

Energy Audit and Efficiency Optimization of an Examination Hall: A Case Study at Universiti Tun Hussein Onn Malaysia (UTHM)

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Energy efficiency in university buildings is increasingly important due to rising electricity demand, operating costs, and the need for sustainable building operation. Examination halls present particular challenges because occupancy, lighting, and air-conditioning requirements vary according to examination schedules. This study presents a preliminary energy audit of the F2 Upper examination hall at Universiti Tun Hussein Onn Malaysia (UTHM) to assess its energy performance and identify practical energy-efficiency opportunities. The audit comprised site inspection, indoor environmental measurements, lighting assessment, equipment evaluation, and active-power logging. Illuminance, temperature, relative humidity, and air movement were measured at nine locations, while electrical power was monitored over nine days from 16 to 24 June 2025. Morning illuminance ranged from 308–528 lux, with all measurements exceeding the reported 300-lux requirement, whereas nighttime illuminance ranged from 254–555 lux, with two readings below the criterion. The installed lighting system recorded a lighting power density of 11.57 W/m², exceeding the reported MS 1525:2019 limit of 8 W/m² by 44.6%. Estimated lighting consumption was 91.584 kWh/day, corresponding to an annual cost of approximately RM12,201.28. Active power varied from 76.98 to 81.03 kW, with higher loading observed on Phase C. De-lamping, LED retrofitting, and daylighting with zoned controls were identified as potential efficiency measures. LED retrofitting was estimated to save 12,348 kWh/year and RM4,507.02/year, with a simple payback period of 2.63 years. The findings highlight practical opportunities for improving lighting efficiency and reducing energy consumption in university examination facilities.

Keywords: Energy Audit, Examination Hall, Energy Efficiency, Lighting Power Density, LED Retrofit, MS 1525:2019, University Buildings

1. INTRODUCTION

Energy consumption in institutional buildings has become an important concern because of increasing electricity demand, rising operating costs, and the need to reduce environmental impacts [1]-[2]. Universities operate a wide range of energy-intensive facilities, including lecture rooms, laboratories, offices, libraries, and examination halls. Among these

facilities, examination halls can experience substantial variations in energy demand because their occupancy and operating schedules change considerably between examination and non-examination periods [3].

An energy audit provides a systematic method for investigating the energy performance of a building [1], [4]-[5]. It involves the examination of energy-use patterns, electrical equipment, environmental conditions, operating practices, and opportunities for energy conservation. In Malaysia, energy audits support efforts to improve energy efficiency, reduce electricity expenditure, lower carbon emissions, and promote sustainable building operation [6].

The principal parameters considered in an energy audit include illuminance, temperature, relative humidity, air movement, electrical power, and energy consumption. Illuminance, measured in lux, is used to evaluate whether lighting levels are appropriate for the activities conducted within a space. Relative humidity and temperature influence thermal comfort and the operation of air-conditioning systems, while air movement provides information regarding ventilation effectiveness. Electrical power logging enables the identification of peak demand, base-load consumption, load variation, and possible inefficiencies.

The F2 Upper examination hall at Universiti Tun Hussein Onn Malaysia (UTHM) was selected for this study because it is frequently used for examinations and can accommodate a high number of occupants during peak periods. The facility relies heavily on lighting and air-conditioning systems to provide suitable visual and thermal conditions. However, without a systematic assessment, excessive lighting, inefficient operating schedules, inadequate ventilation, and unbalanced electrical loads may remain undetected.

The objectives of this study were to determine the electricity consumption profile of the F2 Upper examination hall and identify its major energy-consuming systems. Additionally, the study aimed to assess the lighting, ventilation, and indoor environmental conditions within the space, comparing the measured illuminance and lighting power density against the requirements of MS 1525 [7]-[8]. Finally, the research sought to identify no-cost and low-cost energy-saving opportunities and propose practical measures to improve energy efficiency and reduce electricity wastage. The study focused primarily on electrical energy consumption associated with the lighting and ventilation systems. A preliminary energy audit was conducted through site inspection, environmental measurements, equipment assessment, power logging, and comparison with relevant Malaysian standards.

