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ENERGY ASSESSMENT FOR A SUSTAINABLE LOW CARBON BUILDING

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Abstract

With mounting global environmental concerns, reducing energy consumption has become a priority. In Malaysia, buildings accounted for nearly 43% of the total energy consumption in 2018. This study centres on a detailed energy audit of the Grand Subang Dorset Hotel located in Subang Jaya, Selangor. The aim is to evaluate the building's energy performance, especially considering the recommended building energy index (BEI) by MS 1525, which stands at 135 kWh/m^2/year. The research approach integrates a thorough examination of the hotel's historical electricity bills, on-site observations, data measurements, and collection with equipment such as power loggers, temperature and humidity meters, illuminance meters, and carbon power clamps. Post analysis, electricity load apportioning revealed that the highest electricity consumption system is the air conditioning system of the building. The calculated BEI of the hotel for the past year is approximately 110 kWh/m^2/year, which, being below the MS 1525 recommendation, indicates commendable energy consumption practices. In line with the findings, a range of Energy-Saving Measures (ESMs) are proposed to further optimize consumption. These ESMs vary in terms of costs and implementation periods, each backed by well-reasoned justifications for potential energy savings. While the Grand Subang Dorset Hotel already exhibits a BEI lower than the recommended standard, but there is always room for enhancement. By implementing the proposed ESMs, the study anticipates not just a reduced BEI, but also a notable decrease in the building's carbon emissions. Through this study, the understanding of the public and property owners about building energy efficiency and its consequential impact on the environment are expected to be raised.

Keywords: Building energy index, Carbon footprint, Commercial buildings, Energy audit, Energy efficiency.

1. Introduction

Global climatic changes, attributed to a surge in greenhouse gas (GHG) emissions, are resulting in a myriad of adverse phenomena ranging from rising global temperatures to extreme weather events. These shifts carry extensive implications for ecosystems, human health, economies, and other facets of global sustainability. In addressing this, international efforts such as the Paris Agreement have emerged, striving to cap the rise in global temperatures [1]. Within these ambitious targets, energy efficiency stands out as a central strategy, especially when acknowledging the large contribution buildings make to overall GHG emissions. The International Energy Agency (IEA) emphasizes this point, noting that buildings are responsible for approximately 30% of global final energy consumption and contribute to 27% of global emissions [2].

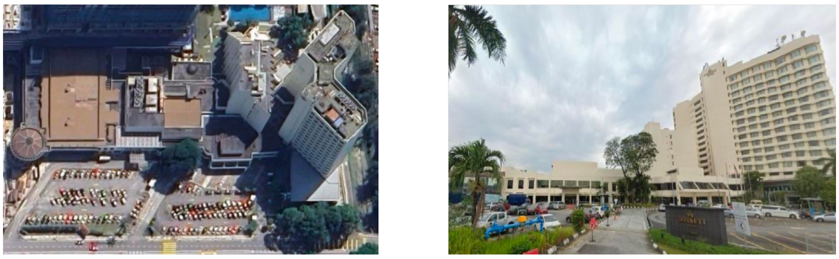
Focusing on Malaysia, the significance of buildings in the nation's energy consumption profile becomes evident. Categorized into industrial, commercial, and residential, these buildings have collectively accounted for a substantial 43% of Malaysia's total energy consumption as of 2018 [3]. Being geographically positioned near the Equator presents Malaysia with additional challenges, most notably a heightened demand for cooling, leading to more considerable energy consumption and GHG emissions. Such a gap in knowledge and practice not only heightens environmental impacts but also brings about economic repercussions, as excessive energy use translates to increased operational costs.

Over the years, the Malaysian government has rolled out various strategies and policies to enhance energy efficiency in buildings. This includes the National Energy Policy (NEP) and the National Energy Efficiency Action Plan (NEEAP). In partnership with entities like Tenaga Nasional Berhad (TNB)/Malaysian Energy Commission and Sustainable Energy Development Authority (SEDA), a positive impact has been made, though there remains substantial scope for further improvement.

A pivotal regulation in this context is the Efficient Management of Electrical Energy Regulations 2008 (EMEER 2008). Under this regulation, buildings that consume in excess of 3 million kWh over six months must adhere to EMEER 2008 by appointing an energy manager and submitting several documents, including energy management policies and audit reports, to ST Malaysia [4]. Additionally, the MS 1525 and Energy audit guidelines provided by SEDA Malaysia serve as the primary standards and framework guiding this research project.

