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Assessment of Energy Efficiency Index and Consumption Analysis in Malaysian Commercial Laundry Operations

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ABSTRACT

A comprehensive energy audit was conducted at a Commercial Laundry in Malaysia to investigate energy consumption patterns and efficiency. The study, carried out from March 2023 to March 2024, revealed that dryers were the primary energy consumers, accounting for 59% of total energy usage. Both washing machines and dryers were operating significantly above ideal consumption levels. Based on these findings, the study recommends equipment upgrades, optimization of operational practices, and implementation of regular maintenance schedules to achieve substantial energy savings and improve environmental sustainability in Malaysia's growing commercial laundry sector.

1. Introduction

Commercial buildings, including laundry facilities, are significant consumers of energy, leading to substantial environmental and financial consequences [1]. This research aims to investigate energy consumption patterns in commercial laundry facilities by examining three key questions: what are the current energy usage patterns of different equipment (washing machines, dryers, and flat irons), how does their actual energy efficiency compare to rated specifications, and what measures can effectively reduce consumption while maintaining service quality? Through comprehensive energy audits and data collection, this study seeks to identify operational inefficiencies, establish baseline consumption data, and develop targeted optimization strategies for laundry equipment. The continuous operation of washing machines, dryers, and other equipment in these facilities results in high energy demands, making it crucial to analyze and improve their Energy Efficiency Index. By conducting detailed assessments of current consumption patterns and implementing proposed measures, this research will provide practical solutions for reducing both greenhouse gas emissions and operational costs while maintaining service quality in commercial laundry operations [2].

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1.1 Laundry Industry in Malaysia

The commercial laundry industry in Malaysia is a thriving sector that mainly serves restaurants, gyms, hotels, and hospitals [3]. The industry has shown impressive growth, reaching a value of US$205 million (RM 973.34 million) in 2022, with most businesses being relatively new, having started between 2020 and 2022 [4]. Success in this industry depends heavily on well-organized supply chains and modern technology [5]. For example, laundries use digital systems to track inventory and deliveries, which helps them operate more efficiently and keep customers happy. The industry faces strict regulations, especially when dealing with healthcare facilities, and there's a growing focus on using sustainable energy sources [7]. An innovative solution some laundries are adopting is micro gas turbines, which generate power on-site and produce hot water from waste heat, helping businesses save money while being environmentally responsible [9].

1.2 Importance of Energy Audit

Energy management and efficiency are vital components of Malaysia's economic growth strategy. The focus is on developing sustainable approaches to energy consumption, particularly in the industrial sector, where proper energy management can significantly reduce environmental impact while maintaining productivity [10].

Preliminary energy audits serve as essential tools in buildings and facilities, offering a detailed look at how energy is being used and where improvements can be made [11]. These audits are particularly valuable because they help identify opportunities to integrate renewable energy sources like solar panels and heat pumps [2], which can reduce dependency on fossil fuels and minimize environmental impact [12].

The success of energy audits in commercial and industrial settings relies heavily on thorough data collection. By carefully tracking energy consumption patterns and production schedules, businesses can identify inefficiencies and implement more effective energy management practices. This detailed analysis provides the foundation for making informed decisions about energy use improvements.

In specific industries like manufacturing and food production, energy audits play a crucial role in optimization efforts [13]. One particularly effective strategy, load apportioning, which involves redistributing energy consumption to off-peak hours. This approach not only reduces costs but also improves overall efficiency. While load apportioning faces some implementation challenges, such as data availability and system integration, it represents a promising direction for future energy management, especially as smart grid technologies continue to advance [14].

1.3 Energy Efficiency Index (EEI)

The Energy Efficiency Index (EEI) is a comprehensive tool that helps evaluate how efficiently energy is used in buildings and equipment, particularly in commercial and industrial settings [2]. It works by measuring different aspects of energy consumption through specific metrics like Building Energy Index (BEI), Lighting Energy Index (LEI), and Air Conditioning Energy Index (ACEI) [15]. These measurements help identify areas where energy use is high and compare them to industry standards, ultimately pointing out where improvements can be made to save costs and benefit the environment [16].

While the EEI is valuable, it does have some limitations. External factors like weather conditions and changes in building occupancy can affect its accuracy. To address these challenges, researchers have developed new approaches, such as incorporating occupancy data and using weather normalization techniques, to make the measurements more reliable [17]. The EEI's applications

extend beyond buildings to equipment assessment as well, such as in commercial laundry facilities, where it helps evaluate the energy efficiency of washing machines and drying technologies, enabling better decisions about equipment selection and operation.

