

Investigation of Energy and Cost Potential in an Office Building Using IoT Lighting System

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Abstract

This investigation is for study and analyzed energy and cost savings of the implementation of Internet of Things (IoT) based lighting system at office building Sunway Geo Tower at Subang Jaya in Malaysia. This study will examine the pattern of lighting energy consumption with and without the introduction of the IoT technology, evaluate how much energy can be saved with the implementation of the technology, as well as the calculation of the costs recovery (ROI). Information on site inspections, interviews, electricity bills and a building facilities management system (CMMS Easy10) were used to collect data. Other calculation analysis was run so as to give an estimation of the energy usage in the absence of the IoT system. The IoT based lighting system operates using motion sensors and two-stage lighting modes: Day Mode (100%) and Night Mode (30%), which are automatically controlled based on occupancy and operating hours. The building uses various types of LED lighting fixtures, including 15W 6" LED downlights, 12W double gang LED downlights, 2×16W LED weatherproof lights, and 30W LED batten fittings, strategically deployed across office zones, toilets, corridors, and staircases. Results show a 30% energy reduction, from 4,948.92 kWh to 3,464.24 kWh per month. These energy savings resulted in significant cost savings and a favorable ROI, thus proving the effectiveness of smart lighting technology. The findings align with MS1525:2019 guidelines and the Green Building Index (GBI), supporting the integration of smart controls in commercial buildings. This paper contributes empirical evidence supporting the practical application of IoT lighting in Malaysian commercial buildings.

1. Introduction

The construction industry is undergoing a significant transformation due to increasing energy costs and global climate change. This shift has encouraged the adoption of sustainable technologies, especially within building services. One notable innovation is the use of Internet of Things (IoT) technology, which has proven particularly effective in lighting systems. IoT enables lighting to be intelligently and automatically controlled through smart sensors, such as motion detectors, occupancy sensors, and ambient light sensors that respond in real-time to human presence and environmental conditions. These sensors are typically connected to centralized systems or Computerized Maintenance Management Systems (CMMS), allowing lighting to be optimized based on occupancy, daylight availability, and pre-set schedules (Khan & Khan, 2024).

In Malaysia, lighting accounts for approximately 15% to 25% of energy consumption in non-residential buildings, as reported in MS1525:2019—Malaysia's national standard on energy efficiency (Suruhanjaya Tenaga, 2019). Despite this, many office buildings continue to rely on conventional lighting systems that are manually operated or function on fixed timers, leading to significant energy waste, particularly in intermittently used spaces like corridors, meeting rooms, and pantries.

IoT-based lighting systems present a practical solution to these inefficiencies. Key components as in Figure 1 motion sensors activate lighting only when movement is detected. Occupancy sensors keep the lights on while a space is in use, and ambient light sensors reduce artificial lighting when sufficient daylight is present. Integration with CMMS allows facility managers to automate lighting operations, monitor energy usage, and optimize performance across different zones of a building (Chen et al., 2022).

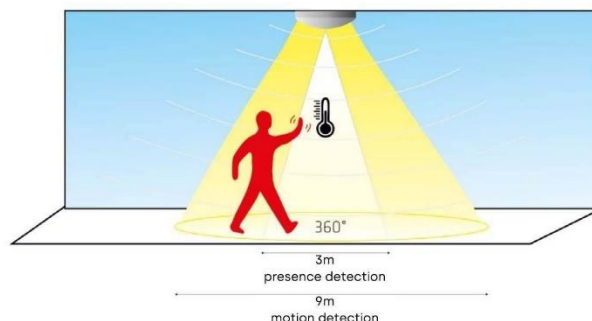


Figure 1: Motion Sensors (PIR - Passive Infrared Sensors) (Gehlot et al., 2021)

Globally, studies have demonstrated that IoT lighting systems can reduce energy consumption by 30% to 50%, depending on building type and usage patterns. In addition to energy savings, these systems lower electricity costs, extend lighting equipment lifespan, and improve user comfort through adaptive brightness levels. Furthermore, the implementation of such systems aligns with environmental sustainability initiatives, including the Sustainable Development Goals (SDGs) and Malaysia's Green Building Index (GBI).

