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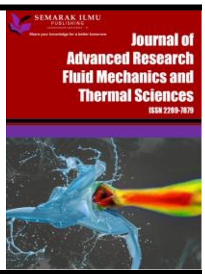

Energy Efficiency Study in Alor Gajah Municipal Council Buildings

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ABSTRACT

Energy efficiency in buildings plays a prominent role in the integrated urban development and environmental planning. By reducing the energy consumption of buildings, the environmental impact and carbon footprint are less, as well as costs for energy are reduced and optimized. The poor results from previous energy efficiency initiatives had forced the Malaysian government to launch National Energy Efficiency Action Plan for 10 years implementation period of 2016-2025 (NEEAP) after taking into account the socio-culture, policy, financial, and administration barriers. The objective of this study was to present and discuss the findings of the energy audit for the Alor Gajah Municipal Council (MPAG) building complex. MPAG will be able to save up to RM2,400,00.00 in energy spending between 2020 and 2030, should all the energy efficiency initiatives be fully implemented together with renewable energy. By investing in energy efficiency MPAG can achieve substantial energy cost savings throughout the facilities, demonstrate energy and environmental leadership, and raise self-awareness of the benefits of energy efficiency. This case study also summarises the recommendations for the implementation of energy efficiency in the building complex. Some suggestions are made in this paper as measures to improve the delivery mechanism. The Internet of Energy (IoE) is an implementation of the Internet of Things technology (IoT) will becoming a legal science tool to serve the purpose of a smart city.

1. Introduction

The State of Melaka aspires to become a Sustainable State by the year 2035 through their Melakaku Maju Jaya Strategic Plan 2035. The Melakaku Maju Jaya 2035 Strategic Plan (PSMJ 2035) is a reference document for the achievement of administrative excellence at the State Government level. Its preparation involves setting out future direction, identifying strategic issues and challenges, drafting strategies towards achieving objectives targeted for the set period. The PSMJ 2035

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document has targeted a period of 15 years (2021 – 2035) to realise the State Government's aspiration and vision: "Towards A Sustainable State" for Melaka. This aim is consistent with the policies on national level towards environmental sustainability.

In 2009 at the United Nations Conference of Parties on Climate Change held in Copenhagen (COP15) the former Prime Minister Datuk Seri Najib Tun Razak declared that Malaysia is adopting an indicator of a voluntary reduction of up to 40% in terms of emissions intensity of GDP by the year 2020 compared to 2005 levels [1]. At the same time, Malaysia also aims to attain high-income status by the year 2020 and the Governments Economic Transformation Programme and Tenth Malaysia Plan are providing the framework for this development. The actual achievement from this plan however, is yet to be published by the government particularly post Covid-19 pandemic. Melaka has already embarked on a path towards sustainable urban growth, as the State took a first step in preparing the Green Technology Blueprint in 2011, which is the vision for the transformation of the State into a Green Technology City State by 2020. In 2014, Melaka furthermore prepared a Green City Action Plan, which details the steps in developing the Green City concept in various sectors such as energy, water, transport, waste etc [2].

The action plan is furthermore a flagship project under the Indonesia-Malaysia-Thailand Growth Triangle (IMT-GT) Green Cities Initiative and was introduced by the former Melaka Chief Minister Datuk Seri Ir. Hj. Idris bin Hj. Haron on the ADB conference on Green Cities Regional Conference in Manila in May 2014 [3]. Energy, especially energy efficiency in government buildings plays a prominent role in the integrated urban development and environmental planning. By reducing the energy consumption of buildings, the environmental impact and carbon footprint are less, as well as costs for energy are reduced. At the same time building facilities are being upgraded, so the operation is optimised and the comfort for the users is improved.

This paper summarises the findings from an energy efficiency study carried out in the municipal council building of Alor Gajah district, one of three districts in Melaka. The study involved walk-through and detailed energy audit in the premises, including survey on thermal comfort among the staff working in the said buildings. The findings were essential towards complementing the aim of the state government towards transforming Melaka and its township towards becoming a sustainable and resilient city.