The building under study in this research is the Dorsett Grand Subang (DGS) Hotel situated in Subang Jaya, Selangor. This hotel operates around the clock, providing services 24/7, while its administrative offices function for 8 hours daily. While the hotel rooms are open all week, the offices run for five days a week, and this schedule continues throughout the year. The DGS hotel is spread across two structures: the tower building, which is 17 stories high, and the superior building that stands at 11 stories, combining to offer a total gross floor area of 66,500 m^2. Examining the hotel's structural features, its walls are made from aerated concrete, averaging around 8 inches in thickness. The external façade is coated with a light-hued paint, minimizing heat absorption.

Notably, the hotel displays a significant window to wall ratio, suggesting that a lot of external heat could permeate in through the windows. While there are not any dedicated shading structures to prevent direct sunlight exposure, it is evident that the windows are equipped with high-grade tinted glazing. The hotel's roof is fashioned from concrete without any insulating layer. Given these architectural details, it can be inferred that the building is likely to experience substantial heat intake. Figure 1 depicts the different view of DGS hotel building.



(a) Top view **(b) Front view**

Fig. 1. DSG building view.

This research is an attempt to bridge these gaps by centring its investigation on a particular commercial building in Malaysia. It delves deep into the building's energy consumption patterns by initiating a comprehensive energy audit. This evaluation encompasses diverse building systems from heating and ventilation to lighting aiming to pinpoint the leading contributors to the building's energy footprint.

The findings from this audit will then act as the foundation for suggesting specific energy-saving measures (ESMs). This not only aids in decreasing the building's environmental footprint but also offers tangible economic benefits, hopefully encouraging a wider embrace of energy-efficient practices across Malaysia. The study's guiding objectives revolve around three main pillars: a meticulous evaluation of building energy consumption, a dedicated effort to enhance building energy efficiency in line with the MS 1525 standards, and the development of a tailored Energy Management System (EMS) for the realm of commercial buildings.

Merely observing energy consumption does not offer a comprehensive understanding of a building's energy efficiency. As per a study by Tahir et al. [5], the Building Energy Index (BEI) is vital as it evaluates energy consumption relative to a building's size. The MS 1525 Standard suggests a BEI benchmark of 135 kWh/m²/year to classify a building's energy efficiency. An energy audit by Pusat Tenaga Malaysia showed most office buildings in Malaysia exceed this benchmark, with BEIs between 200 to 250 kWh/m²/year.

An assessment of three buildings revealed that only one had a BEI below the recommended value, emphasizing the importance of the BEI in determining energy efficiency measures for a building. Therefore, this research encompasses the calculation of BEI to assess the current energy performance of the building based on the historical electricity bills.

The DGS structure obtains its 11 kV high-tension electricity from TNB via a single metering point. This high voltage is then converted to low voltage through step-down transformers. The electrical power is distributed throughout the building using several main switchboards (MSBs). Both the tower and superior blocks have a combined total of 4 MSBs. Figure 2 depicts the path of electrical distribution from TNB to all MSBs within the DGS hotel.

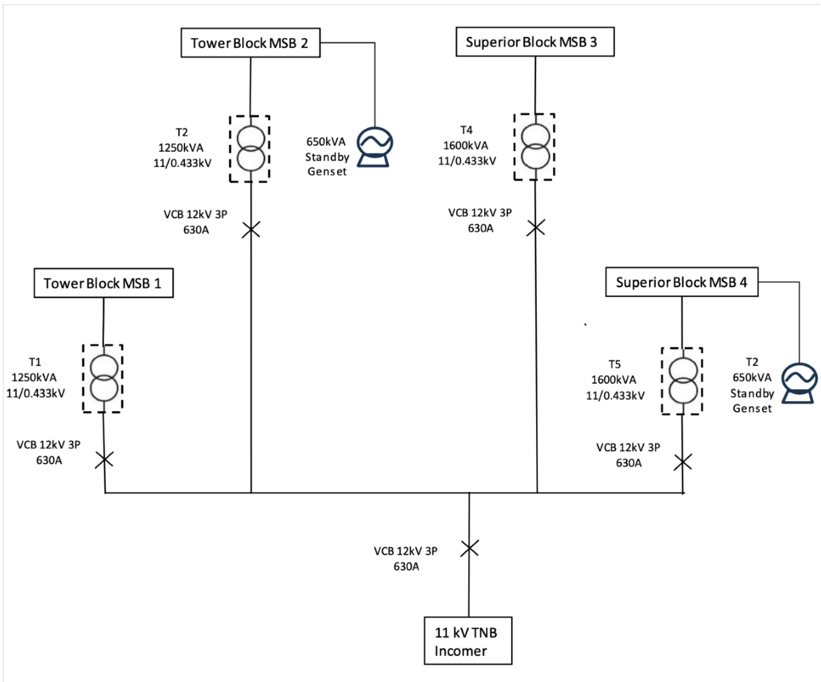


Fig. 2. Electrical distribution in DGS buildings.

