Energy Performance Indicator for Health Care Building: A Case Study of a Small sized Hospital in Indonesia

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ABSTRACT

Energy is needed to guarantee the reliable and safe operation of healthcare buildings. The hospitals and other healthcare building energy performance have been investigated using several sets of energy performance indicators (EnPIs) formulation in several contexts. Often, those EnPIs are meaningless compared to other healthcare buildings, or they are restricted in their ability to guide energy investment planning or operation. This study examined four approaches—kWh/sqm/year, kWh/bed-day, kWh/overnight inpatient, and kWh/sum of inpatient and outpatient—for calculating EnPIs of a small-sized government hospital. The analysis focused on methods for defining EnPIs in the healthcare industry. With a value of 4.62 kWh/patient, it was found that the kWh/sum of in and outpatient was the optimal EnPI model.

Keywords: energy performance, hospital, energy management, bed occupancy, base line

INTRODUCTION

The government's overarching plan for the country's energy industry emphasizes diversification, environmental sustainability, and the most efficient use of domestic energy resources. Furthermore, energy efficiency projects aim to reduce annual energy use by 1%. Despite being underutilized in Indonesia, energy efficiency and renewable energy work hand in hand with cutting CO2 emissions and preparing for energy development. Energy efficiency would reduce emissions from energy production as well as the amount of generation capacity required. (ADB, 2020)

A review of the baseline trend of Indonesia's emission sources indicated a 29% increase in energy contribution from 2010 to 50% in 2030, indicating that energy will take a particular effort to decrease greenhouse gas emissions. However, the use of energy, particularly fossil fuels, necessitates careful consideration of their long-term viability as natural resources and the repercussions of the emissions produced by their combustion. (MEMR, 2020)

The healthcare industry contributes roughly 4.4% of worldwide emissions, with the United States, the European Union, and China accounting for 56%.(Karliner et al., 2019). The WHO defines the healthcare industry as "all organizations, institutions, and resources devoted to producing health actions." A health action is "any effort, whether personal health care, public health service, or cross-sectoral initiative, with the primary goal of improving health." The primary sources of healthcare energy emissions are energy usage, transportation, production, and product disposal. Healthcare facilities and cars (Scope 1) account for 29% of total emissions, while unintended emissions from energy supplies (Scope 2) account for the remaining 29%. Scope 3 emissions are those from the supply chain. Energy use (including electricity, petrol, and fuel) accounts for more than half of the sector's emissions (across the three scopes), with fossil fuel being a significant driver.

The global healthcare climate footprint is the equivalent of 514 coal-fired power units' greenhouse gas emissions. Three significant countries, the United States, China, and the European Union, have contributed the most to the global healthcare climate footprint. Healthcare emissions account for a different proportion of each country's climate footprint. They range from 7.6% in the United States, 6.7% in Switzerland, 6.4% in Japan 1.,5% in India, and 1.9% in Indonesia. Many low- and middle-income countries needed data. Most of the 43 countries studied are close to the global average of 4.4%.(Karliner et al., 2019).

According to a survey of 6 government hospitals in Gujarat, India, the average yearly electricity consumption was 1.27 million kWh, 1,309 kWh/bed/year, and 43 kWh/sqm/year. The middle hospital space was 34,382 square meters, with 1,006 beds. (Kapoor, 2009)

In India, electricity is the primary energy source for hospitals, accounting for more than 90% of total hospital energy use. The kWh/bed per year differs significantly from private and public hospitals. One probable explanation is the offering of different degrees of medical care. They also discovered that the significant energy users for five of those hospitals are HVAC, water pumping, and lights. HVAC consumes 30% to 65% of electrical energy, and lighting is 30% to 40%. (Kapoor, 2009)

Table 1. Healthcare Facilities Energy Benchmark (BCA, 2021)

Type of hospital	Number of buildings (in 2020)	kWh/Bed Space		
		2015	2019	2020
Public Hospital	5	53,477	53,205	53,061
Private Hospital	6	58,382	58,559	58,438
Community Hospital	5	10,263	13,652	12,885
Nursing Homes	30	3,811	3,850	3,845

When comparing the intensity of energy usage in Singapore, the ratio of kWh split by bed spaces differs by type. Nursing facilities had the lowest value of 3,845 kWh/bed spaces, while General Hospitals had the highest value of 58,382 kWh/bed spaces. As shown in Table 1, this benchmarking was completed in 2020.

