]
Ghana	• Replacement into LED lighting • Replacement into the energy-efficient air-conditioning system • PV installation for street lighting	• Energy saving • Cost of conserved energy	26.9	X	[17]
Nigeria	• Replacement into lower wattage of lighting bulb. • Cooling demand reduction • The use of star rated electrical appliances • Energy efficiency awareness	• Energy saving by replacement of lighting bulbs	9.9	X	[24]
Nigeria	• Replacement of LED lighting • PV system installation	• Energy saving • Cost-saving • Payback period • CO_2 mitigation	X	X	[7]
Pakistan	• Replacement of LED lighting • Retrofit air-cooling fans • Retrofit air-conditioning system • Retrofit into energy-efficient PC	• Energy saving • Internal Rate of Return (IRR) • Payback period	60	X	[26]
Azerbaijan	• Thermal insulation of main pipelines in the basement • PV panels installation • Roof thermal insulation • Installation of double-glazed windows and metal-plastic frames • Renovation of heating system and hydraulic balancing of the thermostatic valves	• Energy saving • Cost-saving • Payback period • Net Present Value	56	X	[12]
Ethiopia	• Daylight sensors instalment • Replacement to a lower wattage or LED lighting • Replacement of damaged water fixtures • Use of socket outlets with ON/OFF switches	• Energy saving • Cost-saving • Payback period • ROI	X	X	[11]

Furthermore, the average BEI for Malaysia is 269 kWh/m^2 [83]; however, the recommended BEI should not be more than 135 kWh/m^2 in accordance with the national standard, MS1525:2007 [64]. Moreover, in Figure 8, this study shows a positive performance in terms of the BEI value after the implementation of ECMs through the EPC, in which the BEI value reduces by 74% compared with the baseline BEI. In addition, the BEI after EPC is lower than the MS1525:2007 standard and LEO building. University A has the potential to stand on par with LEO, Diamond, and GEO buildings, which are green buildings in Malaysia.

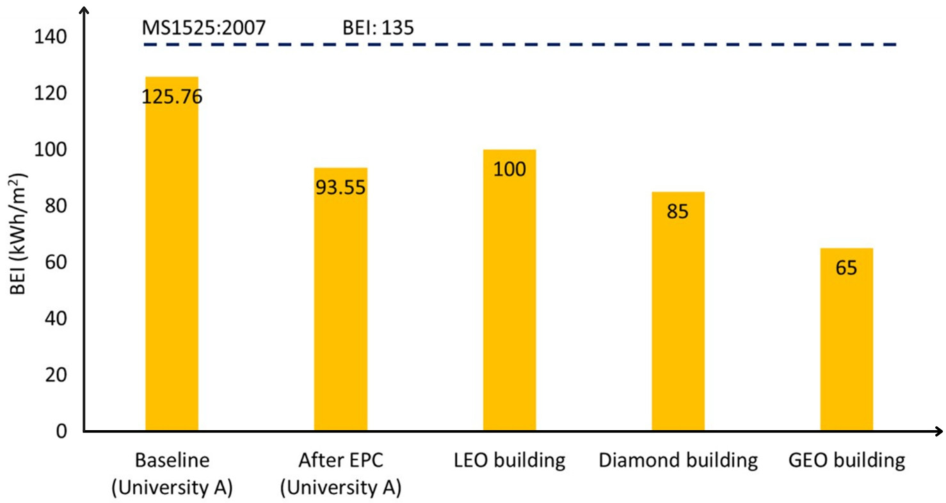

Figure 8. BEI comparison between this study with MS1525:2007 standard and green buildings in Malaysia.

5. Energy Performance Contracting (EPC) Recommendation and Sensitivity Analysis

This study adopted the share savings model (SSM) of EPC model. Based on the analysis of the preliminary energy audit and the proposed ECMs, Table 6 shows the saving value based on the quantum sharing between the ESCO and University A as the building owner for 6.7 years with a shared saving ratio of 95% for ESCO and 5% for University A after the implementation of the proposed ECMs. The baseline electricity consumption and the bills per annum are 22,688,226 kWh/year and RM 11,051,414.66, respectively. The ESCO guaranteed 25.6% of annual savings to University A with the aggregated unit tariff of RM0.487/kWh, which resulted in 5,672,057 kWh in electricity consumption reduction and RM 2,762,291.76/year saving.

Table 6. Annually and accumulated saving values earned by quantum sharing between ESCO and University A.

Party	Quantum Sharing Ratio (%)	Saving Value per Year (RM)	Accumulated Saving Value for 6.7 Years (RM)
ESCO	95	2,624,177.17	17,581,987.04
University A	5	138,114.59	925,367.75
Total	100	2,762,291.76	18,507,354.79

A sensitivity analysis of different quantum sharing ratios between the ESCO and University A is conducted, and the result is presented in Figure 9 which shows that the saving value of ESCO is inversely proportional to that of University A when the quantum sharing ratio is increasing for ESCO.