2. MATERIAL AND METHODS

2.1. Study Location

The study was conducted at the F2 Upper examination hall, located at UTHM, Parit Raja, Johor, Malaysia. The building contains a large examination room, ancillary spaces, corridors, and entrance and exit areas. Its energy demand is influenced by examination schedules, occupant density, lighting requirements, air-conditioning operation, and the use of electrical equipment.

The main examination space is equipped with fluorescent lighting installed in recessed diffuser fittings with mirror reflectors. The hall also uses air-conditioning and ventilation equipment to maintain acceptable indoor conditions during examinations. Because the room is large and environmental conditions may vary spatially, measurements were taken at multiple locations.



Figure 1. Exterior View of Building F2

2.2. Energy-Audit Procedure

The energy audit comprised several key activities, beginning with a preliminary walkthrough inspection of the F2 Upper examination hall to identify major electrical loads, particularly lighting and air-conditioning systems. On-site measurements were conducted to evaluate illuminance at selected points, alongside air movement, temperature, and relative humidity. The installed lighting capacity and lighting power density were then assessed and compared against MS 1525 requirements [1]. To capture variations between daylight-supported and artificial lighting conditions, measurements were carried out during both morning and night periods. Power logging was also conducted over a nine-day period from 16 June 2025 to 24 June 2025.

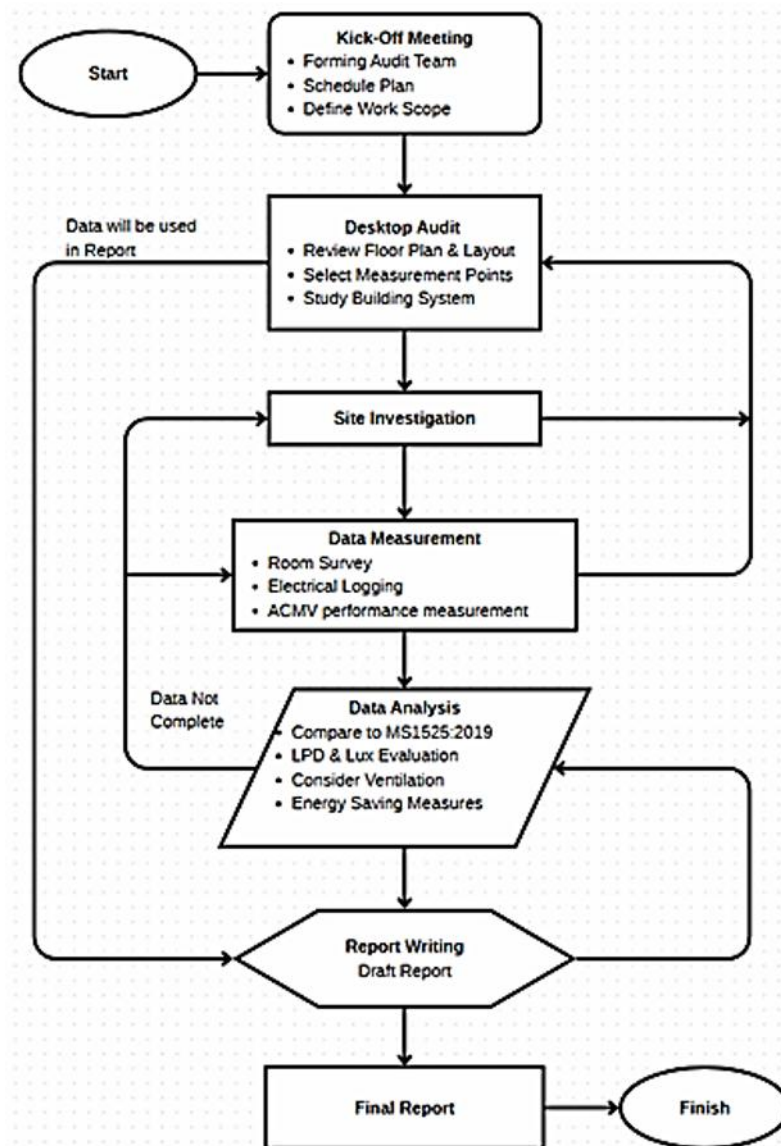


Figure 2. Flowchart of energy audit procedure

2.3. Measurement Instruments

Three principal instruments were used during the audit:

Table. 1 List of instruments were used

Intruments	Function
ME435 power logger	Used to monitor electrical parameters and active power consumption over time.
Testo 540 lux meter	Used to measure illuminance in lux at the selected work-plane locations.
HT625B digital anemometer	Used to measure air velocity, air temperature, and relative humidity.

Following recommended practice for safe electrical testing [9], the instruments were positioned at approximately 1 m above the floor to represent typical occupant conditions. The lux meter was kept away from direct light sources to minimize measurement bias. Air-temperature, air-velocity, and relative-humidity measurements were taken at each selected point, with the anemometer allowed to stabilize before recording.

2.4. Measurement Locations

The examination room was divided into three areas, designated R1, R2, and R3. Three readings were taken at each area, giving a total of nine measurement points. The selected points represented examiner and student locations and were intended to capture spatial differences in illuminance and indoor environmental conditions.

2.5. Illuminance Assessment

Illuminance was recorded in lux at each of the nine measurement points. The measured values were compared with the minimum illuminance requirement of 300 lux used in the original audit based on MS 1525. A reading was considered compliant when it was equal to or greater than 300 lux.

3. RESULTS AND DISCUSSION

3.1. Indoor Environmental Measurements

The measured environmental data are summarized in Table 2. Morning illuminance ranged from 308 to 528 lux. All morning measurements therefore exceeded the reported minimum requirement of 300 lux. The highest morning value, 528 lux, was recorded at R3. This indicates that the lighting system provided sufficient illumination for reading, writing, and examination-related activities during the morning measurement period.

Nighttime illuminance ranged from 254 to 555 lux. Although most locations complied with the 300-lux criterion, two readings were below the minimum requirement: 270 lux at R2 and 254 lux at R3. These results indicate that artificial lighting was not spatially uniform during nighttime operation. The lower readings may be associated with the position of the measurement points relative to lighting fixtures, the spacing of luminaires, or obstruction by furniture and other interior elements.

Air movement was very low during both measurement periods, ranging from 0 to 0.02 m/s in the morning and 0 m/s at night. This indicates limited detectable air movement at the measurement locations. Low air movement may affect occupant thermal comfort, particularly during examination periods when occupancy density is high. It may also indicate that the ventilation system requires additional assessment to determine whether air distribution is balanced and effective.

Relative humidity varied from 66.8% to 73.7%. Nighttime values were generally higher than morning values. Temperature ranged from 24.3 to 24.8°C in the morning and from 27.9 to 29.3°C at night. The higher nighttime temperatures reported in the audit suggest that the thermal condition of the hall varied significantly between the measurement periods and should be considered when evaluating air-conditioning performance, consistent with findings from other UTHM classroom thermal-comfort studies [8], [10].

Table 2. Environmental measurements in the F2 Upper examination hall

Period	Measurement range	Illuminance (lux)	Air movement (m/s)	Relative humidity (%)	Temperature (°C)
Morning	Minimum–maximum	308–528	0–0.02	66.8–70.9	24.3–24.8
Night	Minimum–maximum	254–555	0	70.8–73.7	27.9–29.3

3.2. Compliance With Illuminance Requirements

The morning measurements complied with the reported MS 1525 minimum requirement of 300 lux at all nine points. The results are shown in Table 3.