However, despite these benefits, several challenges hinder widespread adoption in Malaysian office buildings. These include high initial installation costs, limited technical expertise among facility managers, compatibility issues with legacy systems, and concerns over data privacy and cybersecurity (Zainal & Ahmad, 2024; Oyun-Erdene et al., 2024). Additionally, the absence of standardized implementation frameworks further complicates deployment.

To address these barriers, the Malaysian government has introduced policies such as the National Energy Policy (NEP) 2022–2040, which advocates the use of digital and automated building systems to meet the country's carbon neutrality target by 2050. Standards such as MS1525:2019 and certifications like GBI offer further motivation through financial incentives and market recognition. Therefore, this study strongly supports the integration of IoT-based lighting systems as an effective, sustainable and economically sound solution for energy management in commercial buildings. These systems offer many advantages in terms of energy efficiency, reduced operating costs and improved user experience. This review sets the context for evaluating the real-world effectiveness of IoT lighting systems, as demonstrated in the case study of the Sunway Geo Tower in Subang Jaya, Malaysia.

2. Objective

The objectives of study are:

- I. To identify key parameters of IoT based for lighting systems in an office building.
- II. To analyse energy consumption levels before and after IoT implementation for over a three-month period
- III. To estimate potential energy savings and return on investment (ROI) from IoT enabled lighting system.

3. Methodology

In this topic, all the methods used to conduct the research on the implementation of an IoT-based lighting system in an office building are described in detail. It explains the research methodology, including data collection procedures, energy simulation, and financial analysis, which were carried out to achieve the stated research objectives.