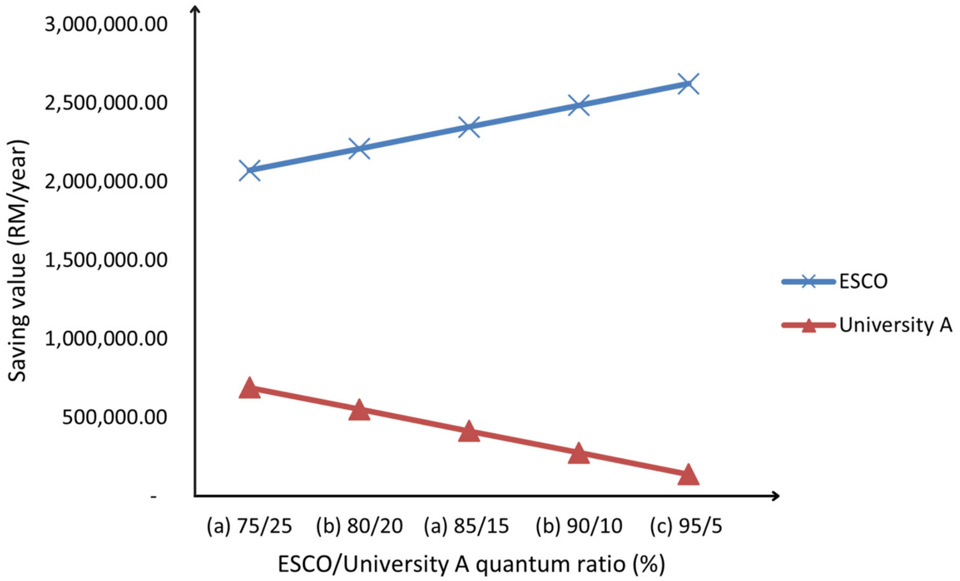

Figure 9. Annual saving value from the sharing quantum ratio of ESCO and University A.

As this study employed the SSM EPC model, the ESCO assumed the technical and credit risk (of the client), which can be advantageous to the client because it eliminates the need for upfront capital expenses, with recurring payments to the ESCO depending on the realised savings. As a result, the project would be incognito leverage [84]. In the Asian market, the adopted EPC models are diverse between SSM or guaranteed saving model (GSM) EPC models, which are influenced by the national policies and accounting rules. For the SSM model adopted in the Asian market, the quantum sharing ratio for ESCO is more than 75%. The determination of the sharing quantum ratio between the ESCO and the client (i.e., the building owner is competitive as to which parties that decide the ratio affect the result in saving the energy of the building). Under the EPC project, both parties enjoy the profits from the energy saving [85]. The client will extract all of the surpluses from the EPC project if the client sets an overall energy cost reduction target rather than a benefit-sharing ratio. If the client sets the sharing ratio higher than the ESCO, then the client will reap more benefits from the saving; however, the ESCO may not offer better services. In contrast, when the ESCO, rather than the client, determines the benefit sharing ratio, then ESCO will take all the surpluses from the EPC project whilst constantly reducing the overall energy usage.

6. Conclusions

In conclusion, University A shows a positive performance in terms of energy and cost savings, building energy index (BEI), return of investment (ROI), and carbon dioxide (CO_2) emission when the energy performance contracting (EPC) model developed using the regression analysis to determine the saving potential in a commercial building is implemented. From the EPC model with energy service company (ESCO)/University, a quantum sharing ratio of 95%/5% forecasts the energy saving from the proposed energy conservation measures (ECMs), chiller optimisation and replacement, lighting retrofit, and EnMS. University A was estimated to save 25.6% energy use, which reduced 5,672,057 kWh in electricity consumption, saved RM 2,762,291.76/year, CO_2 mitigation equal to 3,771,061.22 kgCO_2/year, and ROI of 4.2 years with 5% of interest rate. The BEI reduces by 74% and becomes 93.55 kWh/m^2/year lower than the recommended BEI of the National standard MS1525:2007. In the EPC model, which adopted the share savings model (SSM) EPC model with the minimum of 75% ESCO sharing ratio, a sensitivity analysis of the five quantum sharing ratios shows that the saving value of ESCO is inversely proportional to that of University A as the client when the quantum sharing ratio for ESCO is increasing with a range of ESCO: RM 2,071,718.82 to RM 2,624,177.17, and University A: RM 690,572.95 to RM 138,114.59. Both parties benefitted from the energy savings under the EPC project.

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