

Building Energy Performance and the Influence of the Operational Parameters in an Educational Hospital

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Abstract

The speed at which the demand for energy is increasing around the world has led to anxiety over supply insufficiency. The difficulties associated with setting up energy infrastructure is an additional concern. This paper reviews the amount of energy required by structures and identifies different variables that influence the use of energy by buildings. The energy requirement of a teaching hospital in Iraq was determined (i.e. its energy performance was determined). The energy performance of a building is related to its Building Energy Index (BEI). BEI is measured in kWh/m²/yr and is an indication of how efficient a building is with respect to its usage of energy, i.e. the value of the BEI of buildings helps to ascertain which building is more efficient than the other in their usage of energy. The results of this review indicate that the load and time usage factors are directly proportional to the BEI. The hospital's BEI was determined to be 235 and this value was compared with those of other studies.

Keywords: Building Energy Index, Energy Audit, Energy Consumption, Teaching Hospital.

الخلاصة

إن سرعة الطلب على الطاقة حول العالم في تزايد أدت إلى القلق بشأن التجهيز الغير كفاء للطاقة. وتعتبر الصعوبات المرتبطة بإقامة هيكل الطاقة كاهتمام إضافي إلى ذلك. إن هذا البحث يستعرض كميات الطاقة المرتبطة بهيكل والمتغيرات المختلفة المؤثرة باستخدام الطاقة في المباني. إضافة إلى حساب متطلبات الطاقة في مستشفى تعليمي (أداء طاقة المباني). أداء الطاقة في المباني يرتبط بمعامل أداء الطاقة في المباني (BEI) والذي يقاس ب (kWh/m²/yr) والذي يعتبر مؤشر لكيفية الاستخدام الأمثل للمباني نسبة إلى استخدام الطاقة فيها قيمة (BEI) للمباني تساعد على تحديد إي المباني أكثر كفاءة باستخدامها للطاقة من غيرها. أظهرت النتائج بان الحمل ومعامل استخدام الوقت يتناسبان طرديا مع BEI. وان قيمة (BEI) هي 235 وهذه القيمة قد تم مقارنتها مع دراسات أخرى. كلمات المفتاحية: - مؤشر بناء الطاقة، مراجعة الطاقة، استهلاك الطاقة، المستشفى التعليمي.

Nomenclature

AECm	Annual motor electricity consumption measured in kWh
P	Power measured in kW
TU	Time of use per day
LD	Loading factor measured in %
TUF	Time usage factor measured in %
ND	Number of days used per year
AECI	Electricity consumed by lighting systems per year in kWh
LT	Type of lighting (W/m ²)
A	Respective lighting section area
TU	Daily time of use
AECe	Annual appliance electricity consumption in kWh
TAEC	Total annual electricity consumption in kWh based on electricity bills
AECa	Annual air conditioning electricity consumption in kWh
AECI	Annual lighting electricity consumption in kWh
AECli	Annual air lift electricity consumption in kWh.

Introduction

Some previous related studies indicate that the energy used in different types of buildings in developed countries exhibited a gradual increase of between 20% and 40% in the last decade (Pérez *et.al.*, 2008 ; Aste & Del Pero , 2013) . The energy crisis of the 70's