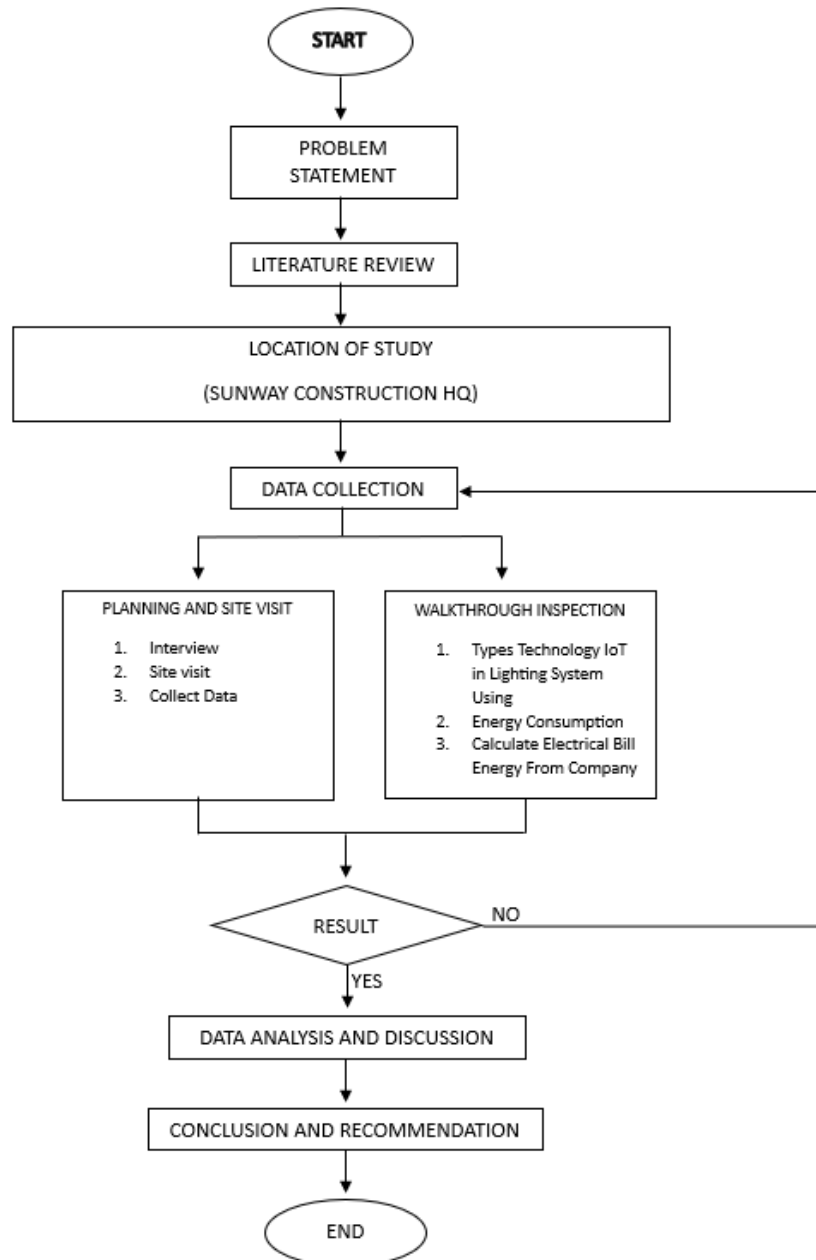


Figure 2: Methodology

4. Result and Data

The data collection, data analysis and findings were derived from the implementation of the IoT-based lighting system at Sunway Geo Tower, located in Subang Jaya, Selangor. The purpose of this analysis is to evaluate the system's impact on energy efficiency and cost savings in the selected building. Data were collected through various methods, including the analysis of monthly electricity bills, site inspections, interviews with facility personnel, and lighting energy consumption analysis calculation. These data were analyzed to determine the

energy savings, cost reduction, and return on investment (ROI) resulting from the implementation of the IoT system.

The Sunway Geo Tower is an 18-storey commercial office building that serves as the headquarters for Sunway Construction. It consists of various functional spaces such as office units, meeting rooms, pantries, toilets, corridors, and staircases. The building was selected as the case study due to its adoption of a smart lighting system based on IoT technology. The lighting system is centrally managed using the Easy10 Computerized Maintenance Management System (CMMS), which monitors and controls lighting activity in different zones across the building. The IoT lighting system operates in two programmed modes. This dual-mode setup, combined with motion sensors and time-based automation, is designed to minimize unnecessary energy use by adjusting lighting based on real-time occupancy and ambient conditions.

Table 1: Types of Mode Energy Control (as stade in table during intevew session with Hasrul on May 8, 2025)

Mode	Energy Percentage Usage	Duration
Day	100%	Used during working hours from 8.00 am to 7.00 pm. During this period, all energy is used at full capacity.
Night	30%	Used after working hours (7.00 pm to 8.00 am) and all day on weekends and public holidays. In this mode, the system operates automatically with a usage rate only in certain areas to save energy.

In this building there are four main types of lighting systems which are divided according to four specified categories. In Table 4.1, the type of lighting system used includes various types of LED lamps as follows:

Table 2: Category and Types of Lighting

Category	Types of Lighting	Number of Unit Lighting
Category 1 (C1)	15W LED 6" (Davis)	615
Category 2 (C2)	Double gang LED downlight 12W	195
Category 3 (C3)	2x16W LED Weatherproof	36
Category 4 (C4)	Single gang 15.5W	8

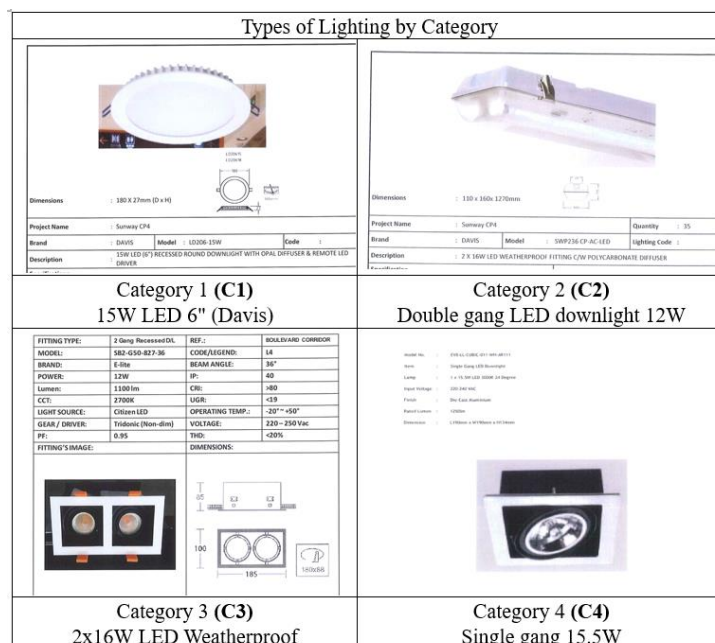


Figure 3: Types of Lighting by Category

4.1 Energy Consumption Analysis

This section compares lighting energy usage before and after the implementation of the IoT system. A simulation was used to estimate energy before IoT consumption, while data after using IoT was derived from electricity bills and system records. The IoT system operates in two modes, Day Mode (100%) and Night Mode (30%) with controlled by motion sensors and CMMS system. The analysis shows a 30% reduction in energy consumption, confirming the effectiveness of smart lighting controls in reducing energy usage.