In Malaysia, commercial electricity tariffs are categorized into three: tariff B, C1, and C2, corresponding to different voltage levels. TNB Malaysia provides two tariff schemes, Time of Use (TOU) and Enhanced Time of Use (ETOU), aiming to charge varied rates based on the time of day and maximum demand (MD) which represents the peak electricity consumption in a 30-minute interval. Potential savings can be accomplished using the ETOU tariff with optimal energy management in commercial buildings, emphasizing the importance of Demand Side Management (DSM) strategies. Furthermore, the importance of managing MD is important in order to reduce significant electricity cost [6].

Hence, the historical electricity bills of DGS had been collected to study its electricity consumption pattern. For the tariff category, DGS is under tariff C2 category and there are three charges in this tariff category which is shown in Table 1. The primary aim of this research is to examine the electrical consumption of the DGS hotel building through an in-depth energy audit. By assessing historical electricity bills from the past year, the study will evaluate the building's energy efficiency performance using the BEI. Ultimately, the research intends to suggest various energy saving measures (ESMs) to lower the BEI, thereby reducing the building's carbon footprint.

Table 1. Tariff C2 charges.

Tariff C2	Charges
For each kW of MD per month during peak period	45.10 RM/kW
For all kWh during peak period	36.5 cent/kWh
For all kWh during off-peak period	22.4 cent/kWh

2. Methodology

This research utilizes a combination of qualitative and quantitative methodologies. Through interviews and surveys with facility teams and building users, qualitative insights into the preferences and challenges associated with Energy Management Systems (EMS) implementation will be gathered. On the quantitative side, an in-depth energy audit in the building will collect data on energy usage, electricity bills, performance of chiller and AHU, lighting and so on. This comprehensive data set will facilitate a clear outlook on the energy performance of the building, hence assisting the proposal of the ESMs. Figure 3 shows the framework of this study.

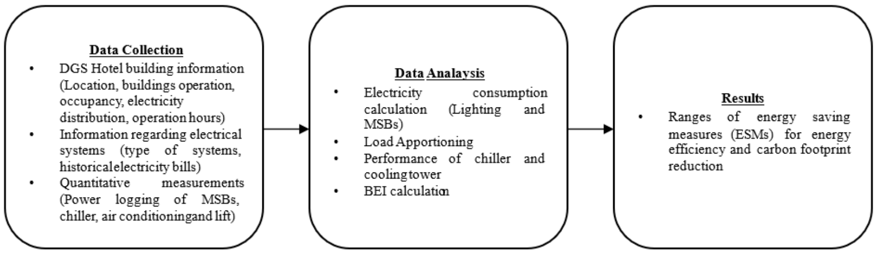


Fig. 3. Methodology framework.

2.1. Equipment

During the energy audit conducted on site, there are different equipment utilized for measurement and monitoring. All the equipment was calibrated to ensure the collected field data were accurate and reliable to be used in data analysis. The list of the equipment is listed in Table 2.

Table 2. List of equipment.

Equipment	Description	Measurement Area
Data-logger	PEL 103 Power Analyzer	Main Switch Board
Data-logger	Power Monic PM35 Power Analyzer	Main Switch Board
Temperature & Humidity meter	Testo 605i	Room with air conditioning
Illuminance meter	Amprobe LM100	Office area

2.2. Data collection

During the energy audit conducted on site, there are different equipment utilized for measurement and monitoring. All the equipment was calibrated to ensure the collected field data were accurate and reliable to be used in data analysis. The list of the equipment is listed in Table 2. The research's data collection hinges on a comprehensive energy audit, encompassing both qualitative and quantitative data. The core goal of this energy audit is to reduce energy use without compromising the building's operational efficiency and comfort levels.

Broadly, data collection processes can be divided into preliminary energy audits and detailed energy audits. A preliminary energy audit, often termed a walkthrough audit, is an initial assessment aiming to identify and understand the building's overall energy consumption patterns and potential energy-saving opportunities. This is primarily achieved through visual inspections, augmented by pertinent documents like operation and maintenance (O&M) records and technical reports.

