Songklanakarin J. Sci. Technol.
43 (6), 1779-1785, Nov. - Dec. 2021

http://www.sjst.psu.ac.th

Original Article

Building energy index (BEI) of hospital buildings in Iraq: A case study♣

Anwer Abdulhussein Gatea*, and Mohd Faizal Mohideen Batcha

Center for Energy and Industrial Environment Studies, Universiti Tun Hussein Onn Malaysia, Batu Pahat, Johor, 86400 Malaysia

Received: 5 December 2020; Revised: 17 June 2021; Accepted: 4 August 2021

Abstract

Hospitals are generally made by a large complex with many buildings serving different functions. These buildings such as the patient registration area, wards, operation theatre, emergency and trauma department and pharmacy operate continuously for twenty-four hours daily throughout the year, hence consuming a large amount of energy. This paper presents a pioneering case study carried out at three hospitals in Iraq, designated as Hospital A, Hospital B and Hospital C to analyze their energy intensity by determining the building energy index (BEI). This study also identified the factors affecting energy usage in these hospitals. Detailed energy audits were carried out in these hospitals, followed by desktop analysis and comparison with BEI values from selected hospitals reported in the literature. It was found that the average electricity consumed annually for a period of three years (2016 to 2018) by Hospital A, B, and C were 19,280,900 kWh, 11,958,121 kWh and 4,275,760 kWh, respectively. It was also found that more than 60% of the energy consumed in all three hospitals were by the air conditioning systems hence becoming the significant energy user (SEU). The study thus proposes methods to reduce the energy consumption in these hospitals without reducing their level of comfort. It was also found that the outside ambient temperature was the main factor that affecting the energy consumption in the building. The study concludes that the BEI values attained for the hospitals in this case study ranged from 360 to 532 kWh/m^2/year, which are relatively high and hence signifies the energy efficiency measures to be implemented in these hospitals.

Keywords: building energy index, hospital, energy efficiency

1. Introduction

In buildings, energy is used for various purposes such as for lighting, air-conditioning, ventilation, operate equipment and many more. Research on energy efficiency in the built environment has focused on ways of providing these services with lower energy consumption levels, and a wide range of performance assessment methods have been developed in recent years (Borgstein, Lamberts, & Hensen, 2018). Services in the buildings will vary depending on the form of the building and its principal uses. They will generally include thermal comfort, air quality, lighting, and others in hospital buildings. Apart from that, equipment will also use energy in the building and may sometimes be significant. Improving the buildings' energy efficiency is a key component for achieving more efficient energy management. Buildings account for 40% of energy consumed in the US, and a similar proportion is observed in Europe (Rouleau, Gosselin, & Blanchet, 2018). Healthcare is provided in complex and energy-intensive facilities ranging from hospitals for critical care to buildings for the medical offices. Overall, they account for a remarkable fraction of energy usage in the building sector, due largely to the very high levels of energy consumption in hospitals and other health care facilities. High energy consumption in hospitals, in particular, is largely due to their continuous use patterns and operation, which depending on the different services provided require substantially variable energy demands.

2. Literature Review

Energy quality, saving capacity and energy conservation research indicates that hospitals account for 6% of overall energy usage in the utility building sector (Teke &

♣Peer-reviewed paper selected from The 9th International Conference on Engineering and Technology (ICET-2021)
*Corresponding author
Email address: anwerabd2014@gmail.com

Timur, 2014). Utility buildings are hotels, large space offices, restaurants, shops, health-care facilities, and educational establishments. In these types of buildings, the HVAC system is the single greatest energy user. It accounts for approximately 60% of a building's overall energy cost. Heating, ventilation and air conditioning (HVAC) systems have a large impact on the net energy consumption of buildings. Not only do they consume high power of the total electricity of commercial buildings, but they also have a large influence on the occupant's comfort and behavior (Harish & Kumar, 2016). HVAC systems have gained attention during planning and designing for achieving energy efficiency in buildings since the last decade. However, in order to optimize energy usage without compromising thermal comfort inside the building, it remains a challenge for building personnel the handle HVAC systems.