Table 2. Healthcare facilities' energy use intensity (BCA, 2021)

Type of hospital	Number of buildings (2020)	kWh/m^2.yr 2015	2019	2020
Public Hospital	12	390	364	365
Private Hospital	6	367	340	340
Community Hospital	5	116	185	174
Polyclinics	7	142	152	151
Private Clinics	4	229	219	205
Nursing Homes	31	83	91	91

Furthermore, benchmarking energy intensity in the same year using the ratio of kWh to building area with air conditioning shows varying values according to the same category, with nursing homes having the lowest at 91 kWh/m2.year and general hospitals having the highest at 365 kWh/sqm.year, as shown in Table 2.

Using a regression method, an energy indexing formula for various types of Malaysian hospital buildings was developed to demonstrate the particular impact of explanatory variables on the explained variable of electrical energy consumption. The energy indexing has been calculated for each hospital category, and the results show that a significant specialist hospital has an average predicted energy performance as high as 191 kWh/sqm. Year, followed by a public hospital at 185.72, a minor specialist hospital at 173.24, and a non-specialist hospital at 147.81. (Zuharah et al., 2021)

A study on particular energy usage benchmarking for commercial buildings was conducted in Indonesia. The survey subjects included 70 hotels, 50 hospitals, 40 retail malls, and 40 office buildings in seven major cities (Jakarta, Bandung, Semarang, Surabaya, Bali, Medan, and Pekanbaru). The EnPI benchmark results for hospitals were 180.81 kWh/sqm.year based on an investigation of 53 hospitals with ten sub-categories of class A, 18 class B buildings, and 25 class C buildings. (BBTKE-BPPT, 2020).

To summarize the literature, hospitals' Energy Performance Indexes (EnPIs) were presented in descending order in Table 3.

Table 3. Comparison of Hospital EnPIs. (Liu et al., 2020)

Country	kWh/sqm/year
US	1,473
Wales	622
UK (average)	550
Scotland	467
Australia (regional public hospitals)	460
UK (NHS benchmark)	445
Australia (capital city public hospitals)	393
India	200
China (electricity only)	96

So far, this investigation has revealed three significant flaws in the typical hospital's energy ENPIs: Because many variables and factors might affect energy performance, kWh/m2 does not provide actionable evidence to advise if a particular hospital is energy efficient or facilitate comparison among facilities. Similarly, kWh/bed per year or bed day per year does not indicate a facility's degree of medical services or the social or cultural features of the interior environment. These ENPIs cannot advise us on optimizing energy-related investments or operations to enable additional renewable or energy-efficiency measures.

Therefore, proper, measurable, and reliable EnPI benchmarking for the healthcare sector is essential, particularly in Indonesia. This paper applied several methods to calculate EnPI at a government hospital in Central Jakarta.

METHOD

The organization should be aware of its energy consumption characteristics, such as base load (i.e., fixed energy consumption) and variable loads caused by production, occupancy, weather, or other factors when identifying an EnPI. The users of the information and their demands are essential aspects to consider when selecting acceptable EnPIs.

There are four main types of EnPIs (International Organization for Standardization (ISO), 2017) : (1) energy consumption measurement: consumption of the whole site or one or more energy uses measured by a meter; (2) The ratio of measured values as the energy efficiency formulation; (3) statistical model: using linear or nonlinear regressions expresses the relationship between energy consumption and appropriate variables; (4) engineering based model: using engineering simulations to show the relationship between energy consumption and appropriate variables.

EnPIs have been benchmarked in a few countries to compare energy use in commercial facilities to compare the energy performance of a building with an established standard or norm. In the field, it can be utilized as a starting point for creating an energy management program in the hospital.

The most common indicators used internationally for benchmarking in hospitals are (a) the hospital's building area energy consumption per square meter per year and (b) Per inpatient bed in the hospital energy consumption per year.

It is critical to remember that these indications are based on the technical qualities of the structure. If enough data is obtained and compiled, comparing hospitals based on energy usage per bed and square meter is preferable. The degree of outsourcing in the hospital is one of the challenges to benchmarking. For example, some hospitals contract out their food and laundry services, resulting in lower energy usage by the hospital and, consequently, lower energy baselines and benchmarks.