Table 3. Morning illuminance compliance

Area	Reading range (lux)	Compliance
R1	308–338	All readings complied
R2	351–409	All readings complied
R3	341–528	All readings complied

The nighttime results are shown in Table 4.

Table 4. Nighttime illuminance compliance

Area	Reading range (lux)	Compliance
R1	347–555	All readings complied
R2	270–394	One reading below 300 lux
R3	254–348	One reading below 300 lux

The results demonstrate that the hall generally achieved adequate illuminance. However, compliance based only on the average or majority of readings may hide local under-lighting. The two nighttime readings below 300 lux are important because examination activities require consistent visual conditions across the occupied area. Additional measurement and adjustment of individual lighting circuits would therefore be appropriate.

At the same time, several illuminance values were substantially higher than 300 lux. The maximum recorded value was 555 lux at night, while the maximum morning value was 528 lux. This combination of local under-lighting and over-lighting suggests that the principal issue is not simply insufficient lighting capacity, but also the spatial distribution and control of the lighting system.

3.3. Lighting Power Density

The installed lighting system consisted of 318 lamps rated at 36 W per lamp. Based on the reported room area of 990 m², the total installed lighting power was 11,448 W, resulting in an LPD of 11.57 W/m². The calculated LPD exceeded the reported MS 1525:2019 limit of 8 W/m² by 3.57 W/m² [7], a pattern of over-lit, non-compliant lighting also reported in other Malaysian institutional-building audits [11]–[12]. The percentage exceedance was calculated as:

$$\frac{11.57 - 8.00}{8.00} \times 100 = 44.6\% \quad \text{Equation 1}$$

Thus, the lighting system used approximately 44.6% more installed power per unit floor area than the reported recommended limit. This finding indicates substantial potential for energy reduction through improved lighting controls, removal of unnecessary lamps, and replacement of fluorescent lamps with more efficient LED systems [13]–[14].

3.4. Lighting Energy Consumption

The original energy analysis identified two categories of fluorescent fixtures, as shown in Table 5.

Table 5. Reported lighting energy consumption

Equipment	Quantity	Rated power per fixture (W)	Operating period (h/day)	Daily consumption (kWh/day)
3 × 36 W recessed diffuser with mirror reflector	98	108	8	84.672
3 × 36 W recessed diffuser with mirror reflector and 3-h battery backup	8	108	8	6.912
Total	106	—	8	91.584

The standard recessed diffuser fixtures accounted for 84.672 kWh/day, or approximately 93.8% of the total reported lighting energy consumption. The emergency backup fixtures accounted for 6.912 kWh/day, or approximately 6.2%. The total daily lighting energy consumption was 91.584 kWh/day under the assumed 8-h operating schedule.

Using the reported tariff of RM 0.365/kWh, the calculated lighting cost was RM 33.43/day. The projected monthly cost was RM 1,002.84, while the projected annual cost was RM 12,201.28.