In a hospital building, artificial lighting installation is the most visible source of energy consumption after heating, ventilation, and air conditioning (HVAC) loads (Patil & Kamath, 2018). Hospitals consume about 20–30% of the electricity for lighting(Harish & Kumar, 2016). We can decrease the usage of lighting power by using the most energy-efficient innovation required in such a facility. LED lighting, a technology that is currently available and has been proven as well as conventional lighting, can already help reduce energy use(Arpornthip, 2020). This, in essence, would help us reduce the footprint of carbon. Lighting also has a significant impact on operating costs, with significant savings if energy-efficient, efficiently controlled lamps and luminaires are installed and maintenance is taken into account at the design stage. Energy-efficient lighting helps in decreasing light power utilization.

Energy consumption analysis and proposing reasonable energy consumption indicators are significant tools for guiding building energy conservation(Lin, Liu, Zhang, & Liu, 2020). Some studies found the energy consumption quota in numerous varieties of buildings. EUI (energy use intensity) index or normalized EUI index was adopted to estimate the energy use of the building. Introduced EUI index and found its influence factors supported based multiple regression analysis, and a benchmark electricity meter for EUI was obtained (Zheng, Wu, Lian, & Zhang, 2020). In terms of Cal-Arch, one amongst the energy analysis tools, the distribution of energy consumption in numerous buildings were explored from the CEUS database in U.S. and Canada, and therefore the EUI index of every building was compared in step with the distribution histogram to estimate the building energy attempted to find the energy consumption quota where 60% of building energy consumption were certain to be less than this value, consistent with energy consumption survey and data collection.

2.1 Energy management and efficiency

Energy management is one of the areas where the government has concentrated on reducing the hospital's daily operating costs. Government buildings are considered to be the dominant electric power consumer (Rahman, Zaki, & Husain, 2019). There are two terms which need to be clearly understood in energy management. The first concerns energy conservation and the second concerns energy efficiency (Asim, Ibrahim, Adam, & Masuri, 2017). Energy conservation means reducing the amount of energy used in a process or system by economizing, minimizing waste, and rational use. In the meantime, energy efficiency is characterized as a ratio or other quantitative relationship between performance output, operation, products or resources and energy input. Energy saving via good energy management in hospital buildings is imperative due to its 24-hour daily operation and very high public demand for clinical services.

Energy efficiency is defined as a means to manage and curb growth in energy consumption. Building energy consumption is efficient when it provides more services for the same energy input or the same services for less energy input (Tahir *et al*., 2017). Energy efficiency is a part of energy services given for the production of required energy services such as heating, lighting, and motion per unit of energy input. Large energy users, such as hospital facilities, need effective energy management to introduce energy conservation energy-saving initiatives without impacting service quality. Reducing the energy usage of healthcare facilities provides several primary benefits: increased profitability; reduced effect of variable energy costs; lower operational and maintenance costs; improved environmental performance; reduced carbon footprint; healthy healing and workplace environment; and healthy societies.

This study is important as according to the author's knowledge, energy efficiency aspects of hospitals in Iraq has been given less attention by researchers and the publication related to this is rather scanty. Despite being one of the world's largest oil producers, Iraq must also begin to emphasize energy efficiency towards conserving the existing resources for future generation as well as joining the international community towards sustainability. Hence hospital has been the focus if this study as hospitals were known to have very high energy consumption annually.

2.2. Iraqi climate

Iraq is situated in the north-east of the Arab world to the south-west of the continent of Asia stretching from latitudes 29-37 °N and longitudes 38-48 °E and occupies a range of around 925 km between north and south (Mahdi *et al*., 2017). Iraq is one of seven Arab states of the Arabic Gulf. Iraq has a dry, hot climate, with long, hot, dry summers and short, cold winters. The climate is affected by the position of Iraq between the semitropical dryness of the Arab desert areas and the Arab Gulf semitropical humidity. January is the coldest month, with temperatures ranging from 5 °C to 10 °C and August is the hottest month with temperatures rising to 35 °C and more.

2.3. Building energy index

Building energy index (BEI) is the indicator used to monitor the performance of energy consumption in buildings, acts as the reference point that provides the baseline for energy performance comparison and also offers the best benchmarking on building energy utilization in order to organize an effective energy- efficiency scheme in the future. This is the ratio of a building's total annual energy usage per total building floor area (Syed Yahya, Ariffin, & Ismail, 2015). The BEI can be calculated as follows:

$$\text{BEI} = \frac{\text{Total annual energy consumption (kWh/year)}}{\text{Total floor area of building (m}^2\text{)}}$$

2.4. Energy consumption in the hospitals

Energy efficiency and energy cost management are one of the most critical issues that most building planners, engineers, and decision-makers are facing. Hospitals, in particular, have a special status because of their 24-hour service, year-round (Saeid Moghimi *et al*., 2013). However, hospitals consume high energy levels by lighting, air-conditioning systems, lifts, general office equipment, medical equipment, and others. Varieties of electrical density loads existed and those were all primarily based on practical and aesthetic criteria, as well as the operating hours. Many specific electrical devices, including the motors, chillers and medical equipment, were also available.