compelled engineers, architects and building managers to come up with more innovative ways of reducing energy utilization in buildings, thereby increasing efficiency. Energy utilization is one of the greatest problems that architects and engineers encounter in building construction (Chua *et.al.*, 2010) . Efficiency in the utilization of energy is very important in hospitals because hospitals consume a large quantity of energy due to several reasons. First, hospitals operate 24 h per day. Second, hospitals use a large number of air conditioners because the indoor environment and air quality of hospitals are important. The use of air conditioners is particularly significant in hot, dry regions, because of high temperature. Efficiency in energy utilization reduces the quantity of energy that is used and leads to lower energy cost. The first process in achieving energy efficiency is the acquisition of baseline energy information, since it is important to know how energy is distributed in a building in order to determine how to minimize its usage. Since 2000, low energy buildings have been receiving increased attention by decision makers (Lim *et.al.*, 2012) . This study aims to determine the energy usage efficiency of a big teaching hospital in the hot, dry climate of Iraq (Teske *et.al.*, 2010 ; Bertoldi *et.al.*, 2008) . In doing this, the value of the hospital's Building Energy Index (BEI) was ascertained. An evaluation was done to determine the hospital's energy distribution with respect to air conditioners, elevators, lights, equipment etc. A breakdown of the energy used in this study shows that 75% of the total energy, which constitutes the highest percentage, was attributed to electricity. The BEI was determined in order to compare the utilization level of the selected hospital (a typical hospital building) with the utilization levels of other hospitals in Malaysia. The utilization level of the selected hospital was also compared with those of low energy buildings and Malaysian standards. The policies of developed countries in the energy sector target the achievement of an efficient utilization of energy as one of their most important goals (Moghimi *et.al.*, 2011; Recently, Zain *et.al.*, 2013) introduced two new indexes namely Effective Building Energy Index (EBEI) and Specific Building Energy Index (SBEI)[8]. The authors presented the benchmarking additional approach in order to minimize energy wastage in the Engineering Complex of the University of Technology Mara, Shah Alam, Malaysia. The BEI of this complex was determined as 149 kWh/m².year, while the EBEI was determined as 186 kWh/m².year. Further, the SBEI was determined as 0.207 kWh/m².year for an occupant. Different approaches were discussed in this study that could reduce energy consumption by up to 20%.

2. Energy Audit

An energy audit evaluates the use of energy in a building (Mahlia *et.al.*, 2004) . Energy audit is an approach which analyzes the flow of energy for the purpose of minimizing the amount of energy used in a building without reducing the comfort of occupants (Wai *et.al.*, 2011; Singh *et.al.*, 2012) . The application of energy audit can enhance efficiency in energy utilization in high-rise buildings. Energy audit is very important in the management of energy (Rathod *et.al.*, 2013). Furthermore, it is very difficult to achieve efficiency in energy utilization in an office building without energy audit. Energy audit also helps to reduce the amount spent on electricity (Worrell *et.al.*, 2008; Choong *et.al.*, 2012). In order to effectively carry out energy audit of buildings, certain advanced skills are needed. These skills will help in the performance of specific activities like identifying the various energy systems, assessing their conditions, analyzing the impact an improvement would have on the systems and preparing the report of the audit.

3. Research Methodology

According to Wikipedia (<https://en.wikipedia.org/wiki/Iraq>), Iraq is a country situated between latitudes 29° and 38° N, and longitudes 39° and 49° E. However, a small area lies west of 39°. The country spans 437,072 km² (168,754 sq mi), and it is the 58th-largest country in the world. Most parts of Iraq are hot and dry with a few parts

having subtropical climate. The average summer temperature is above 40 °C (104 °F) for most of the country, and it frequently exceeds 48 °C (118.4 °F). The temperature during winter rarely exceeds 21 °C (69.8 °F). The maximum temperature during winter ranges from 15 to 19 °C (59.0 to 66.2 °F) with low night-time temperature range of 2 to 5 °C (35.6 to 41.0 °F) [Wikipedia (<https://en.wikipedia.org/wiki/Iraq>)]. The Faculty of Medicine in Babylon University was selected for the evaluation. The field study was done at a teaching hospital located in Hilla, Babylon.

This study examines the characteristics of energy systems of buildings, and data were acquired by both quantitative and qualitative approaches. In investigating the energy usage of the teaching hospital in Iraq, this paper focuses on electricity use. This study employed the use of surveys based on semi-structured interviews with experts involved in the maintenance and management of buildings. Local officials were also interviewed.

4. Energy utilization

Different forms of energy are used in the selected hospital. Among them, the most used form is electricity, which is provided by the Electricity Distribution Directorate of Babylon. In the hospital, electricity is used for two main purposes: to power lighting systems and to power mechanical devices. Based on the fact that hospitals are required to function all day as well as at night and because of the sensitive nature of their activities, they require uninterrupted electricity supply.

5. Electrical energy distribution

To ascertain the hospital's electricity distribution pattern, the various electrical appliances that consume electricity were grouped as follows: air conditioners, elevators, lights, and other appliances. A power logger, which can monitor electricity usage at a particular period of time, was used to measure the electricity utilized by each group.

Load factor and Time usage factor

Load factor means the average load at a particular time divided by the peak load at that time. Load factor is an indication of efficiency in the use of energy. The load factor is a key indicator of the cost of generation per unit (kWh). Based on the number of hours per day, per week, per month, and per year, different load factors are defined. The period T was taken as 24 hours for the daily load factor. Also, different values of T were taken for weekly, monthly, and yearly load factors. In the case of the time usage(or utilization) factor, it is defined as the ratio of the time of usage of an equipment to the total time that it is available to be used.