However, each indicator has specific disadvantages: (a) the hospital energy management needs to define which areas of the hospital building are considered in the benchmark or not (e.g., outdoor space, car parks, corridors, and equipment floors). Furthermore, which area is using HVAC or not in the actual situation? (b) When the number of beds is considered, which element is defined by the type of hospital and the construction design standards? One must think about the tendency towards higher quality health care and greater patient privacy, which may result in fewer beds per room and, hence, a more significant number of square meters per bed. Furthermore, many hospitals have added energy consumption metering in out-patient and in-patient departments. Therefore, independent sub-metering of both may be essential for effective benchmarking.

Moreover, another benchmarking method commonly used in process industries is "benchmarking based on production" by the hospital. The number of patient overnights could be one of the indicators used for "production" in hospitals. It allows one to calculate the energy use per overnight.

Nevertheless, this is heavily influenced by the sort of institution and trends in healthcare facilities. For example, the number of overnights for each treatment has dropped dramatically in recent years as the number of treatments per bed has increased significantly. When the number of inpatients grows and hospital room space becomes scarce, less area per patient is supplied. Climate factors also significantly impact hospital energy usage; therefore, climate-based benchmarks may be more meaningful or need to be normalized sufficiently for an adequate comparison.

This study applied four kinds of principles to determine the Energy Performance Indicator of Government Hospitals in Jakarta, consisting of (1) kWh/sqm/year, (2) kWh/bed day/year, (3) kWh/sum of inpatients/year, and (4) kWh/sum of in and outpatients/year. Next, baseline energy modeling of the four EnPIs is carried out using linear regression to determine the best value of the goodness-of-fit measure for linear regression models.

A. Data Collection

A case study was carried out at a provincial government hospital in the Central Jakarta area; this building has 3 (three) stories and is a type D government hospital with emergency room service hours 24 hours, Monday - Sunday. The primary energy used in the Hospital building comes from electricity with the power contract 197 kVA with the premium tariff, and there is 1 (one) generator unit as a backup with a capacity of 135 kVA. The Hospital building, with a southeast orientation, as depicted in Figure 1, consists of 3 (three) stories with 244 employees. This hospital building has a total air-conditioned floor area of 2450 sqm.

The data collected includes three consecutive years of historical energy consumption, the total number of inpatients, the total number of in- and outpatients, and the total number of bed days.

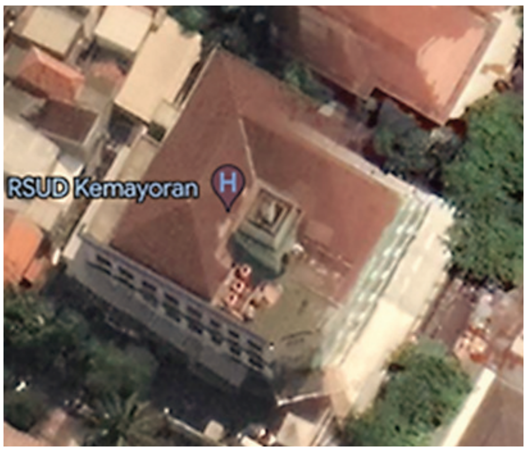

Figure 1. Hospital Building

B. Energy Use Profile

The most extensive distribution of electrical energy consumption in sequence starts with the lighting system (lighting and sockets) at 57.4%, followed by the air conditioning system (AC cooling equipment) at 41.0%, other equipment at 1.0%, and the elevator at 0.6%.

C. Load Profile

Figure 2 shows the weekly load profile of the hospital, with peak load as around 150 kW on Monday, Tuesday, Wednesday, and Friday and around 100 kW on the weekend.

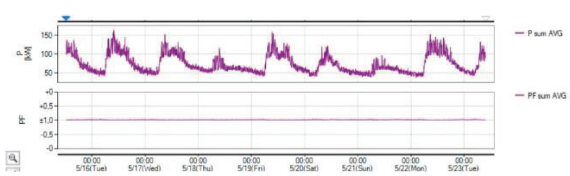

Figure 2. Daily Load Profile of the Hospital

Figure 3 shows the daily energy profile of the hospital and the energy consumption on Monday, Tuesday, Wednesday, and Friday at around 2,000 kWh and 1,400 kWh on the weekend.