Specific data accrued during this phase includes details about the building's location, operational timings, occupancy levels, energy distribution system, architectural design, construction materials, equipment types, and historical energy consumption bills. To gather this information, interviews were conducted with the DGS hotel's facility manager, on-site observations were made during building visits, and additional details were given by the hotel's administration. In contrast, a detailed energy audit delves deeper, focusing on precise measurements and data collection. This includes the assessment of individual energy loads using power logger to collect the energy consumption for two weeks period, the performance metrics of chillers and cooling towers, indoor air quality, ambient room temperatures, relative humidity levels, and lighting illuminance within the building.

To ensure accurate data collection, various specialized instruments, and equipment, listed in Table 2, were employed. For instance, four power loggers were installed at four different MSBs at tower and superior block. The power logger will record the electricity consumed and the maximum power consumed for every five minutes interval over a two week period. This is to have an accurate and clear picture of the consumption pattern of the DGS hotel building with common activities in two weeks.

For lifts in the buildings, power loggers were installed on the sub-distribution board of different blocks for one week time to record the maximum peak load and minimum peak load at different time. For air condition split unit, flowmeter and relative humidity meter were utilized to measure the supply air parameters. This deeper dive not only provides a granular understanding of energy consumption patterns but also aids in identifying specific areas and systems where energy efficiency measures can be effectively implemented.

2.3. Data analysis

Once the data collection is completed, the next step involves a meticulous analysis of the collected data. The first step is to analyse the obtained historical TNB electricity bills for the previous five years to understand the energy consumption pattern. Furthermore, the analysis lies in discerning patterns and areas with high energy consumption. To break this down, key systems behind high energy demands, such as air conditioning systems, lighting solutions, elevators, and other equipment, are spotlighted. To make this data comprehensible, visual aids like graphs and charts are utilized. These visual representations condense data sets into more relatable and easy-to-grasp formats, enabling clearer insights. Beyond visual aids, regression analyses are conducted to show correlations between energy consumption and various determinants, such as the occupancy levels, operational days, and factors like cooling degree days (CDD).

This analytical process offers insights into which factors play pivotal roles in energy consumption fluctuations. Furthermore, the Building Energy Index (BEI) is calculated as recommended by pertinent academic and industry resources. BEI serves as a pivotal metric that assesses the energy efficiency landscape of a commercial establishment. The calculated BEI is then compared to the BEI specified by the MS 1525 standard which serves as a benchmark, and the energy-saving target is set based on achieving the lowest BEI. This comparison not only offers a performance assessment but also establishes a foundational basis for setting energy-saving targets, with an aim of reducing BEI.

Moreover, the operating performance of the chillers in the buildings were judged by calculating the Coefficient of Performance (COP) which determines the total heat removed by the total input energy. ASHRAE chart was also implemented to determine the performance of the chiller system. Other than that, cooling towers effectiveness were also determined using the data gathered during energy audit.

3. Results and Discussion

3.1. Historical electricity consumptions

To assess the energy efficiency performance of the DGS hotel, it is vital to examine its historical electricity usage. Hence, electricity bills from TNB spanning from January 2019 to May 2023 were sought from the DGS facility management. Two primary metrics were assessed from these bills: energy consumption and the Maximum Demand (MD) over this near five-year time frame. The total and average of total energy consumption and MD were also calculated to show the consumption of the building. Table 3 depicts the total and average energy consumption and MD of DGS building over 5 years. A graph representing the electricity usage from January 2019 to May 2023 was created to visualize the trends throughout these years as shown in Fig. 4.

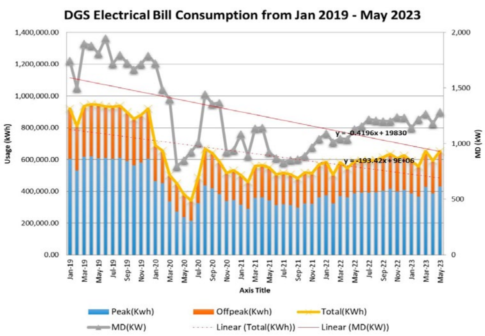


Fig. 4. DGS Energy consumption from January 2019 to May 2023.

The graph revealed a consistent decline in energy usage over the past five years. Notably, energy consumption remained stable from January to December 2019, as proven by the graph's equation indicating a negative gradient across the years.

Table 3. Average energy consumption and MD.

Energy Consumption	Total	Average
Total energy consumption (kWh)	45,023,021	750,384
MD (kW)	84,209	1,403

A significant drop in energy usage was observed in January 2020, primarily attributed to the decision to discontinue the Air Handling Unit (AHU) used for cooling the hotel corridors. Furthermore, the energy consumption during peak period (0800-2200) over the previous 5 years is higher than the energy consumption during off-peak period (2200-0800). This is because there are less offices, function rooms, lighting, air conditioning and other equipment utilized at the off-peak period.