2. Literature Review

Malaysia is one of the most rapidly urbanising countries in Asia, with more than 70% of the population living in urban areas [4]. The Greenhouse Gas (GHG) emissions levels in Malaysia are high compared with other countries at similar stages of development. More than half of Malaysia's emission sources are directly related to urban settings, with emissions mainly coming from the energy sector (76%), the waste sector (12%) and the industrial processes sector (6%). The electricity and transportation sub-sectors are the biggest contributors to emissions from the energy sector [5]. Alor Gajah zoning area mostly 60% are covered under agriculture and green area. Starting from 2007 MPAG had started the emission calculation to identify the high emission contribution to the environment. Melaka state under Melaka Green Technology Corporation has conducted a study on Melaka GHG carbon inventory for the state of Melaka and the district. About 1.96 MT CO_2 eq had recorded on 2013 with emissions per capita 2.33 ton CO_2 eq (Asian Development Bank, 2013).

Increasing rates of urbanisation, recording up to 95% in developing countries, will see cities grow significantly and bringing along with this is a host of socio-economic and environmental challenges from reduced air quality to increased traffic congestion. For example, the Asia-Pacific region is anticipated to see a rise in middle-class consumers of about 2.7 billion people by 2030 [6]. Climate change is a long-term change in the earth's climate that occurs either naturally or by human interference. The main reason for recent climate change is due to the accumulation of heat trapping greenhouse gases (GHG) mainly produced by human activities. Mitigating the impacts of climate change requires an eclectic approach as this is a complex dilemma that cannot be solved from just one angle [7].

The state of Melaka aspires to become a Sustainable State by 2035. This aspiration stems from emphasis towards environmental sustainability at the national level. Melaka has already embarked on a path towards sustainable urban growth. Efforts include government led policies and projects, as well as private sector and citizen initiatives, that seek to enhance livability in Melaka. Melaka took a first step in preparing a comprehensive approach towards urban sustainability, when it adopted the Green Technology Blueprint in 2011 and formalized a vision to transform Melaka "Towards A Sustainable State" [8]. The Green City Action Plan is a next step towards helping Melaka reaching its vision. It is based on the underlying premise that integrated and comprehensive approaches will lead to a greener Melaka [2].

Under Malaysia Energy Efficiency Action Plan policies, the terms energy efficiency, energy conservation and renewable energy (RE) are often interchangeable. They share the same goal and objective to reduce demand for energy, to safeguard the fast depleting natural fossil fuel resources and to protect the environment from harmful carbon emission. Energy efficiency is the objectives to decrease the quantum of energy needed to deliver products and services. On the other hand, energy conservation is the endeavour made to decrease energy usage by using less energy services [9]. The complexity of relationship between improvement of energy efficiency and the utilisation of renewable energy technologies is widely reported. However, if the potentials of both programmes are combined the world energy demand can be reduced by around 25% by 2035. Energy savings from renewable is estimated to be a quarter from total energy demand while energy efficiency measures delivering the rest. Therefore, meeting the objectives of renewable energy can contribute towards the success of energy efficiency measures in reducing global energy demand [10].

Another study on building energy efficiency brings about lower energy use for the same or, then again better-quality outcome. It shields against the expanding energy request from quick urbanization and from top request deficiencies that outcome in routine power cuts [11]. Due to increased energy demand and therefore the depletion of existing fossil fuel based sources, it is required to use the energy more efficient [12]. A study investigated potential energy saving in Masjid Sultan Ibrahim, Universiti Tun Hussein Onn Malaysia. The study found the relamp energy saving action able to reduce 35.5% of total lamp energy consumption [13].

The key step to optimizing energy is an energy audit. It is a survey on energy flow to reduce energy consumption within a building, process or system, without adverse effects on the power output. Therefore, the energy audit is a continuous strategy to manage a building energy pattern. The costs of the audit are related directly, how much data will be collected from the analysis and how many conservation opportunities can be identified. The first distinction is therefore drawn between the costs of the audit that determine the type of audit to be carried out. The other difference is between the types of facility. For instance, a building audit can highlight the requirements for building cover, lighting, heating and ventilation [14].

Alor Gajah district has great potential to become an industry-centric city in the next 20 years. It is supported by local plans that are being implemented at the state level. The need for electricity is expected to increase by 150% based on the projected feedback from Tenaga Nasional Berhad (TNB) and the need to use alternative energy such as solar energy is very much needed.