2. Methodology

2.1 Energy Audit Process

An energy audit at the commercial laundry happens in four main steps. First, auditors visit the laundry to gather basic information about their equipment and how they use energy. Second, they set up monitoring systems to track exactly how much energy is being used over time. Third, they check if all the collected data is correct and study it carefully to find patterns in energy usage. Finally, they create a detailed report that suggests specific ways the laundry can save energy, called Energy Conservation Measures (ECMs). This report combines all their findings and recommendations to help the laundry become more energy efficient.

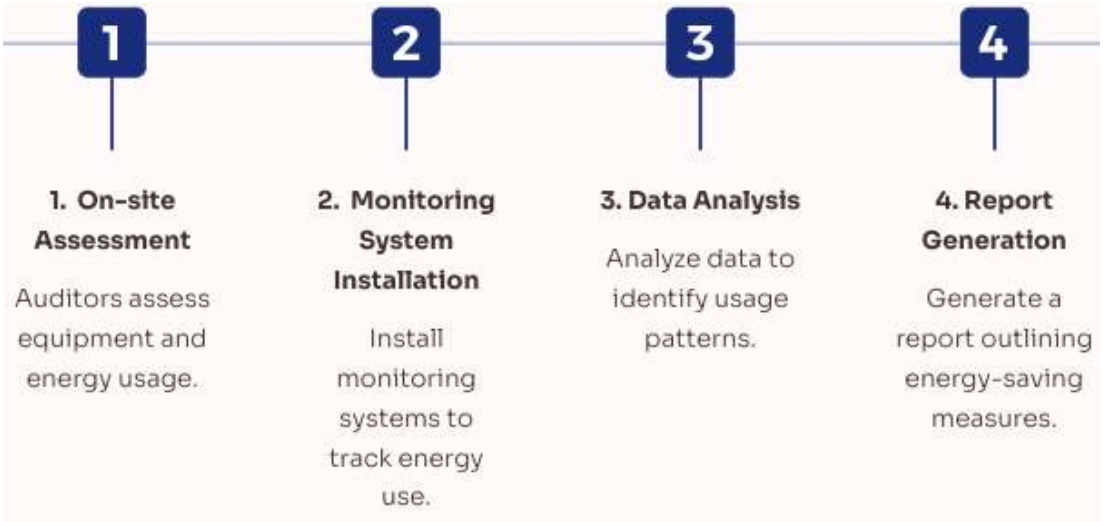


Fig. 1. Energy audit process flow chart

2.2 Instrumentation and Laundry Equipment

In energy audits, accurate measurements are essential for evaluating building performance and making informed decisions. The key tools used in this study served different purposes. The detailed discussion of the instrumentation and equipment used in this study is tabulated in Table 1 below.

Table 1
Function of the instrumentation and equipment used

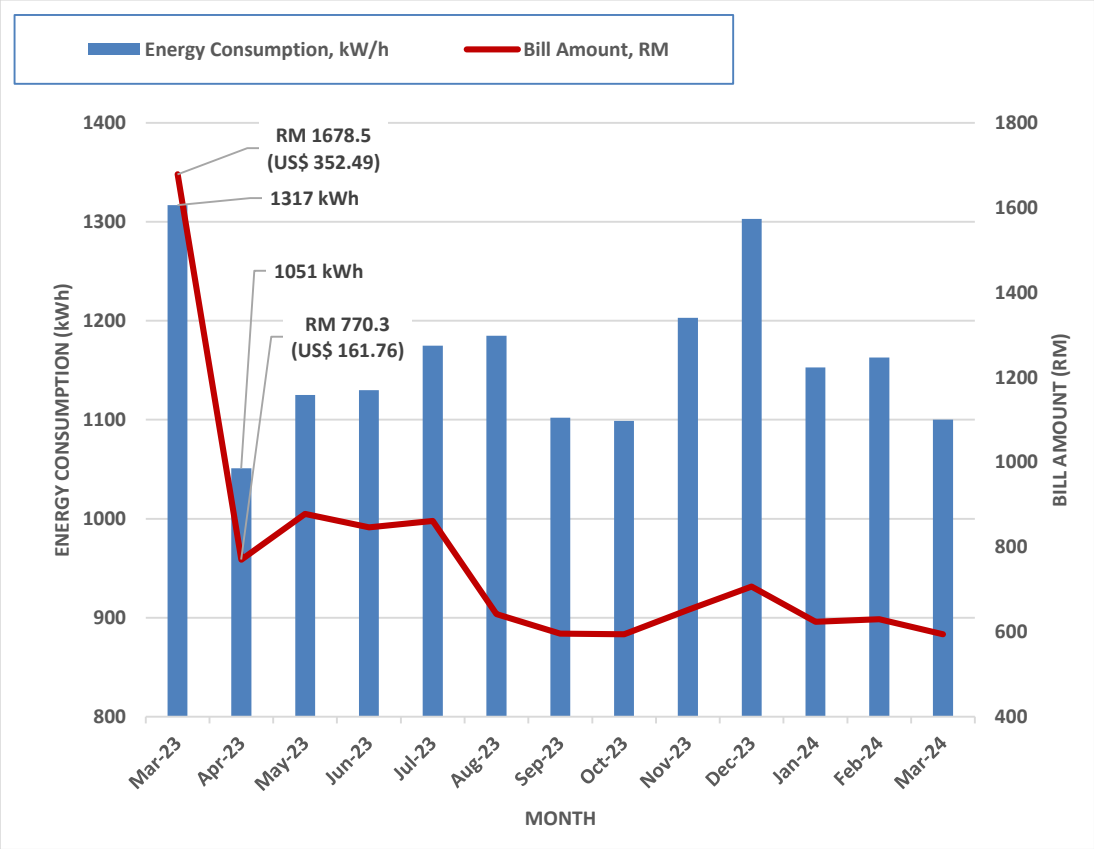
Equipment	Function
Laser Measurement	Measure the floor plan or layout
Power Data Logger	Measure and record a wide range of electrical parameters
Flat Iron	Get rid of wrinkles from variety of fabrics more quickly and efficiently
Washing Machine	Meet variety of fabric and cleaning needs
Laundry Dryer	Efficiently remove moisture from textiles