Air conditioners

The application of the following equation as indicated by (Moghimi *et.al.*,2014) determines the electricity consumed by the air conditioning systems:

$$AECm = P \times TU \times LD \times TUF \times Nd \quad (1)$$

❖ Elevators

There are six lifts in the hospital; four of them are located in the two main hospital cores, while two are used exclusively for the operation rooms. A power logger was used to measure the energy consumed by the lifts in each of the two cores separately.

❖ Lights

The application of the following equation determines the electricity consumed by lightings:

$$AECl = LT \times A \times TU \times TUF \times Nd/1000 \quad (2)$$

❖ Appliances

The following equation was used to determine the electricity consumed by all appliances according to Moghimi et al. (2014):

$$AECe = TAEC - (AECa + AECl + AECl_i) \quad (3)$$

Different substations supply electric power to the hospital. Electric power from each substation is divided in two: electricity for lighting and electricity for mechanical systems. Since hospitals operate 24h a day and as a result of the important nature of hospital equipment, electricity supply should be uninterrupted. Al-Hilla hospital has a generator that supplies backup electric power. The generator makes use of diesel oil.

The second source of energy in the hospital is Natural gas (LPG). It is used for heating water as well as for sterilization, laundry and other purposes.

To realize its aim, this study determined three levels of utilization: energy utilization per year, energy utilization per month, and energy utilization per day.

The electricity consumed yearly and monthly were determined based on the historical energy bills of the hospital.

Measurements were taken every day regardless of whether it was a working day or a weekend. The daily usage was regarded as the same for holidays and weekends.

Energy performance of a structure

In determining the energy performance of structures, i.e. how efficiently such structures use energy, an important factor that is considered is its size. The performance of a structure with respect to its energy usage is related to its BEI, which is used for the purpose of comparison of the energy efficiency of buildings (Altan et.al., 2014; Abdul-Rahman *et.al.*, 2011). According to an online source (<https://umexpert.um.edu.my>), the amount of energy used by a building alone cannot determine whether the building over consumes energy or not. Energy utilization is assessed based on the size of the building. Dividing the energy consumption by the building's size gives rise to the building energy index (BEI), also known as energy performance index (EUI) (Bishop , 2012). According to the mentioned website (<http://umexpert.um.edu.my>) "BEI is calculated simply by dividing the total annual energy consumption of the building (kWh/year) with its total occupied floor area" (m²) as follows:

$$BEI (kWh/m^2/year) = \frac{\text{Total annual energy consumption (kWh)}}{\text{Total nt floor area (m2)}} \quad (4)$$

In order to have a better knowledge of the energy performance of this hospital, its BEI was determined and compared with those of other hospitals in different climates in Malaysia as well as some low energy building in the same country.

The acceptable BEI of a hospital is 120 KWh/m²/year. This value of BEI ensures efficiency in the use of energy.

Energy benchmarking is relatively more accurate than BEI and has been widely employed in comparing the energy performance of buildings (Moghimi *et.al.*,2014) .

Table 1 shows zones' area in the hospital.

Table 1 Zones' area in the hospital.

No.	Zone name	Area (m ²)	Percentage %
1	Entry of management	277.265	12.87%
2	Entry of consultants	184.24	8.58%
3	Special wing of children	369.633	17.16%
4	Special wing of women	760.5	35.29%
5	Store of drugs	225	10.4%
6	Operation theatre	337.5	15.7%

Energy monitoring methods

Three major steps of gathering energy data of buildings were used in this study:

Desktop data collection

(Moghimi *et.al.*,2014) stated in their study that desktop data were collected to minimize the amount of field energy data and decrease the cost and time of gathering data. Based on their study, we utilized the following desktop data:

1. Architectural drawing maps
2. Historical data on energy bills
3. Electrical drawing maps
4. Mechanical drawing maps
5. Technical documents

Methods of obtaining data from the field

The following methods were employed to obtain data from the field:

1. Conducting a survey on the usage of energy by buildings to generate data.
2. Compiling the data obtained from the electricity meters (main and sub meters).

