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ORIGINAL PAPER

Using BIM to propose building alternatives towards lower consumption of electric power in Iraq

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Abstract

This paper investigates the reasons for the dissatisfaction of the Iraqi people with the privatization of electricity due to the significant increase in electricity bills. It examines the main factors that affect the energy demand in the Iraqi houses for cooling and heating by modeling and analyzing existing buildings using Building Information Modeling (BIM). The results of energy consumption from BIM were compared with real consumption of the houses which was obtained from the bills to investigate the reality of the results. The simulation results were well-matched with the real data. Then three buildings were modeled and analyzed with alternative materials for roofs and walls by considering the cost of construction (CC), life cycle energy cost (LCEC) and carbon emission (CE) for each alternative. The best alternative is selected according to the opinion of the occupants, which was achieved by a questionnaire and the data obtained from the BIM models. The questionnaire data and the simulation results were analyzed by using the Analytical Hierarchy Process (AHP) technique. The obtained results were represented in a framework for selecting the best materials for constructing walls and roofs. For walls, it was found that rock block is the best since the final weight from AHP results was 0.5371, and Autoclaved Aerated Concrete Block (AAC block) rib slab is the best for roof with a final weight equal to 0.4218. The final model has LCEC of five times less than the original unit, but CC were equal and CE was decreased from 5 ton/year to less than 0.8 ton/year in the suggested alternative.

Keywords Privatization · BIM · Energy analysis · AHP · Electricity power in Iraq

Introduction

Privatization of electricity is one of the options to deliver electric power in many countries. It has a significant effect on the national wealth and the sustainability concerning energy since people would use less energy to pay lower bills (Filipovic 2006). The electricity privatization depends on a regulatory framework, which is affected by social and political criterions and standards (Vlahinic-Dizdarevic 2011).

During the last 15 years, electricity power in Iraq has been suffering from being insufficient for the national demand (Karim 2010). The Iraqi government tried to overcome this problem by involving private companies to control the supplying system (privatization) and introducing new electric tariffs. This change caused dissatisfaction from the people due to lack of awareness which causes rationalization of electricity consumption and limited use of proper materials in construction to improve the thermal insulation of the buildings.

Building Information Modeling (BIM) can be used to perform life cycle energy cost analysis of the building during the design stage (Potts and Ankrah 2008). This analysis can help in selecting the proper materials to achieve sustainable and economic design (Autodesk Inc 2011; Wong and Fan 2013; Mahjoob and Abed 2015). In the recent years, BIM has been used successfully in many projects to attain sustainable design (Liu 2015). It depends on three aspects: modelling the building, processing of the information and providing data which can evaluate the efficiency and quality of the building (Häkkinen and Kiviniemi 2008). This would help to improve the construction process, estimation of quantities, construction cost and energy consumption for cooling and heating at an earlier time before construction. (Eastman et al. 2011). The importance of thermal analysis in building