3. Results and Discussion

3.1 Energy Consumption Trends

The energy consumption data spans from March 2023 to March 2024, showing how much electricity was used each month at the commercial laundry in Batu Pahat, Johor. The data reveals that energy usage generally increased throughout the year, with some noticeable peaks and valleys. March 2023 had the highest energy use at 1,317 kWh, closely followed by December 2023 at 1,303 kWh. The lowest consumption was in April 2023 at 1,051 kWh.

Figure 2 shows patterns align with busy tourist seasons, suggesting that business activity directly impacts energy consumption [18]. An interesting change occurred between March and April 2023, when the electricity billing category switched from residential to industrial rates. This change explains why March 2023 had the highest bill at RM 1,678.50 while April 2023, despite using only slightly less energy, had a much lower bill of RM 770.30. Understanding these patterns helps in making better decisions about energy management and working toward sustainability goals [19].



Note: RM 1 = 0.21 USD (date = 24 June 2024)

Fig. 2. Monthly energy consumption (kWh)

3.2 Total Energy Consumption for a Month

Figures 3 and 4 shows a recent energy audit conducted between March and April 2024 revealed interesting patterns in a commercial laundry's power usage. Operating from 8:00 AM to 6:00 PM daily, with flexible extensions based on customer demand, the facility's daily energy consumption in figure 3 showed irregular patterns, averaging 34.10 kW with notable spikes and dips. The lowest usage was 27.10 kW on March 14, while the highest reached 49.40 kW on April 11, coinciding with Hari Raya Puasa in Malaysia – a period typically seeing increased laundry service demand.