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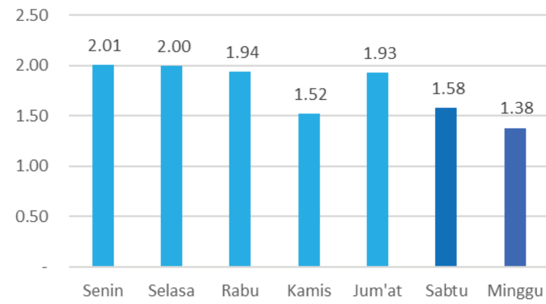


Figure 3. Daily Energy Profile (kWh)

RESULTS

A. Energy Performance Indicator

Hospital energy consumption data for the last three years was collected and divided by the area of the hospital with air conditioning. The data collected is monthly; the graph is shown in Figure 4 below. The calculation results show that the PPI in 2020, 2021, and 2022 are 159.68, 137.06, and 161.29 kWh/m2/year, respectively. Monthly data shows varying EnPI from the lowest value, 9.71 kWh/m2/month, to 15.86 kWh/m2/month.

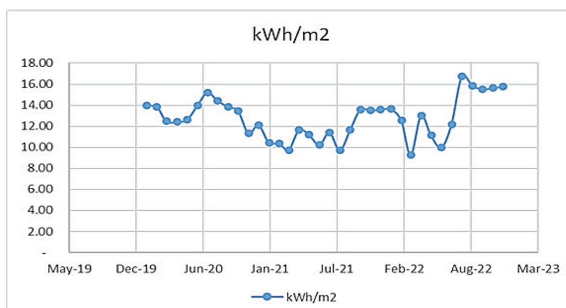


Figure 4. kWh/m2/month

Next, EnPI is calculated based on the electrical energy consumed divided by the number of bed days. A bed-day is when a person is acknowledged as an inpatient confined to a bed and stays overnight in a hospital. (Organization for Economic Cooperation and Development, 2022).

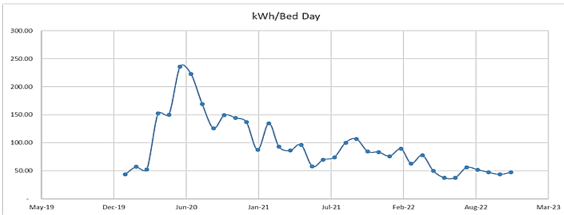


Figure 5. Monthly kWh per bed day

The EnPI based on kWh/bed day in 2020, 2021, and 2022 is 1,640, 1,074, and 676 kWh/bed day/year, respectively. As shown in Figure 5, monthly data shows the EnPI varies from 37 kWh/bed day/month to 236 kWh/bed day/month.

The third EnPI method is applied based on the hospital's "production." In hospitals, "production" may refer to the number of patient overnights and in- and outpatients. Therefore, the energy consumption per patient per overnight can be determined.

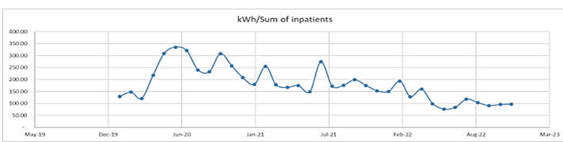


Figure 6. kWh / sum of inpatient

Figure 6 shows the kWh/sum of inpatients in the hospital. The EnPI based on kWh/inpatient in 2020, 2021, and 2022 are 235.42, 187.57, and 116.02 kWh/inpatient, respectively, resulting in 179.67 kWh/patient. Monthly data shows varying EnPI from the lowest value of 76 kWh/inpatient to 335 kWh/inpatient.