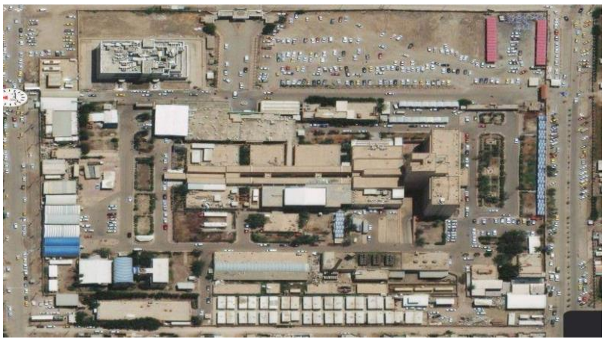
In the same line of research carried out a detailed analysis of audits for 30 healthcare buildings in Greece (Hellas) to quantifying the potential global energy savings like 20%, hence suggesting potential energy-saving processes in this healthcare (Santamouris, Dascalaki, Balaras, Argiriou, & Gaglia, 1994). Additionally, reported potential primary energy saving up to 71% in a Belgian hospital by using thermal energy storage in combination with a heat pump instead of gas-based boilers and water chiller (Vanhoudt, Desmedt, Van Bael, Robeyn, & Hoes, 2011). Different researchers are proposed various energy-saving measures. high-efficiency electric motors with variable speed drives can save up to 1–3% of the total electricity consumption (Saidur, Hasanuzzaman, Yogeswaran, Mohammed, & Hossain, 2010).

3. General description of hospitals in the case study

Three hospitals in the present case study were located at the southern part of Iraq, in the Nasiriyah city. This city is situated along the banks of the Euphrates River, about 225 miles (370 km) southeast of Baghdad, near the historic city of Ur. These aerial views of these hospitals were obtained from Google Map as in Figure.1.

The first hospital, Imam Hussein Educational Hospital (designated as hospital A) is a medium sized is one of the major hospitals in Iraq. It has a capacity of 400 beds, with an area of about 86,454 m^2. The GPS coordinate for this hospital is (31.059160 °N, 46.246035 °E). The main building of the hospital began operating in 1983 and it operates continuously for 24 hours daily. Figure.1 (a) presents one perspective of the main building of the hospital. It is divided into different blocks that have a cross figure and are linked by a central core, where is located the vertical communication (stairs and elevators). In these blocks are installed the education areas, the outpatient offices, inpatient hospital zones and support services.

The second hospital, Bint Alhuda Educational Hospital (designated as hospital B), is a medium-sized hospital is in Nasiriyah. It is a specialist hospital for women and maternity, with a total of built area of about 59,192 m^2 Figure.1 (b). The GPS coordinate for this hospital is (31.081003 °N, 46.247617 °E). The main building of this hospital began operating in 1985 before some expansion took place over the years, and it operates 24 hours daily.



(a) Hospital A
(Retrieved from https://goo.gl/maps/JhFiVC1Qjcz3Gx9F7)

(b) Hospital B
(Retrieved from https://goo.gl/maps/Rzsyt4Yujpb5U8Vs7)

(c) Hospital C
(Retrieved from https://goo.gl/maps/G1ZJ5CqqGtuiaZDXA)

Figure 1. Aerial view of three-hospital buildings and their surrounding from Google Map

The third hospital, Nasiriyah Heart Center (Hospital C), is a small hospital in Nasiriyah. The total area for this hospital is only 13,890 m^2 Figure.1(c). The coordinate for this hospital is (31.024625 °N, 46.241747 °E). The hospital began its operation in 2013 it is a very important hospital for this city and other nearby cites as it is the only hospital that specializes in heart treatment. This hospital also operates every day including weekends.

Based on the monthly electricity consumption bills, the energy consumption (kWh) of the three hospital buildings was very high throughout the 12 month-periods because the buildings occupied throughout the year. Figure 2 shows the annual Energy consumption comparison from 2016 until 2018 for the three hospitals.