Moreover, a sharp decline in energy consumption was recorded from January to June 2020, largely due to the impact of the Covid Pandemic on the hospitality and tourism sectors. Another observation was the consistently lower energy consumption in February of each year, likely due to its shorter length (28 days). The graph also indicated a downward trend in MD over the five years. Overall, there were not any noticeable exceptions in the MD trend. It is worth noting that factors like the hotel's occupancy and the local climate, particularly fluctuations in temperature, influence both kWh usage and kW demand.

3.2. .Regression analysis

There are numerous factors that influence energy consumption in buildings. Four key elements affecting building energy use in Malaysia: weather and location, building's physical characteristics, building system appliances like HVAC, and occupancy level and behaviour [7]. Specifically, climate variations, with temperatures ranging between 22°C to 32°C, can alter usage patterns, such as turning off cooling appliances on cooler, rainy days. The building's insulation and physical properties play a pivotal role too.

In the context of the DGS building's energy consumption, there are three pivotal factors: the level of occupancy, the total working days in a month, and the Cooling Degree Days (CDD). CDD serves as an index indicating the intensity of warmth during a day or over a span of days [8]. The CDD data for the Selangor region was sourced from www.accuweather.com, using a base temperature of 24℃.

The regression analysis focuses on data from June 2022 to May 2023, representing the latest annual period and offering insights into the building's current energy scenario. Table 4 outlines the data on occupancy levels, working days, CDD, and energy consumption from June 2022 to May 2023.

Table 4. Average energy consumption and MD.

Month	Occupancy Level (%)	Working days	CDD	Energy Consumptions (kWh)
Jun-22	51	30	121	594,553
Jul-22	43	31	151	590,827
Aug-22	48	31	120	597,211
Sep-22	61	30	113	614,170
Oct-22	57	31	110	635,048
Nov-22	47	30	99	608,075
Dec-22	53	31	89	625,210
Jan-23	34	31	99	591,181
Feb-23	48	28	94	557,614
Mar-23	56	31	115	653,379
Apr-23	30	30	132	593,098
May-23	48	31	163	653,510

The scatter plot in Fig. 5 shows the relationship between energy consumption and occupancy levels for DGS building. The derived linear regression line, represented by the equation (y = 1478.6x + 538517), suggests a positive correlation between these two variables. This indicates that as the occupancy level of the building increases, the energy consumption also tends to rise. However, the R^2 value of 0.222 implies that only approximately 22.2% of the variation in energy consumption can be explained by changes in the occupancy level. In other words, while there is a connection between occupancy and energy usage, nearly 78% of the energy consumption's variance is due to factors other than occupancy. This suggests that, though occupancy has an impact, there are other influential determinants affecting the energy consumption of the building.

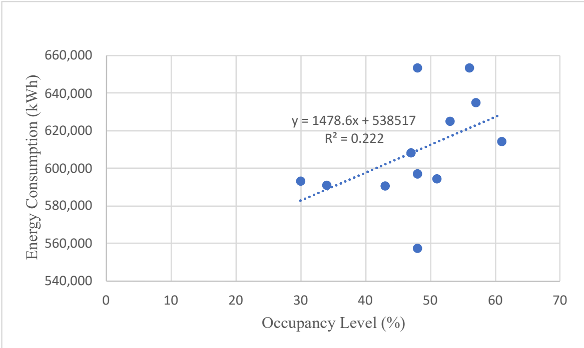


Fig. 5. Energy consumption against occupancy level.

The scatter plot in Fig. 6 illustrates the relationship between energy consumption and the number of working days within the building. The linear regression line, given by the equation y = 20601x - 17115, indicates a positive correlation between the number of working days and energy consumption. This suggests that as the number of working days in a month increases the energy consumption of the building tends to rise accordingly. The R^2 value of 0.429 signifies that approximately 42.9% of the variance in energy consumption can be attributed to changes in the number of working days. This means that while working days have a considerable influence on energy consumption, other factors account for the remaining 57.1% of the energy consumption's variance.

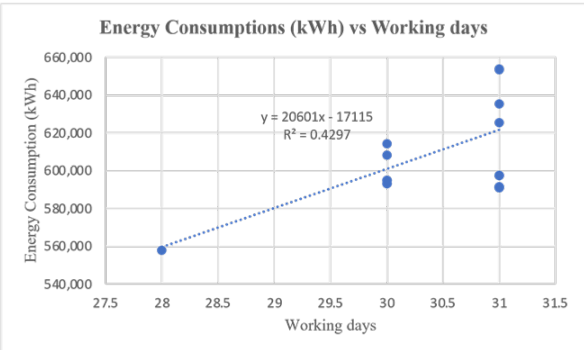


Fig. 6. Energy consumption against working days.