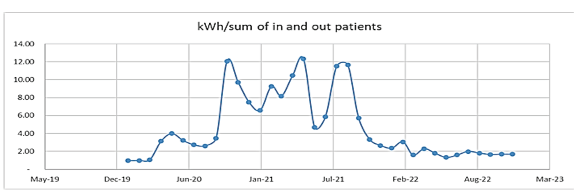
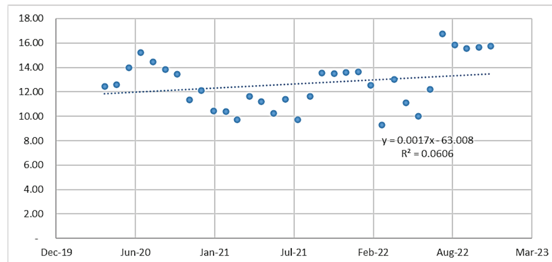


Figure 7. kWh/ sum of in and outpatient

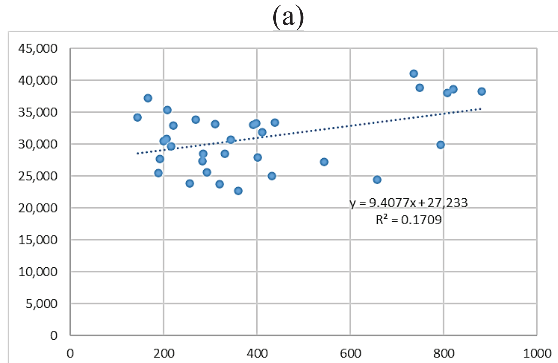
Figure 7 shows the kWh/sum of in and outpatients of the hospital. The outpatient of the hospital consists of Emergency Response. The EnPI based on kWh/ sum of in and outpatients in 2020, 2021, and 2022 is 4.29, 7.69, and 1.9 kWh/patient, respectively, resulting in a 4.62 kWh/patient average. Monthly data shows varying EnPI from the lowest value of 0.96 kWh/patient/month to 12.33 kWh/patient.

B. Energy Baselines

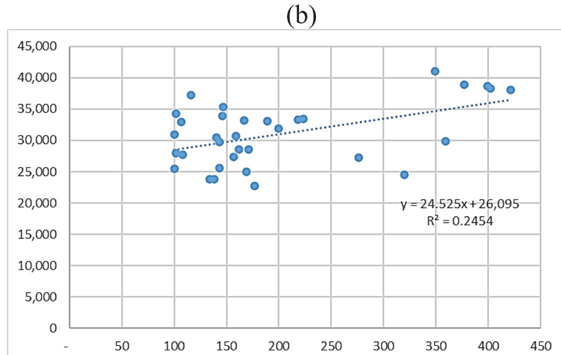
Energy Baselines (EnBs) are attributes used to compare EnPI values over time and quantify changes in energy performance. Linear regression analysis for each EnPI has been done, as depicted in Figure 8. The goodness of fit of the linear equation varies from 0.0606 to 0.4509.



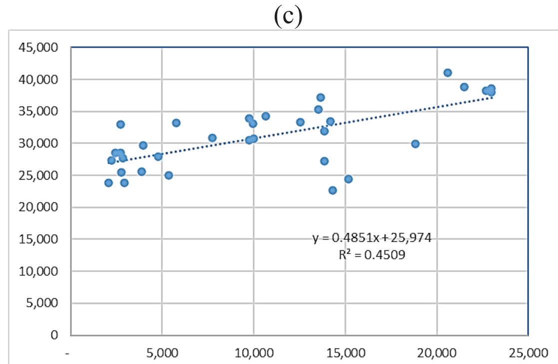
(a)



(b)



(c)



(d)

Figure 8. Energy baselines linear regression (a) kWh/sqm, (b) kWh/bed days, (c) kWh/inpatient, (d) kWh/Patients.

CONCLUSION

The analysis results show that the average hospital EnPI based on the ratio of kWh and the air-conditioned area is 152.67 kWh/sqm per year. This value is lower than the Singapore benchmarking for community hospitals and Malaysian minor specialist hospitals. It is also lower than the EnPI benchmarking for hospitals in Indonesia, which is 180.81 kWh/sqm per year.

The average hospital EnPI based on kWh and bed day ratio is 2,939 kWh/bed day/year. This value is less than Singapore benchmarking for Community Hospital but higher than India, which values 1,309 kWh/bed per day/year. The EnPI based on kWh/inpatient is 179.67 kWh/inpatient on average, while the EnPI based on kWh/ sum of in and outpatient is 4.62 kWh/patient.

Linear regression analysis of the baseline shows that the equation's goodness of fit is 0.4509, its slope 0.4851 kWh/patient, and its intercept 25,974 kWh. The best EnPI model from the four approaches was kWh/sum of in and outpatient.

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