4.1.1 Actual Energy Data from Electricity Bills

Energy consumption data was obtained from monthly electricity bills provided by the building facilities management team. The values represent lighting consumption after the implementation of the IoT-based system. Table 2 show the comparison covers for three-month period and illustrates the actual impact of the smart lighting system on energy consumption.

Table 3: Summary of Monthly Electricity Bills

<i>Month</i>	<i>Usage (kWh)</i>	<i>Total Bill (RM)</i>	<i>Maximum Required (kW)</i>
February	238,143	RM156,000.05	961.00
Mac	252,900	RM163,850.60	960.00
April	265,085	RM170,517.41	968.00
Total Average	252,043	RM163,456.69	963.00

Table 2 includes electricity rates with additional charges such as ICPT (RM0.16/kWh) and the Renewable Energy Fund (1.6% of total bill). The total energy consumption shown represents the entire building, covering all systems including lighting, HVAC, lifts, and pumps. Since there is no separate breakdown for lighting, this study assumes 20% of the total energy consumption is allocated to lighting, based on guidelines from MS1525:2019, GBI, and the International Energy Agency, which suggest lighting accounts for 15%–25% of energy in modern office buildings.

By using the building's average monthly consumption of 252,043 kWh and average monthly cost of RM163,456.69, the estimated lighting energy usage is calculated using eq.1 below:

$$\text{Lighting Energy Consumption} = 20\% \times 252,043 = 50,408.6 \text{ kWh/month} \quad \text{Eq. (1)}$$

This data was obtained after the implementation of the IoT system, this study continued using the simulation calculation method in subtopic 4.1.2. Subsequently, the data obtained from this bill can be used as a reference to compare with the energy simulation calculation without IoT to assess the actual impact of energy savings throughout the use of smart lighting systems.

4.1.2 Simulation of Energy Use Before IoT

This simulation calculation aims to estimate the implementation of total electricity consumption by the lighting system before the use of IoT technology. Referring to Figure 3, the simulation was conducted to estimate the energy consumption by the conventional lighting system based on the type of lamp, number of units, and the building's operating period.

The highest energy consumption is recorded by lighting – 15W LED 6" Davis lamps – with a total of 9,225 kWh for 615 units, as these are widely used in main areas such as offices and the lobby. Which includes 12W Double Gang LED downlights used mainly in toilets and lift lobbies, consumes 2,340 kWh for 195 units. The 2×16W LED Weatherproof lamps used in emergency staircases, records 1,152 kWh for 36 units. Lastly with only 8 units located at Level 18, consumes 120 kWh. The distribution reflects usage patterns based on area function and frequency of use.