3. Methodology

The audit is divided into 3 stages: walk-through, detailed audit and implementation plan as shown in Figure 1. As the project comprises a total of 9 buildings, the final implementation plan comprises all 9 buildings in order to combine the measures into larger projects. This creates economy of scale of the individual measures and streamlines the implementation. It will also enable smaller buildings to improve the energy performance, as their smaller investments will be combined with larger investments in the larger buildings.

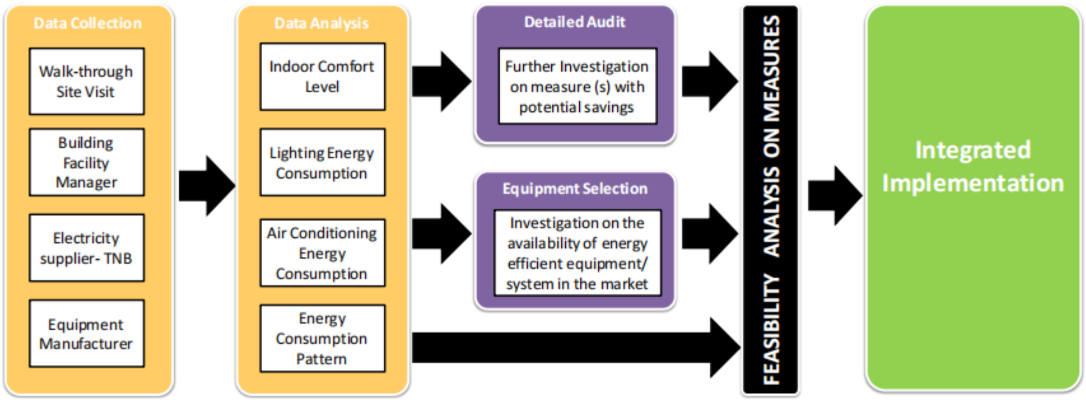

Fig. 1. Process flow of energy audit

4. Data Collection

Data collection was carried out in the following ways; walk-through audit, direct measurements, interview and data collection from facility managers, data from electricity supplier – TNB, and obtaining information from equipment suppliers.

4.1 Walk-Through Site Audit

The whole facility walk-through site audit was carried out. During the audit, the building envelope, the indoor comfort level including lux, temperature, CO_2 and humidity levels, the quantity and specification of energy consuming equipment including lighting and cooling systems, operational practices and building energy system were investigated. The majority of the facility has been directly surveyed, but in the cases that the rooms were inaccessible, the installations in these rooms were estimated based on the installations in similar rooms in the building.

4.2 Interview and Obtaining Data from Facility Managers

Information on operation hours and function of rooms and installations were obtained from the facility managers or other staff. Technical drawings and electricity bills were acquired from the building owner. Actual measurements were taken if the drawings were unavailable.

4.3 Obtaining Data from Electricity Supplier

Electricity demand log files were obtained from electricity supplier, Tenaga National Berhad (TNB). The building has Remote Meter Reading equipment installed, which transmits the power demand every 30 minutes to the electricity supplier.

4.4 Obtaining Information from Equipment Suppliers

Based on the information on the installed equipment obtained during the site audit, technical data and specification on the equipment were obtained from equipment suppliers.

5. Energy Audit Instruments

Detailed survey and measurements were carried out in the building. The instruments used for the audit are listed in Table 1 below.

Table 1
Instrument list

No	Types of Instruments
1	Fluke 62 MAX Infrared Thermometer
2	Tenmars Light Meter TM 202
3	RS-1260 Humidity Temperature Meter
4	Stanley TLM99 30m True Laser Measure
5	Fluke 323 True RMS Clamp Meter
6	Testo 540 Light Intensity Measuring Instrument
7	Psensor-RH Portable CO_2/Temp/RH Meter
8	Prova 6200 Graphic Single Phase Power Clamp
9	UT Laser Surface Thermometer
10	GE Panametrics PT878 Ultrasonic Liquid Flow Meter
11	Testo 177-T4 Logger with Display
12	CHK GridSense PowerMonic PM35 Power Quality Analyser
13	Olympus 26 mg Pocket Thickness Gauge

5.1 Data Analysis

Based on the collected data, the indoor comfort levels were analysed. The data was sorted by room category such as lobby, office room, toilet, etc. Based on the historical electricity bill, the baseline electricity consumption and cost were determined.