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Fig. 1 Research methodology

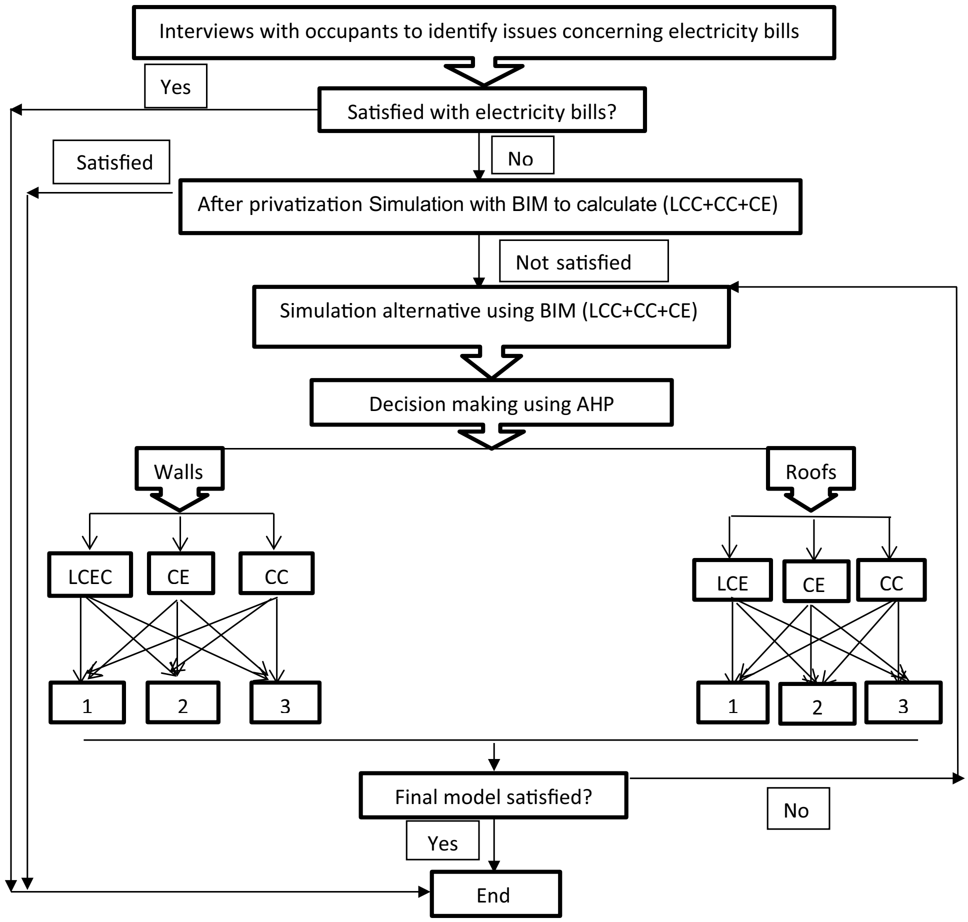


Table 1 Occupants survey results

Privatization	Electricity bills before privatization	Electricity bills after privatization	Walls insulation	Roof insulation	Windows insulation	Sustainability demands	Underground surroundings	Indoor environment
4.85	3.22	4.01	4.35	4.3	2.85	4.15	3.09	4.32

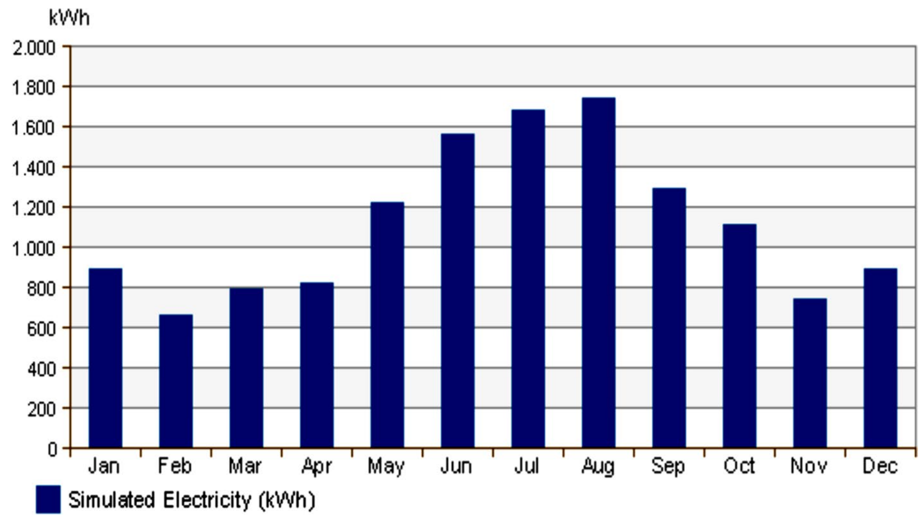
Fig. 2 BIM model

Table 2 Costs for original house

Part	LCEC (IQD)	CC (IQD)
Wall (generic block)	32,421,500	7,514,830
Roof (normal reinforced concrete)	32,421,500	8,863,884

design is getting more attention recently, since it increases the knowledge of energy costs in the life cycle of the building (Laine et al. 2007). In the construction industry complex decisions can be supported by using BIM methodology and