Results and discussion

1. Electricity consumption

The amount of electricity consumed on a daily basis was determined separately for weekdays and weekends to obtain the daily electricity utilization.

The yearly, monthly and daily electricity utilization are shown in Table 2 for each zone in the hospital.

Table 2: Data of electricity utilization for all zones in the hospital.

No.	Name of zone	Yearly Energy consumption (kWh)	Monthly Energy consumption (kWh)	Daily Energy consumption (kWh)
1	Special wing of women	1159.437	34783.1	303817.6
2	Special wing of children	563.5319	16905.96	147667.3
3	Operation theatre	514.5429	15436.29	134830.3
4	Entry of management	422.7103	12681.31	110766.6
5	Store of drugs	343.0286	10290.86	89886.86
6	Entry of consultants	280.887	8426.611	73603.35

In Fig. 1, the annual motor energy utilization at a constant time usage factor for different zones in a teaching hospital with load factors of 0.25, 0.45, 0.65 and 0.85 are shown. An increase in load factor causes an increase in the rate of annual motor energy utilization.

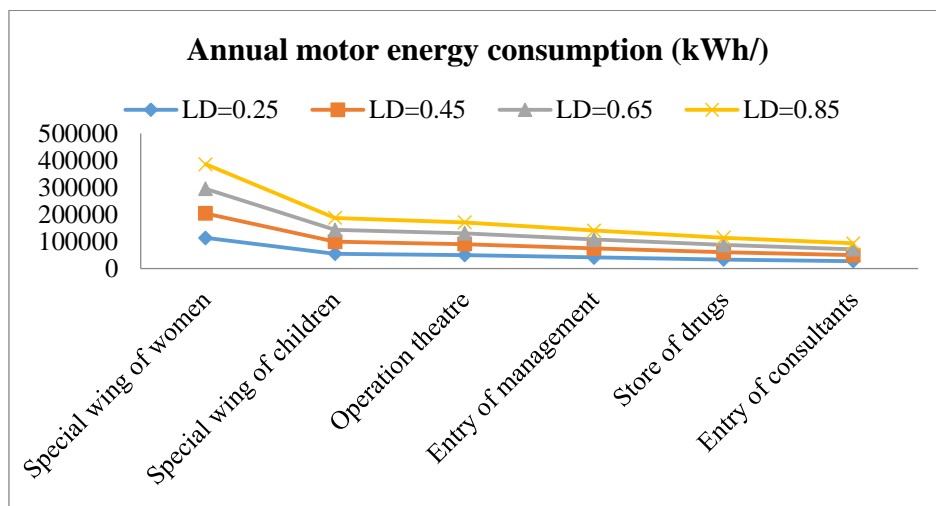


Fig. 1: Annual motor energy consumption of different zones with different load factors.

In Fig. 2, the daily, monthly and yearly motor energy consumption of different zones in the hospital are shown. Fig. 2 shows that in the special wing of women, which is the biggest area in the hospital, the energy consumed by air conditioners is more compared to other zones.