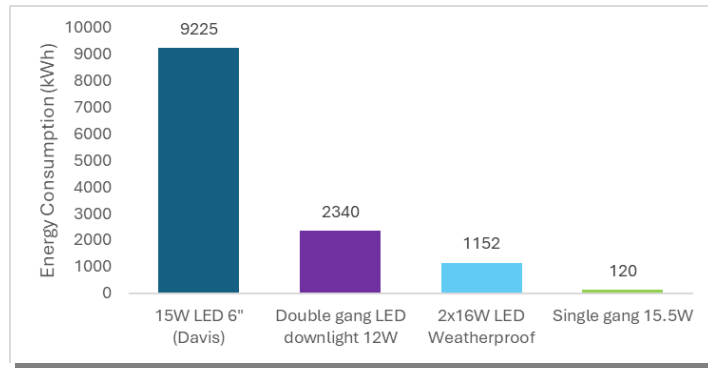


Figure 4: Energy Consumptions base on Types of Lighting

4.1.2.1 Energy Consumptions by Level (Month)

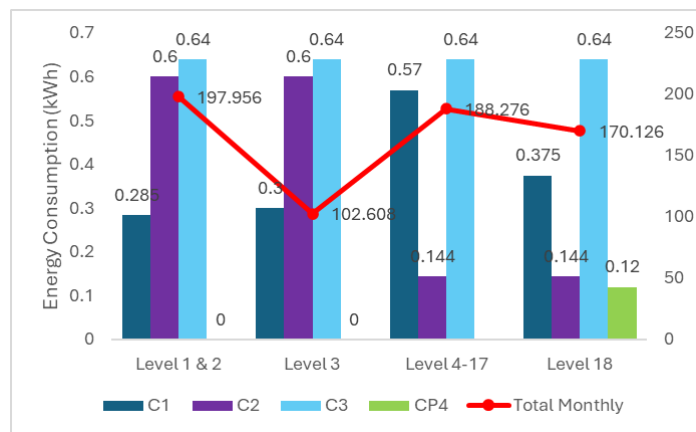


Figure 5: Energy Consumptions by Level (Month)

Figure 5 shows the estimated monthly energy consumption for lighting is 197.96 kWh each for Levels 1 and 2, 102.61 kWh for Level 3, 188.28 kWh per level for Levels 4 to 17, and 170.13 kWh for Level 18. The estimated simulated monthly energy consumption across all levels is 3,304.51 kWh.

This calculation still does not include of the use of two modes (Daylight mode and Night Mode) in the IoT system of energy consumption in Sunway Geo Tower. Therefore, to obtain an accurate simulation calculation, analyse the difference before and after the use of the IoT system in the lighting system in this building. The formula for the calculation according to the two modes is as Eq.2 and Eq.3

Day Mode:

$$kWh_{Day} = \frac{Watt \times Unit\ Numbers \times 11\ Hours \times 22\ Days}{100} \tag{Eq. (2)}$$

Night Mode:

$$kWh_{Night} = \left(\frac{(Watt \times Unit\ Numbers \times (13h \times 22d \times 24h \times 8d))}{1000} \right) \times 0.3 \tag{Eq. (3)}$$

This simulation calculation is analyzed by taking into account the number of units on each level according to each lighting system category and the total amount of energy consumption in one month. Table 3 show the total consumption and monthly energy consumption after taking into account according to Day mode and Night mode, implementation of IoT system.

Table 4: Table Summary for Energy Consumption after IoT system implementation

<i>Level/ Mode</i>	<i>Category 1</i>		<i>Category 2</i>		<i>Category 3</i>		<i>Category 4</i>		<i>Total kWh</i>
	<i>Day</i>	<i>Night</i>	<i>Day</i>	<i>Night</i>	<i>Day</i>	<i>Night</i>	<i>Day</i>	<i>Night</i>	
Level 1 & 2	68.97	40.92	14.52	8.6	15.49	9.18	-	-	157.63
Level 3	72.6	43.02	14.52	8.6	15.49	9.18	-	-	163.41
Level 4 - 17	137.94	81.74	34.85	20.65	15.49	9.18	-	-	299.84
Level 18	90.75	53.77	34.85	20.65	15.49	9.18	30.01	17.78	320.26

By using this simulation data, the expected amount of energy consumption before the use of IoT can be formulated to make a comparative analysis between energy consumption before and after the use of IoT can achieve the objectives of this study. In addition, to facilitate the calculation for analysis, this study calculates the total amount according to (categories C1-C4).

Therefore, the total amount in Table 4 show the total electricity consumption for the entire building in a month, with a division into two main operating modes. This amount is calculated from the total amount of each level that has been simulated.

Table 5: Total Energy Consumption Base on Operation Mode

<i>Operation Mode</i>	<i>Energy Consumption (kWh)</i>
Day mode	3,107.52
Night Mode	1,841.40
Total	4,948.92

4.2 Comparison of Electricity Bill Simulation and Data

Based on the pre-IoT simulation, the lighting system energy consumption was 4,948.92 kWh per month. Meanwhile, based on the electricity bill after the IoT implementation, the total building energy consumption was an average of 252,043 kWh per month. Using a conservative estimate that 20% of the total consumption was for the lighting system, the lighting system consumption value after the IoT was estimated using Eq.(4):

$$\text{Energy consumption after IoT} = 20\% \times 252,043 \text{ kWh} = 50,408.6 \text{ kWh} \quad \text{Eq. (4)}$$

This comparison shows that the pre-IoT consumption simulation is much lower than the actual consumption of the post-IoT lighting system estimated through the electricity bill. This shows that the simulation data only involves a certain part of the lighting that is conservatively calculated based on the list of lights, number of units and operating hours, while the bill data involves all lighting zones including areas that are inaccessible during data collection, parking and areas that may not be fully included in the simulation data for an accurate comparison.