The energy consumption of the cooling system was estimated based on the input power and operation hours of units. The energy consumption of the lighting system was estimated based on the number of lamps, the wattage of lamps and the operation hours.

5.2 Detailed Audit

For the impact of changes in the cooling demand a simulation was made to assess the potential energy savings. The potential energy savings measures for the building complex and forms the basis for the final recommendation of the energy efficiency project for the building, where each individual type of measures is described and the impact is calculated based on the specific characteristics in the building and the equipment. The measures have been grouped in a manner that allows them to be implemented as stand-alone measures, although they will have some dynamic impact on each other. For instance, reducing the power consumption of lamps will reduce the cooling load.

5.3 Building Characteristic

This section describes the physical characteristics, functions and the operation of the building complex. It gives an overview of energy consumption pattern, which will be further elaborated in the following sections.

5.4 Location

Majlis Perbandaran Alor Gajah (MPAG) serves as the local authority for Alor Gajah district and is located along Lebuh AMJ. There are 3 buildings on the compound, which are named Block A, bungalows B and C, D and E, F and G, H, I, J and K, M, kindergarten, Surau and internal hall as shown in Figure 2 below.

Fig. 2. MPAG sky view building layout

6. Results and Discussion
6.1 Energy Consumption and Costs

The energy usage is primarily electricity, which is used for lighting, cooling and equipment in the building complex. The supply is common for all the buildings within the complex and is from the national electricity company, TNB. Figure 3 shows monthly consumption is fluctuating between 29,600 kWh/month and 46,400 kWh/month, with a monthly average of about 38,100 kWh/month.

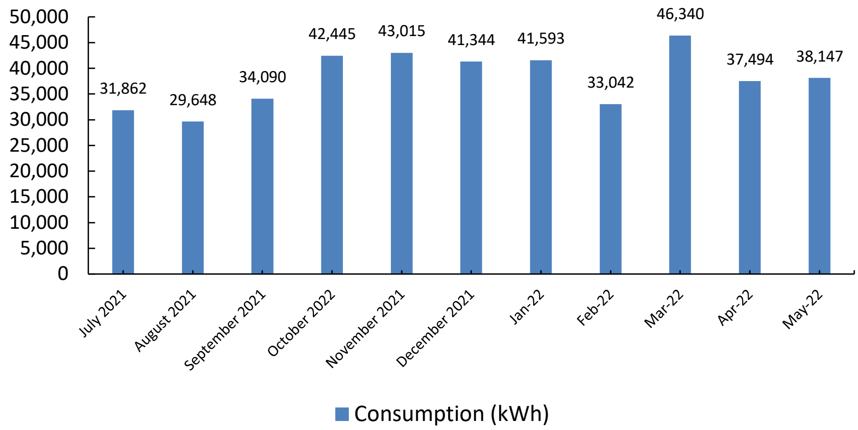

Fig. 3. Monthly Electricity Consumption

The electricity cost for the period of 2021/2022 is based on the electricity tariff that was prevailing in the period. The figure below shows the cost in 2021/2022 and the future cost based on the increased tariff for 2014. Figure 4 shows average monthly electricity cost will increase from RM 18,700 to RM 21,300. The yearly electricity cost is expected to be around RM 270,000 with the new tariff, which is about 19% increment.