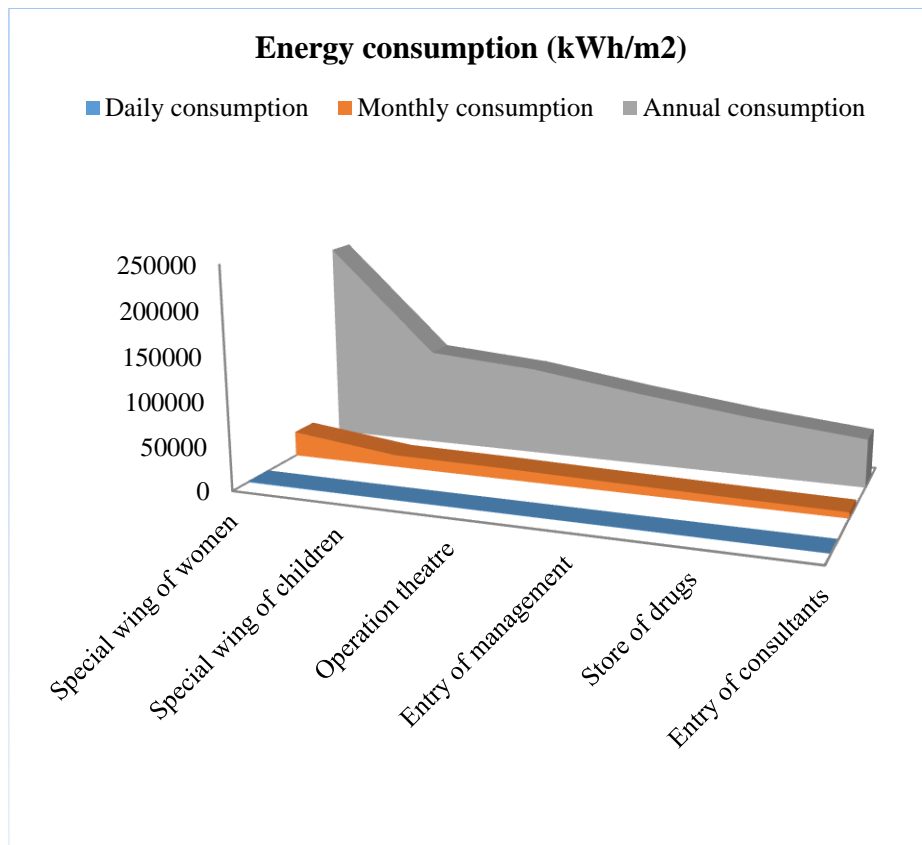


Fig. 2: Daily, monthly and yearly motor energy consumption at different zones

Fig. 3 demonstrates the effect of time usage factor on the annual motor energy consumption at different zones. In the case of a constant load factor (0.5), the results show that the annual energy consumption for lighting increases with increasing time usage factor.

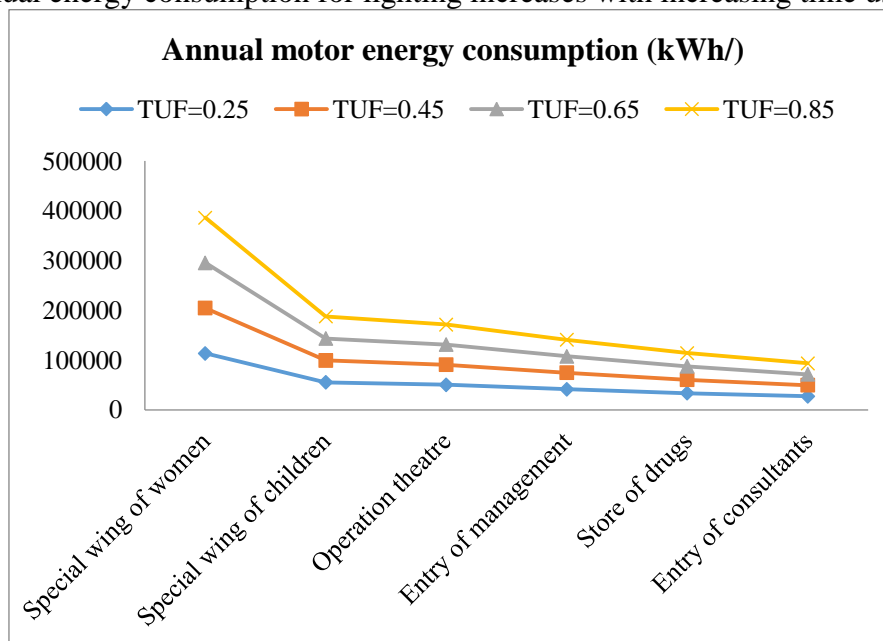


Fig. 3: Annual motor energy consumption at different zones with different time usage factor

Fig. 4 demonstrates the effect of time usage factor on the annual lighting energy consumption at different zones. The results show that the annual energy consumption for lighting increases with increasing time usage factor.