The electricity consumption for the three-hospital building was recorded (as shown in Table 1) through the collection of monthly electricity bills for the past three years from 2016 to 2018. The electrical system for the three hospitals was distributed to the use of air-conditioning systems, lightings, heating system, plug loads, medical equipment and others while artificial lighting system is used to illuminate interior office space, surgical room, and external areas such as a corridor. Overall, the electricity usage of all three hospital buildings was found to significantly vary throughout the year, depending on the weather. Table 2 presents the calculation of average building energy index (2016- 2018).

The building energy index values for the hospitals during the three years from 2016 to 2018 are shown in Figure 3.

To determine the energy usage level of the hospitals, a comparison between the studied hospitals and three hospitals in Malaysia as reported by S Moghimi *et al*. was made. It was found that the energy intensity for the Iraqi hospitals in this study were relatively higher, in comparison to hospitals in Malaysia. This was attributed to the very high consumption of electricity due to the usage of the air-conditioning system, particularly during summer in Iraq. Apart from that, all three hospitals in Malaysia considered in this study have undergone energy management activities for several years and hence the BEI values have dropped due to the implementation of various energy efficiency measures as reported by (S Moghimi *et al*., n.) . This also shows the potential for Iraqi hospitals to also benefit from energy efficiency in their operation.

4. Results and Discussion

4.1 Total electricity consumption in the hospital

Electricity is the main source of energy in these hospitals and is supplied by the ministry of electricity of the republic of Iraq the electrical energy is distributed throughout the building from the various substations. In each section, normal and essential electricity is divided into two sectors: lighting-power electricity and mechanical electricity. As hospitals operate 24 hours a day, seven days a week, and due of the importance of many types of equipment, they have to be supplied with electricity throughout. A generator that uses

Table 2. Average building energy index (2016 to 2018)

Designation	Hospital A	Hospital B	Hospital c
Average annual energy consumption (kWh)	19,574,967	12,100,426	4,317,093
Gross floor area (m^2)	36,797.33	25,016.589	12,001.626
Average building energy index (BEI) kWh/m^2/year	532	484	360

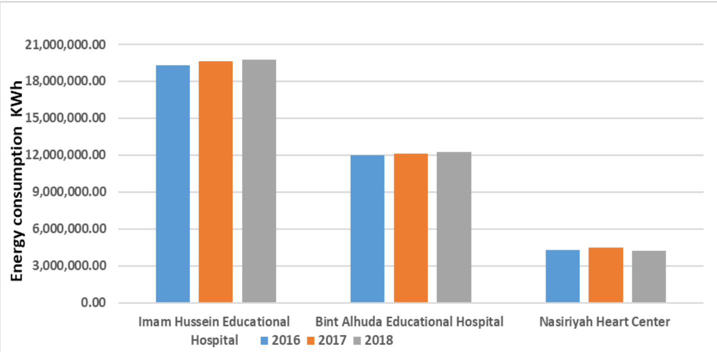


Figure 2. The annual energy consumption for hospitals comparison from 2016 until 2018

Table 1. Energy consumption in 2016 to 2018

	Hospital A			Hospital B			Hospital C		
Month	2016 kWh	2017 kWh	2018 kWh	2016 kWh	2017 kWh	2018 kWh	2016 kWh	2017 kWh	2018 kWh
January	674900	698900	723700	393338	425748	410109	137200	147600	126860
February	713400	728200	733300	386143	430077	441735	140700	144900	137060
March	1118300	1212600	1149600	524877	555526	537915	247400	196960	267180
April	1793100	1910500	1843300	1135618	1131275	1123827	396200	426140	495000
May	1928100	1968300	1982100	1304060	1316425	1346701	423720	493100	429490
June	2313700	2372000	2387500	1503267	1459710	1540608	526500	564100	505680
July	2506500	2558800	2513700	1543614	1581353	1581957	556500	579240	515400
August	2525800	2478500	2564600	1525786	1593517	1563686	564050	572550	503160
September	2313700	2282000	2358500	1361228	1394710	1395041	548850	510800	483660
October	1677500	1712400	1764400	1140681	1103790	1169016	365920	428040	360000
November	1079700	1102200	1113600	778789	721198	768134	228160	292240	238000
December	636200	631200	654100	360720	381420	369680	140560	135360	123000
Total	19280900	19655600	19788400	11958121	12094749	12248409	4275760	4491030	4184490