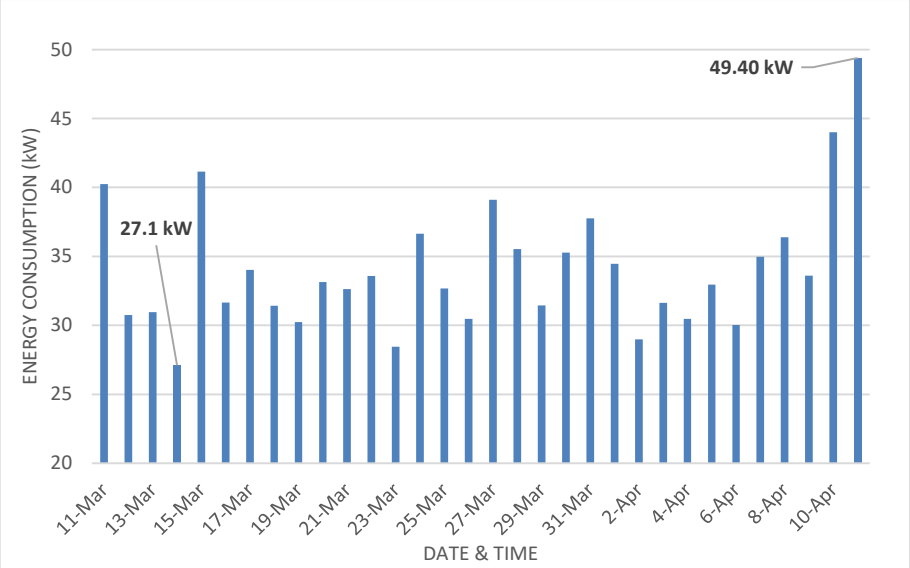


Fig. 3. Total energy consumption by day

Looking at hourly consumption patterns from the figure 4, the data showed consistent daily routines aligned with business hours. Energy use typically ramped up between 8 a.m. and 6 p.m., with the highest recorded usage of 5.53 kW occurring at 10:45 a.m. on March 27. The pattern generally showed morning increases, afternoon peaks, and evening declines, with a noticeable dip during lunch hours. These patterns reflect the business's operational schedule and provide valuable insights for improving energy efficiency and reducing costs.

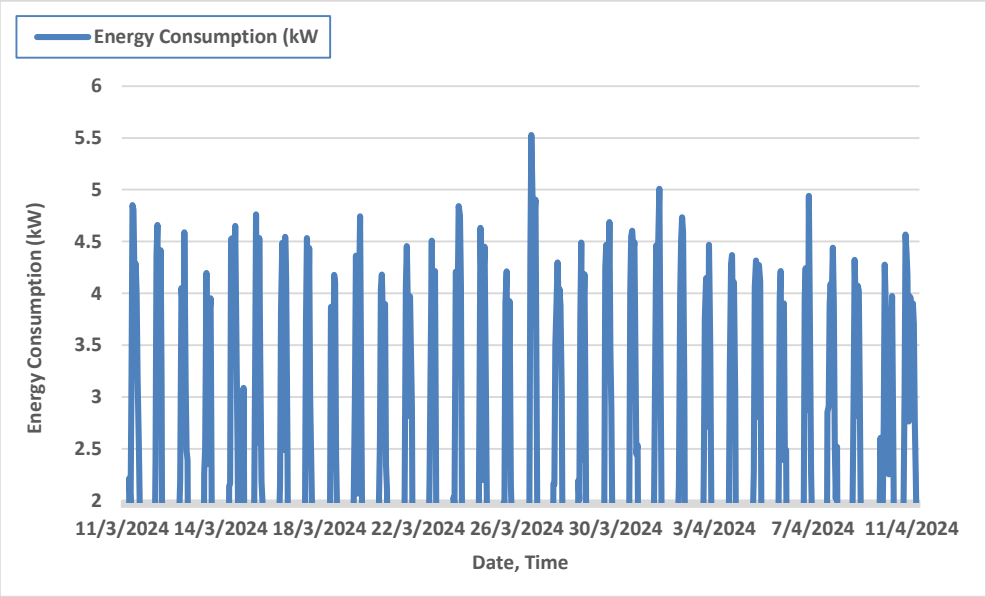


Fig. 4. Total energy consumption by hour

3.3 Load Apportioning

Commercial laundries track energy usage by monitoring how much power each piece of equipment consumes. This approach helps facilities charge customers fairly based on actual usage and promotes energy conservation. By keeping tabs on the power consumption of machines like washers, dryers, and irons, businesses can spot ways to save energy and identify equipment that might need maintenance or replacement [20].

Figure 5 revealed that dryers are by far the biggest energy users, consuming 647 kWh or 59% of total power usage. Flat irons and washing machines used much less, at 17% and 15% respectively, while other equipment accounted for the remaining 9%. These findings suggest that focusing on making dryers more efficient could lead to significant energy savings. Managers can use this kind of data to make smart decisions about scheduling, maintenance, and equipment upgrades to reduce overall energy consumption and operating costs.