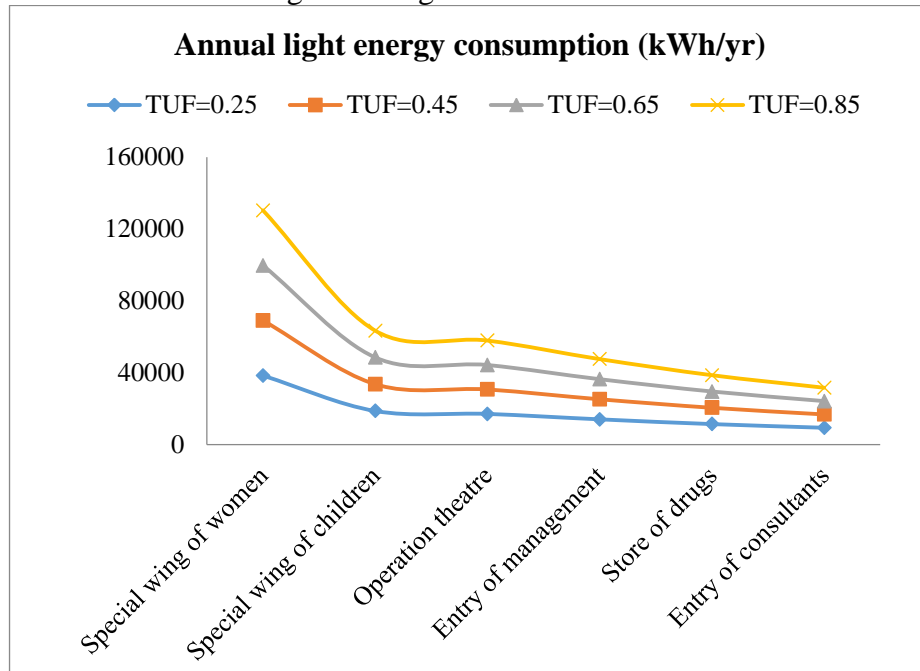


Fig. 4: Annual lighting energy consumption at different zones

Fig. 5 shows the daily, monthly and yearly lighting energy consumption at different zones in the hospital. Fig. 4 displays that the biggest area in hospital (special wing of women) consumed more energy for lighting than the other zones.

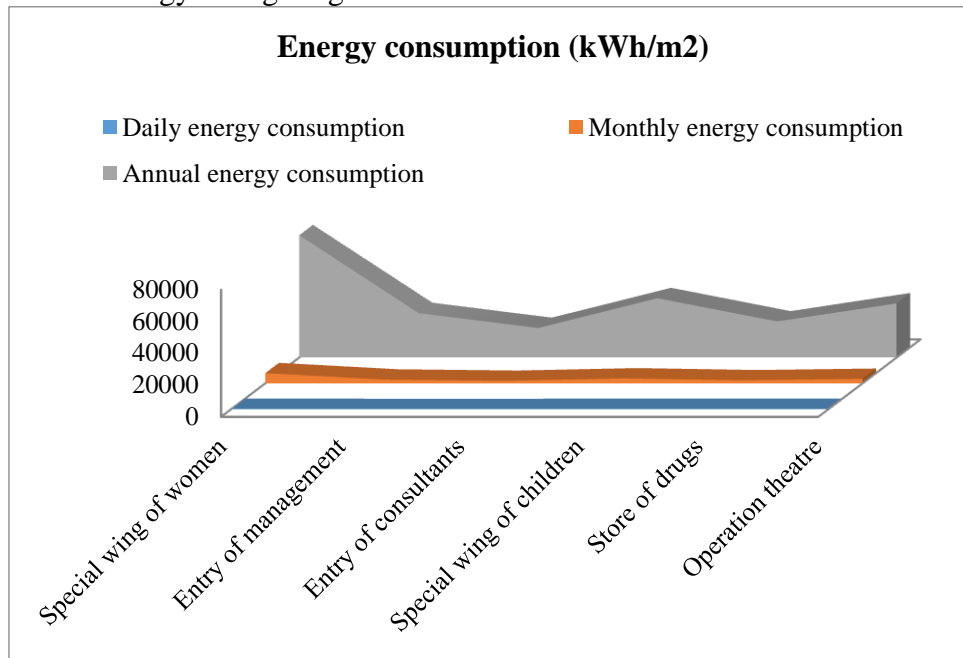


Fig. 5: Daily, monthly and annual lighting energy consumption at different zones.

The next figure (Fig. 6) is a representation of the relationship between load factor and BEI. Based on this figure, it is clear that BEI is proportional to the load factor, i.e. as load factor rises, BEI also rises. Fig. 7 shows the comparison between different hospitals and the case study in terms of BEI. The results show that the BEI of the case study (235 kWh/me/yr) was less than those of UKMMC and hospital B but more than that of hospital A.

Based on the comparison, UKMMC was observed to have the highest BEI, while the case study represents the mid value between hospitals A and B.