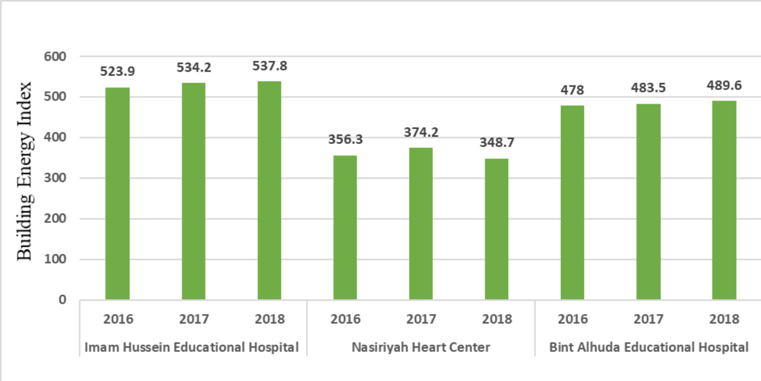


Figure 3. BEI for the hospitals

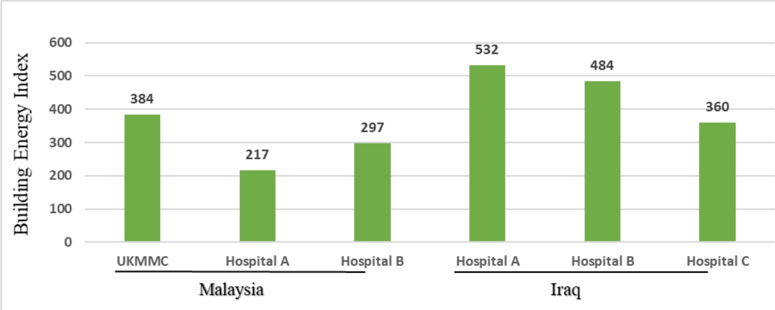


Figure 4. Comparison of BEI of hospitals in Iraq with selected hospitals in the literature

diesel oil in a small part provides the backup power at the hospitals. Figure 5 shows the relative value of the different energy use resources obtained from an energy audit performed during 2018. The highest consumption from the component was HVAC; all of the three hospitals used a central air condition system. The Electrical demand end-use distribution in hospitals to four-part, lighting, HVAC, equipment and others.

Several studies have shown that building heating, ventilation, and air conditioning (HVAC) systems are the main end-use energy consumers in buildings in the area of the gulf-cooperation countries. Indeed, in most Gulf Cooperation Countries, air conditioning accounts for almost 60% of overall energy use in a typical building (Krarti, 2015).

4.2. Factors that affect energy consumption in the hospitals

Good energy use and planning in hospitals can be a significant factor in energy efficiency because the building sector is one of the largest consumers of total energy consumption relative to other sectors. From Figure 2 we may infer that the overall energy consumption during the three years considered for review is not regular. As fuel consumption (used for heating purposes) decreases, energy consumption (used for cooling) increases. It should be noticed that a large portion of the energy demand and use is correlated with the buildings' air conditioning as clearly demonstrated in Figure 6. That correlates the monthly outdoor temperature consumption of electricity in Iraq during 2016. Energy use remains low and flat during winter months and is mainly due to base-load demands such as plug loads, lighting, and other equipment operated independently of outdoor conditions. When in the summer months, air conditioning energy consumption increases with rising outdoor temperature.

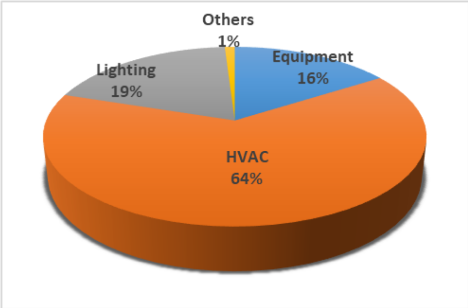
4.3 Opportunities for energy saving in the hospitals

A detailed energy audit was carried out which was followed by an in-depth analysis of the data obtained. This was done to find out the energy consumption of the equipment installed in the building. This led to the identification of opportunities for energy saving. The average annual energy consumption for a lighting system for hospital A, B, and C (3,719,243.7 kWh), (2,420,085 kWh) and (906,589.6 kWh), the use of LED light and manually controlled electric switches used to "turn it off when it's not needed" offer great opportunities for energy savings.