The scatter plot in Fig. 7 displays the relationship between the Cooling Degree Days (CDD) and the energy consumption of a building. The regression line equation, y = 336.93x + 570013, suggests that for every unit increase in CDD, the energy consumption increases by approximately 336.93 kWh, indicating a positive correlation. However, the R^2 value of 0.0716 reveals that only about 7.16% of the variability in energy consumption can be explained by the CDD. This suggests that while there is a relationship between CDD and energy consumption, other factors not represented in this plot likely have a more significant influence on the building's energy use.

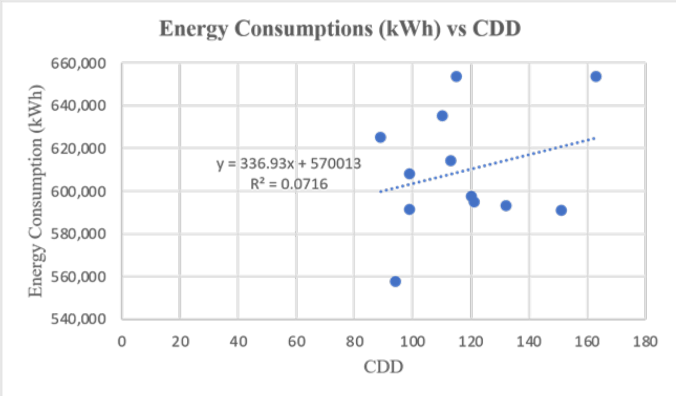


Fig. 7. Energy consumption against CDD.

3.3. Building energy index (BEI)

BEI is a crucial indicator for assessing a building's energy efficiency. To gauge energy use in relation to a building's size, the BEI is utilized. This metric is calculated by dividing the building's total yearly energy usage (kWh) by its total occupied floor space (m^2). For assessing the energy efficiency of the DGS hotel, the total energy consumption from the past year was considered to get a perspective on the building's recent performance. Eq. (1) was utilized to determine the BEI for the duration from June 2022 to May 2023.

The calculated BEI, based on DGS hotel's total net floor area, stands at 109.98 kWh/year/m^2. This value is beneath the BEI guideline set by MS 1525, which recommends 135 kWh/year/m^2 for commercial properties. This suggests that DGS hotel is functioning efficiently in terms of energy usage. However, there's potential to further enhance this efficiency, by aiming for an even lower BEI. This would consequently reduce both energy consumption and the building's carbon footprint. Table 5 provides details on the BEI computation.

$$BEI = \frac{Anual\ \ Eenergy\ Consumption\ (\mathrm{kWh})}{Net\ Floor\ Area\ (\mathrm{m}^2)} \qquad (1)$$

Table 5. BEI for DGS hotel from June 2022 to May 2023.

Item	Figure
Annual Energy Consumption from Jun 22-May 23	7,313,876
Net Floor Area (m^2)	66,500
BEI (kWh/year/m^2)	109.98

3.4. DGS load apportioning

To enhance energy efficiency, it is crucial to lower the BEI. The equation suggests two potential methods for this: reducing annual energy consumption or increasing net floor area. However, expanding the floor area is not a feasible solution as it would, in turn, lead to higher energy consumption due to the need for additional equipment to maintain comfort. Therefore, the most effective approach to decrease BEI is to cut down on daily energy consumption while ensuring the same level of interior comfort. To achieve this, it is vital to pinpoint the primary energy consumers within the DGS hotel, including systems like air conditioning, lighting, cold storage, elevators, heating machines, water pumps, and other devices. After evaluating the data from power logging, it is found that the hotel's daily energy consumption is 19,596 kWh, with the air conditioning system (encompassing AHU and chillers) accounting for 65% of the total.

Other significant consumers include miscellaneous equipment, lighting, cold storage, and elevators. The continuous operation of air conditioning systems in hotels is essential to ensure a comfortable environment for guests. This is especially crucial in hot tropical climates like Malaysia, where buildings experience significant heat gain during the day, necessitating the non-stop functioning of these systems. Additionally, the building's insulation and envelope, as discussed earlier, are not optimal. This means the air conditioning must exert more to balance out the heat entering and leaving the building. While other systems, such as lighting, contribute to DGS building's energy consumption, they have already been optimized with the use of LED lights that are in excellent condition.