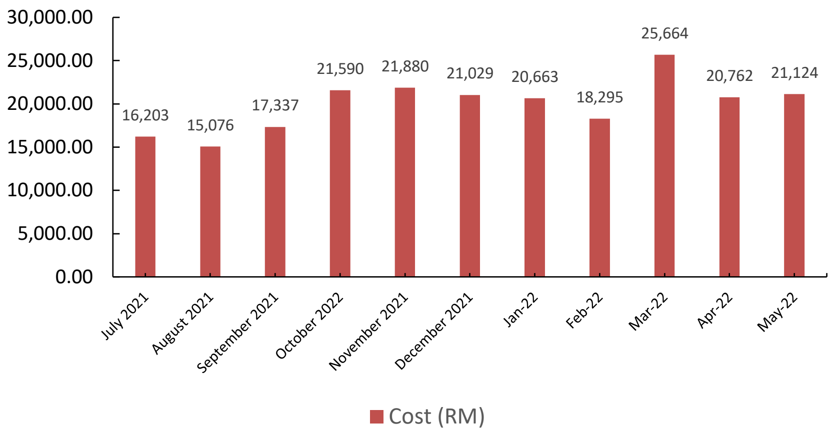

Fig. 4. Monthly Electricity Cost

6.2 Energy End-uses

Figure 5 shows the bulk of the energy is used for cooling in the buildings with a total of 67% of all the electricity consumption. Some 14% of the electricity is consumed for lighting and the balance 19% is taken up by other equipment, such as lifts, printers, water heater, office equipment etc. MPAG only uses split units to provide cooling. They consist of an indoor and an outdoor unit. The indoor unit distributes the cold air to the room whilst the outdoor unit removes excess heat via a fan. The lighting system is mainly ceiling lights for general lighting.

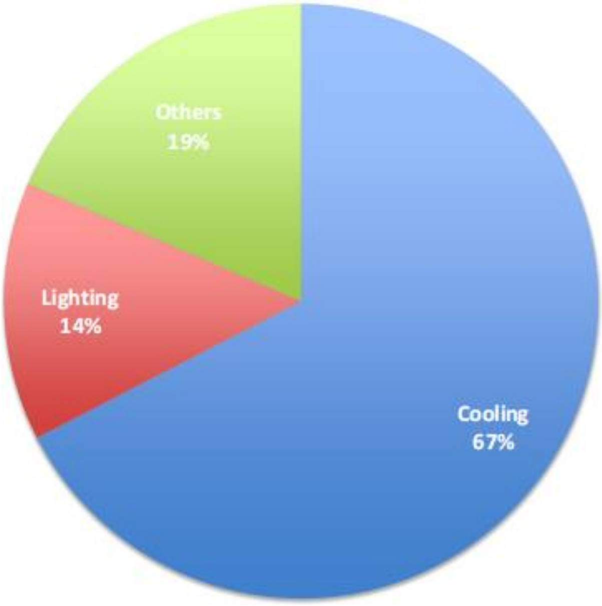

Fig. 5. Energy consumption by major consumer categories

The majority of lamps are T8 fluorescent tubes installed in ceiling lights and they take of 58% of the load as shown in Figure 6 below. Compact Fluorescent Lamps, CFL, are used in mainly down lights and they consume about 37% of the total electricity consumption for lighting. Other lamps take up about 5% of the electricity for lighting and a part of these lamps are energy efficient LED lamps.

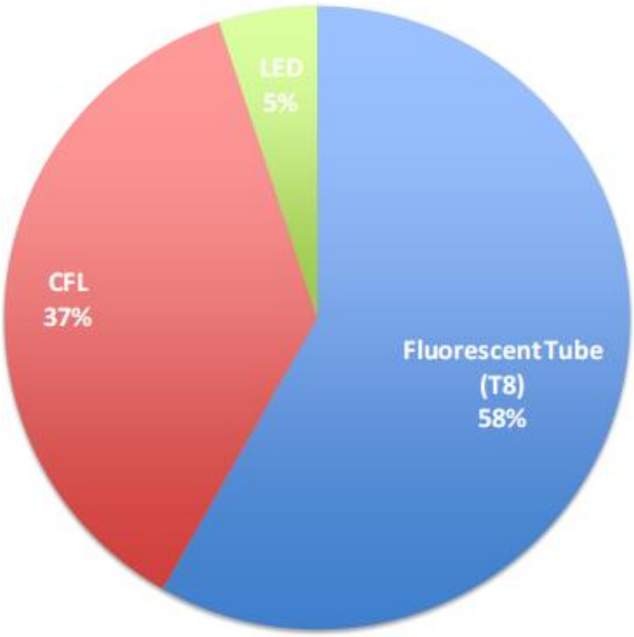

Fig. 6. Load distribution for the lighting system

6.3 Lighting System

The types and quantity of lights used in the building were surveyed and compiled in a database. The annual energy consumptions are estimated based on the wattage of lamps and the operation hours. Most of the lightings are controlled manually. There are no sensors or timers installed to automatically control the light.

The operation hours of lamps at different rooms and spaces are used to calculate the energy consumption of lighting system in the complex. The operation hours for different room categories are summarized in Table 2 below. However, there can be different operation hours for rooms under the same category. This will be taken into account in the detailed calculation.