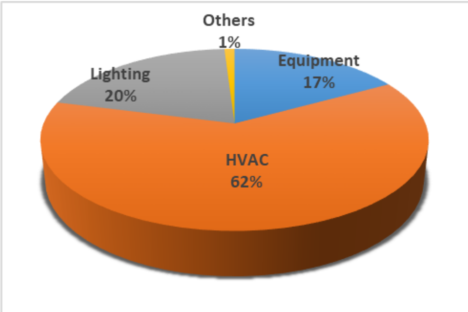
Most opportunities for energy savings are in defining the required size of an HVAC system calculating the peak heating and cooling load in the audited building. The proposed energy-saving tool will also help. The electrical and more particularly power engineers to reduce electricity consumption while maintaining the quality of service. However, there are still opportunities for energy saving, without sacrificing the level of comfort, and overall quality of patient care or services.

5. Conclusions

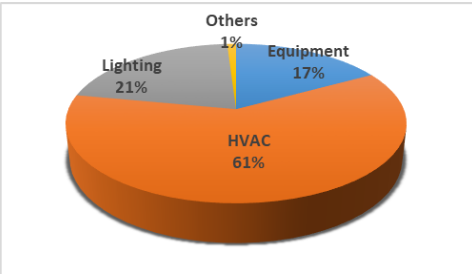
A case study was conducted in three hospitals in Iraq to evaluate their energy intensity in terms of building energy index (BEI). These hospitals were Iman Hussein Educational Hospital (Hospital A), Bint al Huda Educational



Hospital A



Hospital B



Hospital C

Figure 5. Hospitals energy consumption by end-use

Hosptal (Hospital B) and Nasriyah Heart Center (Hospital C). From the detailed energy audit carried out, load apportioning was established for all three hospitals. It was found that the significant energy user (SEU) for all three hospitals were the air-conditioning system which accounts to more than 60% energy use. It was also found that the usage of air-conditioning system was closely correlated to the outside ambient temperatures, which were the highest during summer where average temperature soars to 40 ºC. As a result, the energy consumption in all three hospitals studied recorded their highest energy usage at this period. Apart from the energy consumption for air-conditioning which ranged around 61–64%, other important energy users were the lighting system which consumed 19–21% and hospital equipment which used about 16–17% of energy from the total energy consumption. The average annual energy consumption for these three hospital buildings from 2016- 2018 was 19,574,967 kWh, (12,100,426 kWh, for hospital A and B, respectively, and for hospital C 4,317,093 kWh. The BEI values obtained for the hospitals A, B and C were: 532, 484 and 360 kWh/m$_2$/year. It can be concluded that the BEI values for Hospital A and B were relatively high and hence it is imperative to implement energy efficiency measures to lower these values in the future. As for Hospital C, the lower BEI value was attributed to the limited function of the hospital compared to the other two. Being a pioneering study, more studies similar to the present one are recommended towards developing a range of BEI for hospitals in Iraq as well as establishing a guideline for the Ministry of Health in Iraq for energy saving in the healthcare sector.

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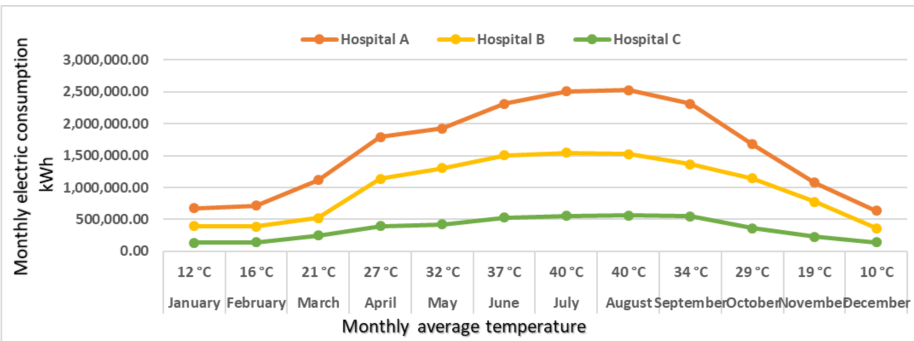

Figure 6. Monthly electrical load versus monthly average ambient temperature for Iraq.

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