Therefore, the potential to further reduce energy usage from lighting is minimal and largely dependent on the behaviour of the occupants. However, this analysis suggests that to elevate the building's energy efficiency, efforts should focus on individual components and equipment. Regular maintenance, efficient operation of devices like chiller systems, and updating outdated components to more energy-efficient versions, such as cooling tower parts, are essential steps in this direction. Consequently, a variety of energy-saving measures (ESMs) will soon be introduced in this project, backed by justifications related to energy conservation and carbon footprint reduction. The load apportioning is shown in Fig. 8.

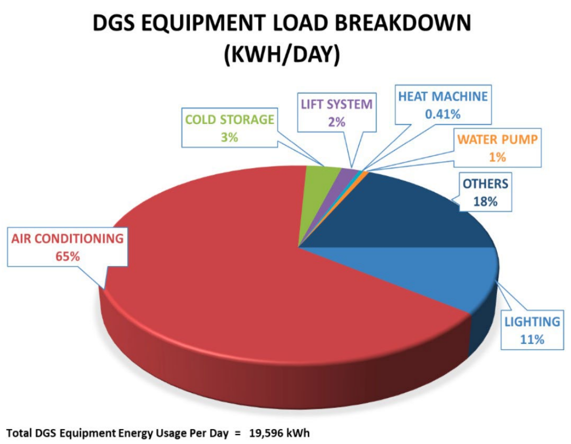


Fig. 8. DGS Load apportioning.

3.5. Energy saving measures (ESMs)

In response to the energy audit conducted at the DGS hotel, seven strategic Energy Saving Measures (ESMs) have been proposed to lower energy consumption and reduce the carbon footprint which shown in Table 6. The first ESM entails setting up a Sustainable Energy Management System (SEMS), a foundational initiative expected to streamline energy use and foster continuous improvement. With an investment of RM 20,000, the SEMS is anticipated to significantly reduce the Building Energy Index (BEI) to 106.68 kWh/year/m². The second and third ESMs address inefficiencies in the hotel's cooling infrastructure. The second measure involves a comprehensive re-evaluation of the Cooling Tower (CT) system to enhance its efficiency, potentially improving energy performance by 2%.

Table 6. Proposed energy saving measures (ESM).

ESM	ESM 1	ESM 2	ESM 3	ESM 4	ESM 5	ESM 6	ESM 7	Total
	Setting Up a Sustainable Energy Management System	Reinspecting and reevaluating the effectiveness of the Cooling Tower (CT) system	Reinspecting and reevaluating the effectiveness of the AHU & FCU system	Replacement Program for Energy Efficient Split Unit Air Conditioning	Incorporating existing AHU with VSD controller equipped with CO_2 / Temperature controller	Increasing the overall temperature setting to be at 23 degrees C - 24 degrees C	Retrofit High Efficiency Chiller	
Estimated Investment (RM)	20,000.00	20,000.00	15,000.00	11,400.00	150,000.00	250,000.00	300,000.00	766,400.00
Estimated Energy Saving (kWh)	219,416.28	146,277.52	146,277.52	14,739.00	219,416.28	219,416.28	219,416.28	1,184,959.16
Estimated Cost Saving (RM)	80,086.94	53,391.29	53,391.29	4,392.00	80,086.94	80,086.94	80,086.94	431,522.36
Estimated CO_2 Saving (ton/year)	138.23	92.15	92.15	8.62	138.23	138.23	138.23	745.86
Payback Period (Year)	0.25	0.37	0.28	2.6	1.87	3.12	3.75	12.24
BEI Savings	3.3	2.2	2.2	0.22	3.3	3.3	3.3	17.82
Overall Savings Percentage (%)	3	2	2	0.2	3	3	3	16.2

The third measure calls for a detailed inspection and optimization of the Air Handling Units (AHUs) and Fan Coil Units (FCUs), targeting issues such as air leaks and chilled water distribution imbalances. These efforts are projected to yield energy savings of approximately 146,277 kWh per annum. The fourth and fifth ESMs are equipment upgrades aimed at reducing energy consumption. The fourth measure suggests replacing existing split unit air conditioners with inverter type models, aligning with MS 1525 standards, and potentially saving up to 44% of energy. The fifth ESM involves the integration of Variable Speed Drive (VSD) controllers equipped with CO_2 and temperature sensors into the AHU systems, enabling more precise control and an expected 3% reduction in energy usage. Adjustments to operational practices form the sixth ESM, which proposes an increase in the overall temperature setting to within the 23°C to 24°C range, in line with comfort standards. This adjustment is expected to contribute a further 3% in energy savings. The seventh and final ESM recommends retrofitting the existing chiller system to a higher efficiency model.