Fig. 3 Electricity demand for as built houses



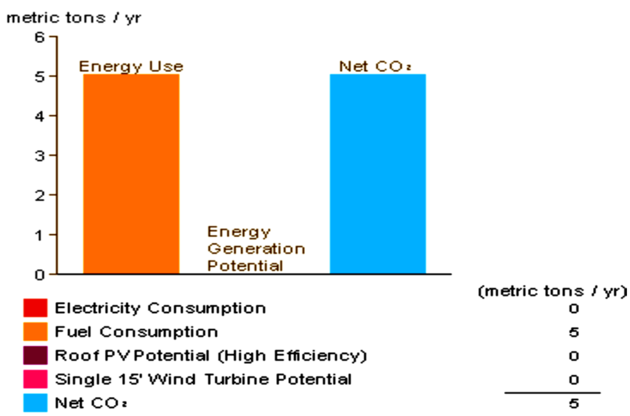


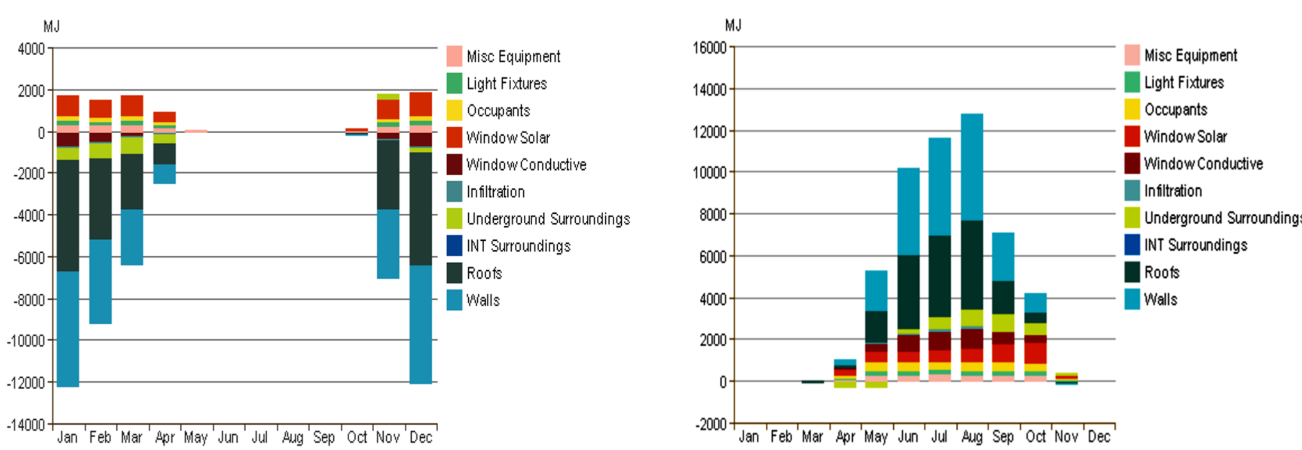
Fig. 4 Annual carbon emission

different techniques such as multicriteria decision-making (Ustinovicius et al. 2005; Pavlovskis et al. 2017).

This study focuses on the occupant opinion concerning the privatization of electricity and the degree of comfort in winter and summer. Then we try to find solutions using BIM with AHP technique to propose the best alternatives that can reduce the electricity consumption considering the life cycle energy cost, construction cost and carbon emission.

Research methodology

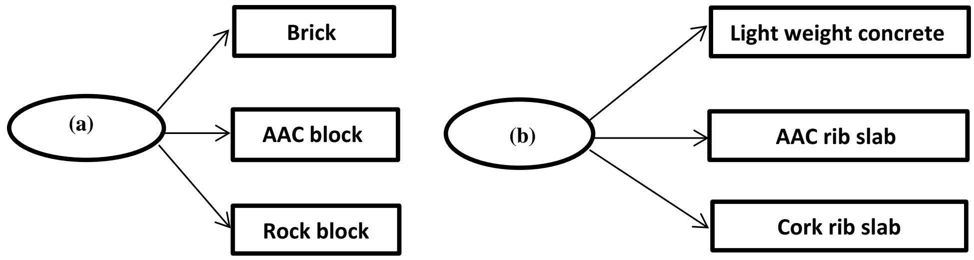
Figure 1 shows the research methodology. The research work can be divided into the following parts: the first part was a survey conducted with the occupants of the house in the case study area (housing evaluation). The questions of the housing evaluation were around the number of the members of the family, number of hours that the family are at home, the satisfaction of the members of family, the quality of the construction materials of the walls, roofs, windows and underground surroundings in winter and summer for cooling and heating, satisfaction