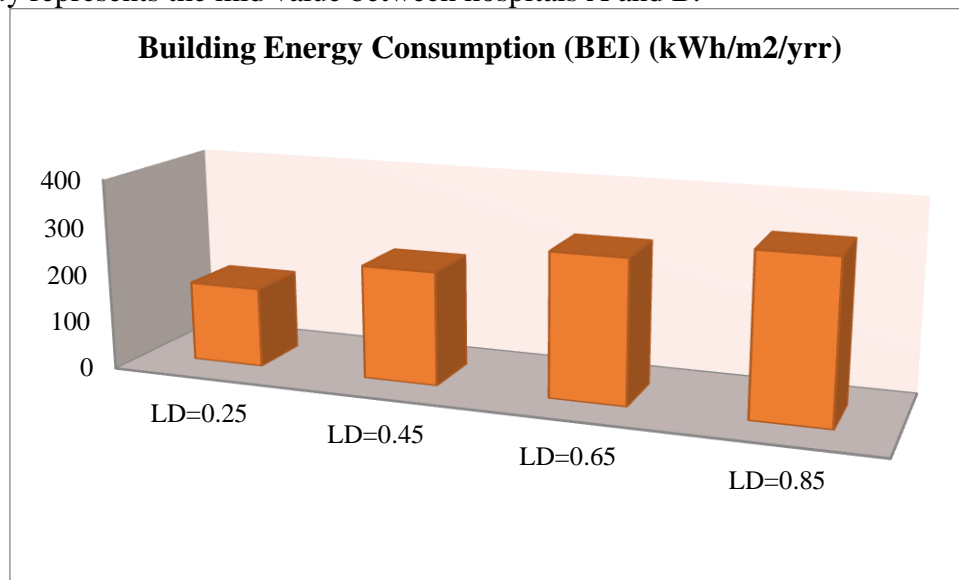


Fig. 6: Relationship between load factor and BEI

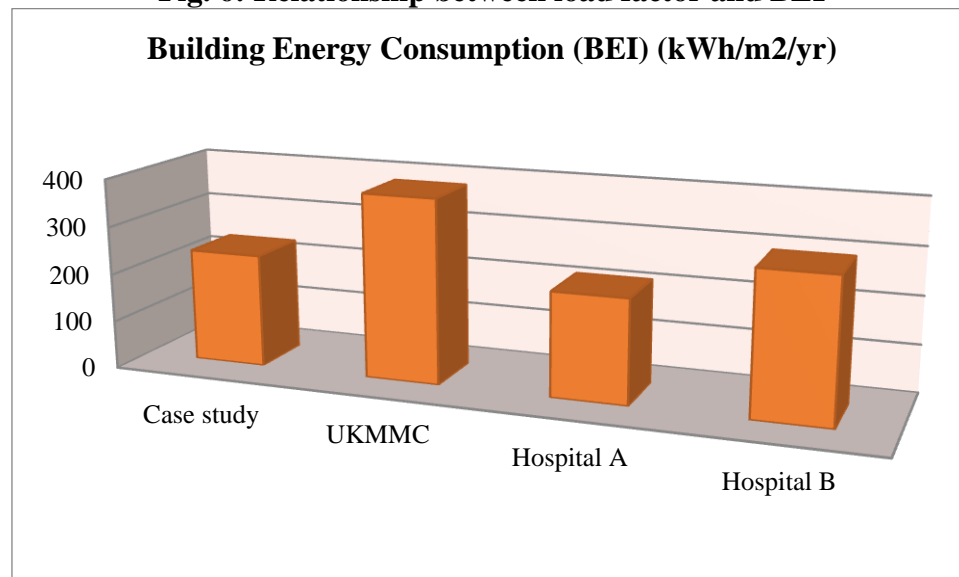


Fig. 7: Comparison between different hospitals and the case study in terms of BEI

Conclusions

1. Increasing the load factor will increase the annual motor energy consumption because of the higher range of electrical energy used daily to start up the air conditioners.
2. Higher number of hours of work per day means higher time usage factor, which increases the annual motor energy consumption. This also applies to annual lighting energy consumption. It means that the time usage factor is directly proportional to the annual motor and lighting energy consumption.
3. The results show increasing BEI, which represents the overall hospital performance according to the increase in the load factor.
4. BEI depends on some factors (load factor, time usage factor and area). A larger area needs more energy; thus, the BEI will increase due to high increment in energy consumption in comparison to area.

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