Despite the high upfront cost of RM 300,000, this upgrade is predicted to improve energy savings by up to 40%, underpinning the hotel's commitment to sustainable practices. In summary, these seven ESMs represent a holistic and integrated approach to energy conservation within the hotel. Collectively, they are projected to result in an annual energy reduction of 1,184,959.16 kWh, cost savings of RM 431,522.36, and CO_2 emissions decrease of 745.86 tons. The strategic implementation of these measures underscores a financially viable model for energy management in the hospitality industry, offering a comprehensive approach to sustainability with a payback period of 12.24 years and a substantial reduction in the BEI by 17.82 points.

4. Conclusion

In summary, the aim of this research was to assess one of the commercial buildings about its energy consumption. This is because the building sector in Malaysia had evolved drastically in terms of energy consumption which results in releasing more carbon dioxide to the atmosphere. This eventually causes a lot of problem regarding human health, global warming and so on.

Despite there were policies and initiatives taken by the Malaysian government, however the urgent needs of assessing the buildings in Malaysia in terms of energy efficiency were still in a hurry state. Therefore, this research assessed the building performance via a detailed framework to understand the energy consumption pattern of the DGS hotel building.

Different data had been measured and collected at the building and were analysed using different calculation and illustration to propose the ESMs that are aimed to reduce the BEI of the building while maintaining the comfort level of the building at certain standard. Based on the results obtained, several conclusions can be made:

- As the result of Covid pandemic and the discontinuing of using AHU for corridor cooling, the energy consumption of DGS hotel was having steady decrement from 2019 to 2023.
- Three manipulated factors were affecting the energy consumption but the number of working days per month was having most significant impact on the energy consumption from 2022 to 2023.
- The BEI of DGS hotel from 2022 to 2023 was 109.98 kWh/year/m^2, which lower than recommended standard from MS 1525 but there are rooms to reduce the BEI which reduces the carbon emissions of the building.
- The air conditioning system consumed the highest energy (65%) out of total energy consumed peer day followed by others, lighting, cold storage, lift, water pump and heat machine.
- The proposed ESMs are set to deliver marked benefits, cutting energy use by 1,184,959.16 kWh, reducing costs by RM 431,522.36, and cutting CO_2 emissions by 745.86 tons/year, with a BEI reduction of 17.82 over a 12.24-year payback period.

At the end of this research, the outcomes are expected to contribute to the body of knowledge especially in terms of increasing energy efficiency of the building which transforming the building into low carbon and sustainable place. This is due to the lack of the studies investigating the impact of implementing systematic energy audits and ESMs on the carbon emissions, which are directly linked to environmental impact instead of electricity cost. The carbon emissions reduction is the end goal of this research which fill the gap of the research with other studies.

Lastly, the research also expects to develop the energy management system with continuous improvement and monitoring of the facility management to maintain the excellent performance of the building.

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References

1. Paris Agreement. (2015). Paris agreement. *Report of the Conference of the Parties on its twenty-first session, held in Paris from* 30 *November* to 13 *December* 2015.
2. Liu, Z. et al. (2021). Nexus between green financing, renewable energy generation, and energy efficiency: Empirical insights through DEA technique. *Environmental Science and Pollution Research*, 30(22),1-14.
3. Energy Commission. (2015). *Malaysia Energy Statistics Handbook* 2015. Statistics-Malaysia Energy Information Hub. Suruhanjaya Tenaga (Energy Commission).
4. Hor, K.; and Rahmat, M.K. (2018). Analysis and recommendations for building energy efficiency financing in Malaysia. *Energy Efficiency*, 11(1), 79-95.
5. Tahir, M.Z.; Nawi, M.N.M.; and Rajemi, M.F. (2015). Building energy index: A case study of three government office buildings in Malaysia. *Advanced Science Letters*, 21(6), 1798-1801.
6. Ayyappan, P.; Kumar, J.; and Venkiteswaran, V.K. (2019). Maximum Demand Management: An overlooked energy saving opportunity in industries. *Proceedings of the International Conference on Sustainable Energy and Green Technology*, *IOP Conference Series: Earth and Environmental Science*. Kuala Lumpur, Malaysia, 012156.
7. Hassan, J.S.; Zin, R.M.; Majid, M.Z.A.; Balubaid, S.; and Hainin, M.R. (2014). Building energy consumption in Malaysia: An overview. *Jurnal Teknologi*, 70(7), 33-38.
8. Brown, S.L. et al. (2022). Evaluating climatic influences on the technical performance of built infrastructure assets. *Journal of Performance of Constructed Facilities*, 36(2), 04022004.