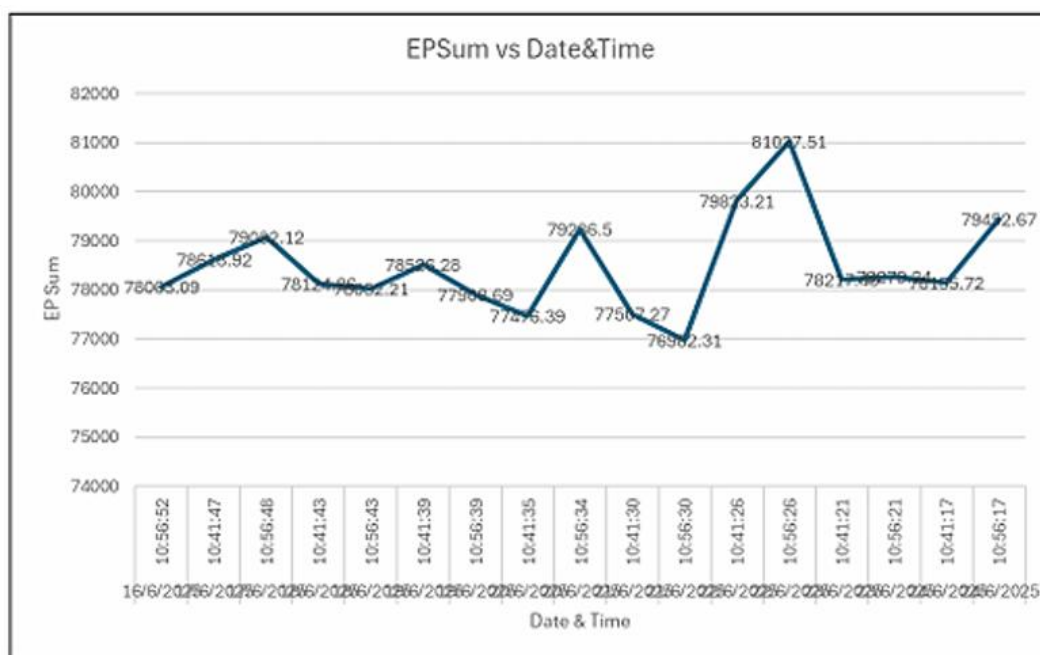
Table 6. Reported lighting-energy cost

Period	Energy consumption	Estimated cost
Daily	91.584 kWh	RM 33.43
Monthly	2,747.52 kWh	RM 1,002.84
Yearly	33,428.16 kWh	RM 12,201.28

These cost estimates are based on continuous operation according to the assumed schedule and should therefore be interpreted as baseline estimates. Actual annual costs would depend on examination schedules, holidays, occupancy, operating hours, tariff conditions, and whether all lighting circuits operate simultaneously.

3.5. Active-Power Logging

Active power was logged over nine days, from 16 June 2025 to 24 June 2025. The reported total active power, represented by EPSum, varied from 76,982.3 W to 81,027.5 W.

**Figure 3.** EP Sum vs Date & Time Graph

The lowest recorded value was 76,982.3 W on 21 June 2025 at 10:56:30, whereas the highest value was 81,027.5 W on 22 June 2025 at 10:56:26. The difference between these values was approximately 4,045.2 W. This variation indicates that the building load was relatively stable but changed according to occupancy, lighting operation, air-conditioning demand, and other equipment use.

The recorded phase values also indicated that Phase C carried the highest load in most observations. This may suggest phase imbalance. Phase imbalance can contribute to inefficient electrical distribution and should be investigated by qualified electrical personnel [15]. Further monitoring at shorter intervals would be useful for determining whether the imbalance is persistent or associated with particular operating conditions.

3.6. Energy-Efficiency Opportunities

3.6.1. De-lamping

The original project proposed reducing the installed lighting power from 11,448 W to the reported standard power of 7,920 W, corresponding to an LPD of 8 W/m². The excess power was:

$$11,448 - 7,920 = 3,528 \text{ W}$$

Equation 2

Using the reported 36-W lamp rating, the theoretical number of lamps to be removed was:

$$\frac{3,528}{36} = 98 \text{ lamps} \quad \text{Equation 3}$$

Assuming 8 operating hours per day and 250 operating days per year, the reported annual energy saving was:

$$3,528 \times 8 \times 250 \div 1000 = 7,056 \text{ kWh/year} \quad \text{Equation 4}$$

The corresponding annual cost saving was:

$$7,056 \times 0.365 = \text{RM}2,575.44/\text{year} \quad \text{Equation 5}$$

De-lamping has the advantage of requiring relatively little capital expenditure, as also observed in comparable lighting-audit case studies [16]. However, the theoretical removal of 98 lamps should not be implemented solely from the LPD calculation. A lighting redesign, trial de-lamping, and post-intervention illuminance assessment would be necessary to ensure that all examination positions continue to meet the required visual conditions.