Table 6: Comparison Lighting System Energy Consumption

<i>Condition</i>	<i>Energy Consumption (kWh)</i>
Simulation Before Using IoT	4,948.92
Electrical Bill After Using IoT	50,408.60

Table 5 shows comparison of the impression that the lighting system estimated from the bill (50408.6 kWh) covers a wider and more intensive space, while the simulation is based on the lights identified in the selected layout in the CMMS system (Easy 10) used in Sunway Geo Tower. Therefore, the simulation value is suitable for relative analysis of savings, while the bill value is for reference of the actual overall performance of the building.

Based on the simulation before IoT, the energy consumption of the lighting system was 4,948.92 kWh per month, while based on the electricity bill after IoT implementation, the estimated lighting consumption was 50,408.6 kWh per month. However, this difference occurs because the simulation only focuses on the lighting system, while the actual electricity bill covers the entire use of the lighting system in the building including areas that could not be accessed during data collection.

When compared in the context of the lighting system specifically, the value of 3,464.24 kWh is used to represent the estimated use of the lighting system after IoT considering a 30% decrease compared to the simulation use. Therefore, using the simulated total of 30% of the post-IoT energy consumption, this is taken and analyzed for comparison in energy and cost saving.

This reduction estimate is estimated from the reference MS1525: 2019 Code of Practice on Energy Efficiency and Use of Renewable Energy for Non-Residential Buildings which also states that lighting automation through motion sensors and time control can save energy at an average rate of 30%. And is taken into account through the Malaysian Green Building Index (GBI) Guidelines, which states that lighting automation systems and the use of sensors can reduce lighting energy consumption between 25% to 35%. Therefore, a conservative value of 30% was chosen as an estimate based on all the above factors.

4.2.1 Energy Reduction Calculation

This calculation for calculate energy savings achieved through the implementation of IoT-based lighting systems in the Sunway Geo Tower building. The purpose is to measure how much lighting energy consumption has been reduced after the IoT technology was installed. For this study, a conservative estimate of 30% reduction was used, in line with average savings documented in similar case studies and energy standards. Therefore, the new energy consumption is calculated as:

Table 7: 3.2.1 Energy Reduction Calculation

Total Monthly Consumption	Reduction Assumption
4,948.92 kWh	30% energy savings

Therefore, the new energy consumption is calculated as:

$$\text{Energy consumption after IoT} = 70\% \times 4,948.92 \text{ kWh} = 3,464.24 \text{ kWh} \tag{5}$$

$$\text{Reduction} = (4,948.92 - 3,464.24) \div 4,948.92 \times 100 = 30.00\% \tag{6}$$

Therefore, Implementation the IoT-based lighting system successfully reduced lighting energy consumption by 30%, which is a significant improvement in energy efficiency. These results highlight the effectiveness of smart lighting controls in reducing operational energy consumption in commercial office buildings.