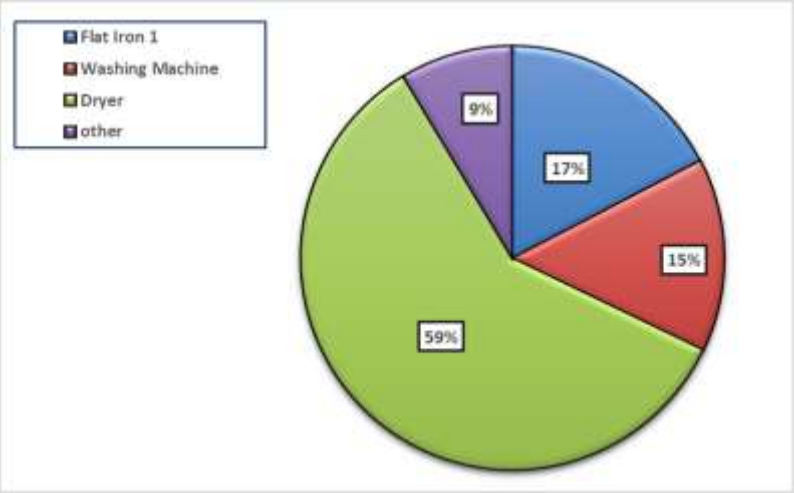


Fig. 5. Power consumption by equipment

The study examined how different pieces of laundry equipment use energy, aiming to find ways to make operations more efficient. The dryer was identified as using particularly high amounts of energy, suggesting that improving its efficiency could significantly reduce overall energy usage and make the operation more environmentally friendly. Figure 6 shows the energy data collected between March 11 and April 11, there were noticeable ups and downs in how much energy was used per kilogram of laundry. While most measurements showed energy use around 0.1 kWh/kg, there were two unusual readings: one unusually low at 0.02 kWh/kg and another unusually high at 0.16 kWh/kg. These variations might be explained by several factors, such as differences in how much laundry was being processed each day, what types of fabrics were being washed, or potential problems with the equipment.

Fig. 6. Specific energy consumption (SEC)

3.4 Energy Efficiency Index (EEI)

The Energy Efficiency Index is calculated by dividing the total energy consumed by the total weight of laundry processed as in Eq. (1):

$$\text{EEI} = \text{Total Energy Consumed ((kWh))} / \text{Total Weight of Laundry (kg)} \quad (1)$$

The calculation can be done using Eq. (1) for different timeframes (daily, weekly, monthly) as long as both the energy consumption and laundry weight are measured over the same period. This helps laundry facilities track their efficiency over time and compare their performance against industry standards. A lower EEI indicates better energy efficiency. Table 2 and 3 reveal significant energy efficiency gaps in commercial laundry compared to ideal standards.

Table 2
Ideal and real-life comparison for washing machine and dryer

Equipment	Ideal Consumption (kWh/kg)	Real Life Consumption (kWh/kg)	EEI
Washing Machine	0.21	0.52	2.48
Dryer	0.65	2.04	3.14

For washing machines, while the ideal energy consumption should be 0.21 kWh/kg of laundry [21], Table 2 showed that the commercial laundry for this study machines consume 0.52 kW/kg, indicating they use about 2.5 times more energy than recommended (EEI = 2.48). The situation is even more pronounced with their dryers, where actual usage is 2.04 kWh/kg compared to the ideal 0.65 kWh/kg [21], meaning they consume approximately three times more energy than they should (EEI = 3.14). These inefficiencies can be attributed to several factors, including the age of the appliances, operational practices such as water temperature selection, and maintenance routines. Addressing these issues could lead to substantial improvements in energy efficiency and cost reduction.

Table 3
Ideal and real-life comparison for flat iron

Equipment	Ideal Consumption (kWh/kg)	Real Life Consumption (kWh/kg)	EEI
Flat Iron	41.7	47.45	1.14

The EEI is a simple way to measure how efficiently an appliance uses energy, where a score of 1.0 means perfect efficiency, using exactly the amount of energy it should. Table 4 shows that the commercial laundry's flat iron scored 1.14 on this index, which means it's consuming 14% more energy than ideal. This extra energy consumption not only increases electricity bills but also has a greater environmental impact. The inefficiency could be due to several factors: the flat iron might be an older model, it might need maintenance, or it could be used improperly, such as being left on for too long. These issues would need to be addressed to improve its energy efficiency.

4. Conclusions

The energy audit revealed significant insights into the facility's energy consumption patterns, highlighting critical areas for improvement. Substantial fluctuations in monthly and daily energy usage were observed, with the dryer emerging as the most energy-intensive equipment, consuming

59% of total energy. The Energy Efficiency Index (EEI) comparison exposed considerable inefficiencies, with the washing machine and dryer consuming 2.48 and 3.14 times the recommended energy levels, respectively. To reduce energy waste and costs, launderette owners should take these practical steps: regularly check and maintain all machines, especially dryers, to prevent energy waste; replace old machines with energy-efficient models; teach staff to use the right cycle settings and load sizes; install a simple system to measure daily energy use; add heat recovery units to capture and reuse heat from dryers; and set business hours from 8:00 AM to 6:00 PM, staying open longer only when customer demand is high. By implementing these straightforward improvements, the commercial laundry can significantly cut energy costs while becoming more environmentally friendly. The study not only provides a comprehensive assessment of the facility's energy performance but also emphasizes the critical role of energy audits in identifying and addressing efficiency opportunities within commercial laundry operations. Recommendations for future work include the implementation and thorough evaluation of the proposed energy-saving strategies to validate their effectiveness and long-term impact.

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