3.6.2. LED Retrofitting

The proposed retrofit replaced the existing 36-W lamps with 18-W LED alternatives, representing a nominal 50% reduction in lamp power. Based on the reported 318 lamps, the proposed new lighting load was:

$$318 \times 18 = 5,274 \text{ W} \quad \text{Equation 6}$$

The resulting LPD was:

$$\frac{5,274}{990} = 5.78 \text{ W/m}^2 \quad \text{Equation 7}$$

This value is below the reported 8 W/m² limit set by MS 1525:2019 [7]. The original project estimated annual energy savings of 12,348 kWh/year and annual cost savings of RM 4,507.02/year. Based on an assumed purchase and installation cost of RM 60 per unit, the total retrofit cost was:

$$318 \times 60 = \text{RM}19,080 \quad \text{Equation 8}$$

The simple payback period was calculated as:

$$\frac{19,080}{4,507.02} = 2.63 \text{ years} \quad \text{Equation 9}$$

The reported payback period of 2.63 years indicates that LED retrofitting could be economically attractive, comparable to payback periods reported for LED and efficient-lighting retrofits in other Malaysian university buildings [17]-[18]. In addition to reducing lighting power, LED systems may reduce maintenance requirements because of their longer service life. Nevertheless, the proposed 18-W replacement should be verified for luminous flux, colour rendering, glare, compatibility with existing fittings, emergency-lighting requirements, and actual illuminance at all examination positions.

3.6.3. Daylighting And Lighting Controls

Daylighting provides an opportunity to reduce artificial-lighting demand during periods when sufficient natural light is available, with daylight-linked lighting controls shown to reduce lighting energy consumption in educational buildings [19]. Potential measures include:

- Rearranging seating and work areas to improve access to daylight.
- Using reflective surfaces or light shelves to distribute daylight deeper into the room.
- Installing daylight sensors or automatic lighting controls.
- Zoning lighting circuits according to window proximity and occupancy.
- Switching off or dimming lighting in areas that already exceed the required illuminance level.

Daylighting should be implemented carefully because excessive solar gains, glare, and uneven illuminance can reduce occupant comfort. A practical approach would be to combine daylight sensors with zoned lighting controls and verify performance through morning and afternoon illuminance measurements.

4. CONCLUSIONS

This study presented a preliminary energy audit of the F2 Upper examination hall at UTHM. The audit examined illuminance, air movement, relative humidity, temperature, installed lighting power, lighting energy consumption, and active electrical power.

The morning illuminance values ranged from 308 to 528 lux, and all recorded morning readings met the reported MS 1525 minimum requirement of 300 lux. At night, illuminance ranged from 254 to 555 lux, with two readings below the requirement. These results indicate that the hall generally had adequate lighting but exhibited local under-lighting and over-lighting.

The calculated lighting power density was 11.57 W/m^2 , which exceeded the reported MS 1525:2019 limit of 8 W/m^2 by 44.6%. The existing lighting system was estimated to consume 91.584 kWh/day, corresponding to an annual energy cost of approximately RM 12,201.28 under the assumptions used in the original project.

The active-power logging results showed a relatively stable but variable electrical load between 76,982.3 W and 81,027.5 W. The consistently high loading observed on Phase C suggests a possible phase imbalance that should be investigated through a detailed electrical assessment.

Three energy-efficiency opportunities were identified. De-lamping could theoretically save 7,056 kWh/year and RM 2,575.44/year. LED retrofitting was estimated to save 12,348 kWh/year and RM 4,507.02/year, with a simple payback period of approximately 2.63 years. Daylighting, combined with zoned controls and daylight sensors, could further reduce artificial-lighting demand.

The recommended implementation sequence is to begin with operational improvements and trial de-lamping, followed by detailed verification of illuminance distribution. LED retrofitting should then be considered where fixtures are suitable and the required visual conditions can be maintained. Future work should include longer-duration power monitoring, detailed HVAC assessment, verification of tariff classification and current electricity rates, electrical phase-balance testing, and post-intervention measurement of energy and indoor environmental performance [20]-[23].

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