4.2.2 Cost Savings Calculation

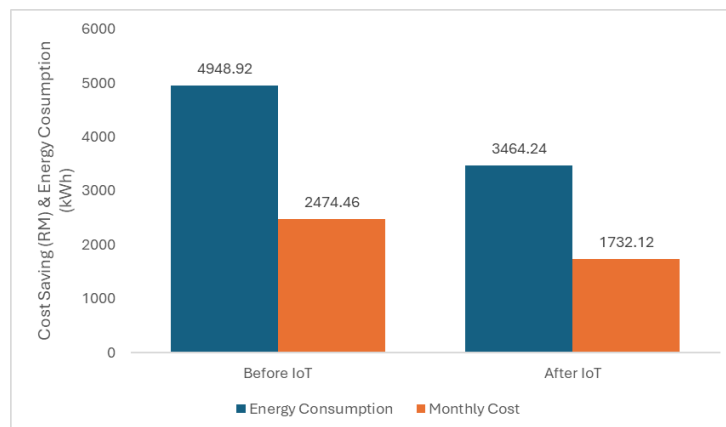


Figure 6: Graft Cost Savings

The 30% reduction in energy consumption shown in Figure 5 shows that IoT-based smart lighting systems are very effective in reducing energy waste in large-scale office buildings. In addition to saving monthly operating costs, they also reduce the energy load on the national grid, and contribute to Environmental Sustainability and Governances (ESG). Furthermore, these savings can be calculated in the long term to determine the economic value of the IoT system investment, as will be discussed in the next subsection on Return on Investment (ROI). If the current electricity tariff rate is RM0.50/kWh, then:

Cost Before IoT	= 4,948.92 kWh × RM0.50	= RM2,474.46/month
Cost After IoT	= 3,464.24 kWh × RM0.50	= RM1,732.12/month
Monthly Cost Savings	= RM2,474.46 - RM1,732.12	= RM742.34/month

This reduction is due to the effectiveness of the CMMS system automation function and the use of motion sensors that only activate lights when there is a user presence, as well as the activation of Night Mood that limits the operation of lights to only 30% capacity at certain times. Therefore, the estimated savings that occur each month are 1,484.68 kWh equivalent to RM742.34/month.

4.3 Return on Investment (ROI)

The (ROI) represents the time required to recover the cost of implementing the IoT-based smart lighting system at Sunway Geo Tower through monthly energy savings. Based on interviews with the facility management team during a site visit in May 2025, the total investment cost was estimated at RM50,000, which includes:

- a) Purchase and installation of motion sensors in critical areas (e.g., staircases, toilets, walkways),
- b) System integration with the Easy10 CMMS (including automation of Day and Night modes),
- c) Technical training and initial system maintenance.

From the analysis before, the system generates an estimated monthly electricity savings of RM742.34, based on reduced lighting energy consumption after IoT implementation. The ROI is calculated as:

$$\text{ROI (months)} = \text{RM}742.34 / \text{RM}50,000 \approx 67.3 \text{ months} \quad (7)$$

This indicates that the investment would be recovered in approximately 5 years and 7 months. While the payback period is moderate, the system offers long-term benefits through continuous energy savings, enhanced operational efficiency, and support for sustainable building management practices.

5. Conclusion

The research objectives outlined at the beginning of the study were successfully achieved through data collection, simulation, analysis, and site observation at Sunway Geo Tower, an 18-storey office building in Bandar Sunway, Selangor.

The first objective, which was to identify the key parameters of a smart IoT lighting system, was fulfilled through site visits and interviews with the facility management team. The building utilizes the CMMS Easy10 system integrated with motion sensors in various zones such as toilets, pantries, staircases, and meeting rooms. The lighting system operates under two automated modes: Day Mode (100%) and Night Mode (30%), indicating a structured and energy-efficient lighting control system that aligns with smart building principles.

In addition, a combination of simulated data (Before IoT) and actual electricity bills (After IoT) was used. The simulation showed a monthly energy consumption of 4,948.92 kWh before IoT. After implementation, energy usage was reduced to 3,464.24 kWh, representing a 30% reduction. This significant improvement is attributed to the motion sensors' ability to eliminate energy waste in unoccupied areas, and the automated scheduling via CMMS.

Finally, estimated the potential cost savings and ROI of the system. Based on the energy reduction and the commercial tariff rate of RM0.50/kWh, the monthly cost savings amounted to RM742.34. With a total implementation cost of approximately RM50,000, the payback period (ROI) was calculated at 67.3 months, or 5 years and 7 months. While the return period is relatively long, it reflects a steady and measurable return on investment in the long term.

Therefore, this study confirms that IoT-based smart lighting systems are a viable solution for improving energy efficiency and reducing operational costs in office buildings. Although the initial cost of implementation is high, but still give the long-term benefits. The system supports sustainable building operations, enhances facility management, and aligns with Malaysia's green building initiatives and national energy policies. These findings demonstrate the potential of IoT technology as a key enabler in the transition toward smart and sustainable building development in Malaysia.

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