Table 2
Lighting operation hours by room category

No	Type	Daily Operation Hours	Annual Operation Hours	Remarks
1	Cafeteria	10	2,440	Weekdays
2	Corridor	24	5,856	Weekdays. For some locations it is 10 hours/weekday
3	Gym	12	2,928	Weekdays
4	Lobby	24	5,856	Weekdays. For some locations it is 10 hours/weekday
5	Meeting Room	10	2,440	Weekdays
6	Office Room	10	2,440	Weekdays
7	Open Office	10	2,440	Weekdays
8	Prayer Room (Surau)	10	2,440	Weekdays
9	Stairs	24	5,856	Weekdays. For some locations it is 10 hours/weekday
10	Store Room	10	2,440	Weekdays
11	Toilet	24	5,856	Weekdays

*For annual operation hours, the calculation is done based on the basis of 365 days/yr (52 weeks), 2 day/ weeks as weekend which is equivalent to 52x2= 104 days, Public Holiday= 17days/yr, work day= 365-104-17= 244 days/yr

6.4 Indoor Comfort Level

The indoor comfort level was surveyed by measuring the lux, temperature, CO_2 and relative humidity levels in the buildings. This section provides information about the comfort level as well as providing indications of potential energy wastages in the use of the buildings. The diagrams below show the results of the audit. It shows the measured values by providing the average value as well as the maximum and minimum values registered. As the measurements have been made throughout the buildings in all rooms and locations, the diagrams provide the aggregated results for each room category. The results are compared to the recommended levels set by either standards or best practices.

6.4.1 Lux level

Figure 7 shows the lux levels are compared with the required levels set by the MS 1525:2019 guidelines for energy efficiency. Most of the office spaces are under lit. This can be due to either poor lamp efficacy or some areas are walkways where less light is required. In addition, the storerooms and toilets are over lit, this may indicate that in some of these spaces there may be sufficient daylight during the day time, and artificial lighting may not be required.

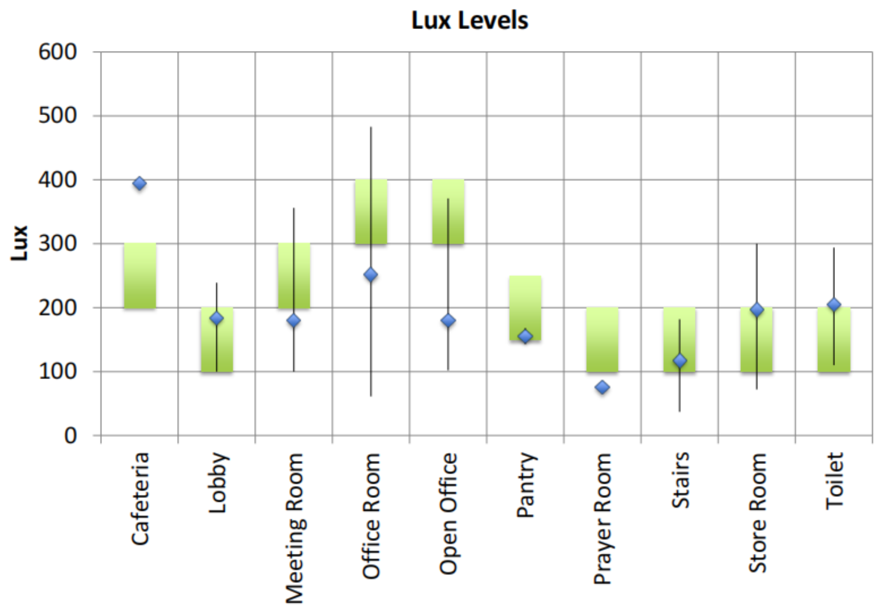

Fig. 7. Measured luminance levels. The average of the measured values is shown in blue, with the maximum and minimum levels. The green area shows the recommended levels

6.4.2 Temperature levels

In most air-conditioned areas, average temperatures are between 23°C and 28°C. The recommended temperature level for air-conditioned areas is between 24-26°C as shown in Figure 8 below. For the meeting rooms the temperatures registered are high, but this may be due to that the rooms were not in use at the time of the measurements and therefore not air-conditioned.

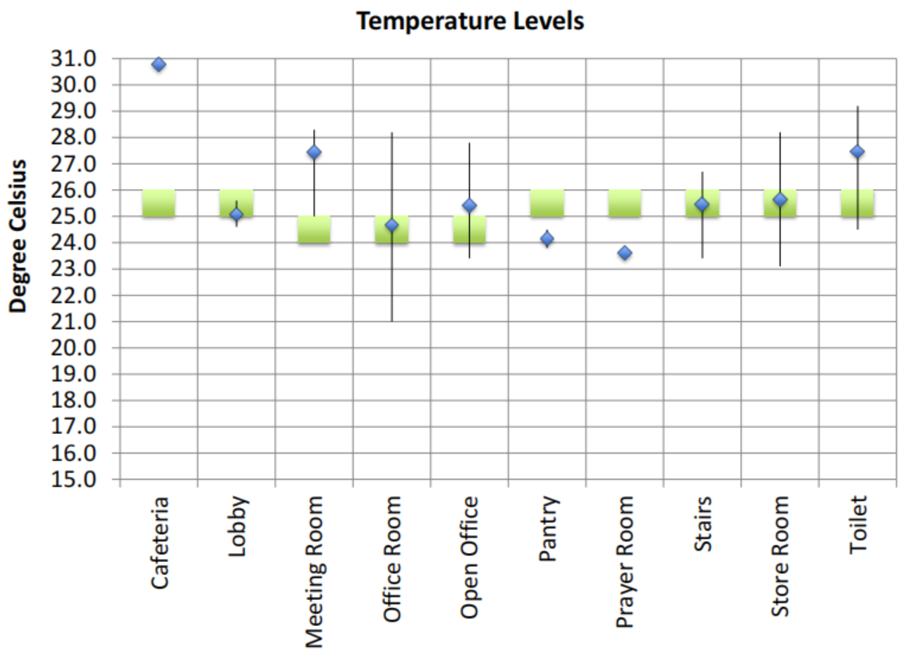

Fig. 8. Measured temperature levels. The average measured temperature is shown in blue, with the maximum and minimum levels. The green area shows the recommended levels

6.4.3 Carbon dioxide (CO_2)

Figure 9 shows the levels of CO_2 are well within the recommended best practice levels set by Department of Occupational Safety and Health (DOSH). In general, the levels are about half of the required ceiling level for best practice, and the amount of fresh air is very high in the building. This indicates that fresh, warm outside air may be introduced to the building through open windows, doors or leaks in the building envelope and thus increases the cooling load and leads to energy wastage.

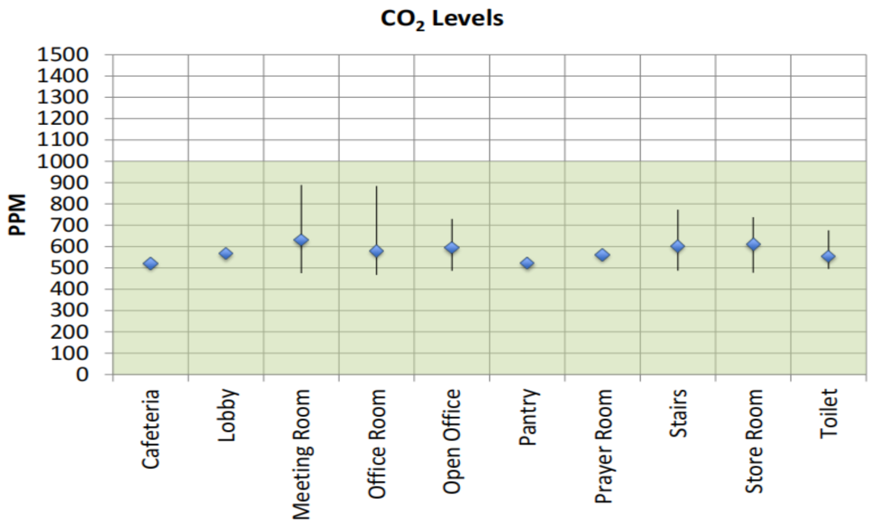

Fig. 9. Measured CO_2 Levels. The average CO_2 level is shown in blue, with the maximum and minimum levels. The green area shows the recommended level

6.4.4 Relative Humidity (RH)

Most of the relative humidity readings are well within the required level as shown in Figure 10. However, in some areas such as meeting rooms and offices it can drop below 40%. This indicates energy wastage in terms of excessive dehumidification by the air-conditioners.

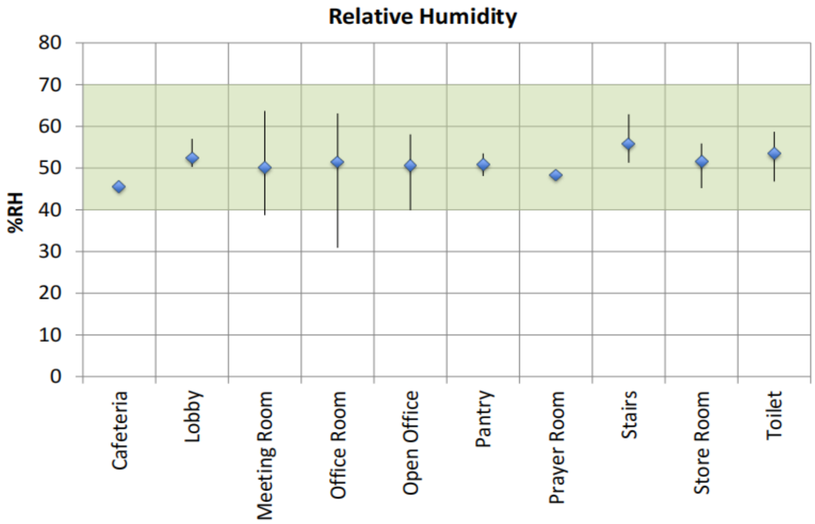

Fig. 10. Measured relative humidity. The average relative humidity levels are shown in blue, with the maximum and minimum values. The green area shows the recommended level

6.5 Findings

The low CO_2 levels indicate that there is a high amount of fresh air infiltration into the building through open doors, windows and leaks in the building envelope. Increasing the air tightness on the building envelope, could reduce the cooling load for the building as well as the need for dehumidification. Potential measures are to seal leakages and ensure doors are closed.

Some office rooms are found to have a high room temperature. These are mainly rooms exposed to direct sunlight along the perimeter of the building. Installing shading devices or better heat reflective film on the windowpanes can reduce heat radiation from direct sunlight.

6.6 Building Energy Index (BEI)

The Building Energy Index (BEI) is an indicator used to benchmark building energy performance either externally or internally. Benchmarking externally means comparing building energy performance level against other buildings. The performance is normally levelised to energy consumption per square meter per year of the building (kWh/m^2/year). There are some limitations in using this tool to compare buildings since the usage of the specific building may differ significantly in terms of function and hours of operation from other buildings.

For internal benchmarking the BEI can be used to compare the energy consumption of the building for different time periods, for instance monthly or yearly. Changes in the BEI will reveal changes in the use of the building, such as change in occupancy or operation hours etc. In this report, the BEI is based on the ratio between the annual electricity consumption and the air-conditioned floor area. The BEI is presented below with the annual equivalent BEI based on the monthly electricity consumption, in order to show the variations in the BEI and the average annual BEI.

7. Conclusion

The energy for lighting is mainly consumed in the work areas such as open offices, office and meeting rooms, which account for 82% of the total consumption. They are taking up the biggest area of the complex and are operating 10 hours per day during the week days. Controlling the light usage by installation of motion and/or daylight sensors and timers can reduce the energy consumption for lighting in areas such as toilets; staircases and other infrequent used areas, where the light is switched on currently.

In addition to the main equipment i.e., air-conditioning and lighting systems, there are other electrical appliances that also contribute to the total electricity consumption of the building complex. Because the energy consumption is rather small, and the types of appliances and equipment varies (and in some cases special purpose equipment), it may be difficult to improve the energy efficiency for this equipment. However, for energy consuming equipment it is always important to consider energy efficiency when replacing the equipment. Energy conscious purchase by choosing the most energy efficient model or considering products with energy rating labels such as the Malaysian 5-star energy label (refrigerators, split air-conditioners, fans, televisions etc.) or the US energy star (computer equipment), will ensure energy savings for smaller appliances.

The Internet of Energy (IoE) impacts on smart cities' power sector. IoE is an implementation of the Internet of Things technology (IoT) into distributed energy systems and aims to achieve energy efficiency, to avoid energy wasting, and improve environmental conditions. IoE technology includes, among others, utilizing smart sensors and renewable energy integration. Therefore, the IoE is becoming a legal science tool to serve the purpose of a smart city.

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