(a) Monthly heating load and **(b)** Monthly cooling load

Fig. 5 **a** Monthly heating load and **b** Monthly cooling load

Fig. 6 Construction alternatives



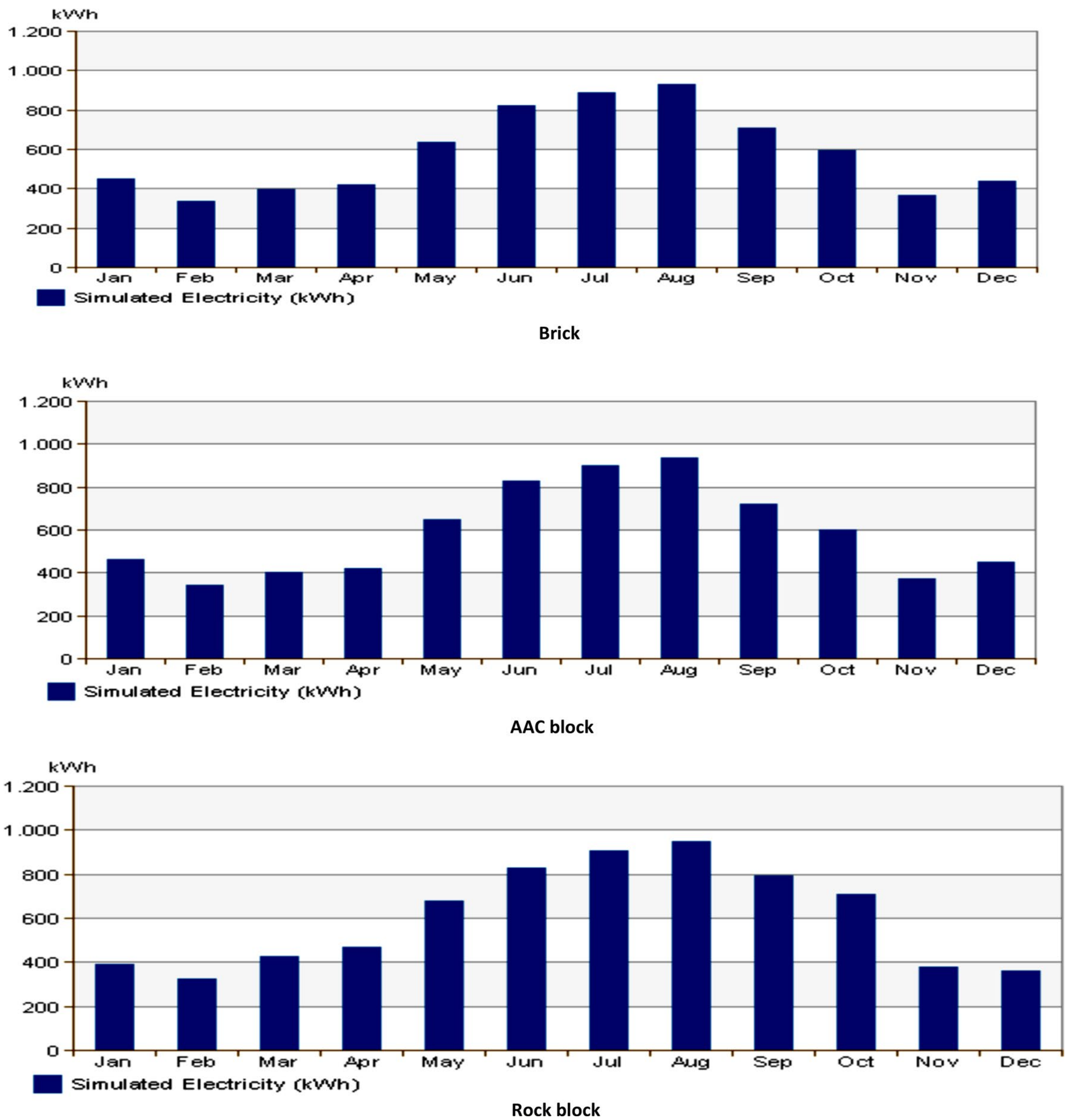


Fig. 7 Electricity consumption for walls alternatives

about the bills of electricity before and after privatization, costs of the bills every season and sustainability of the building.

The questions are measured on a five-point semantic differential using two adjectives with a neutral point (e.g., '1 = totally disagree and 5 = totally agree). The format of

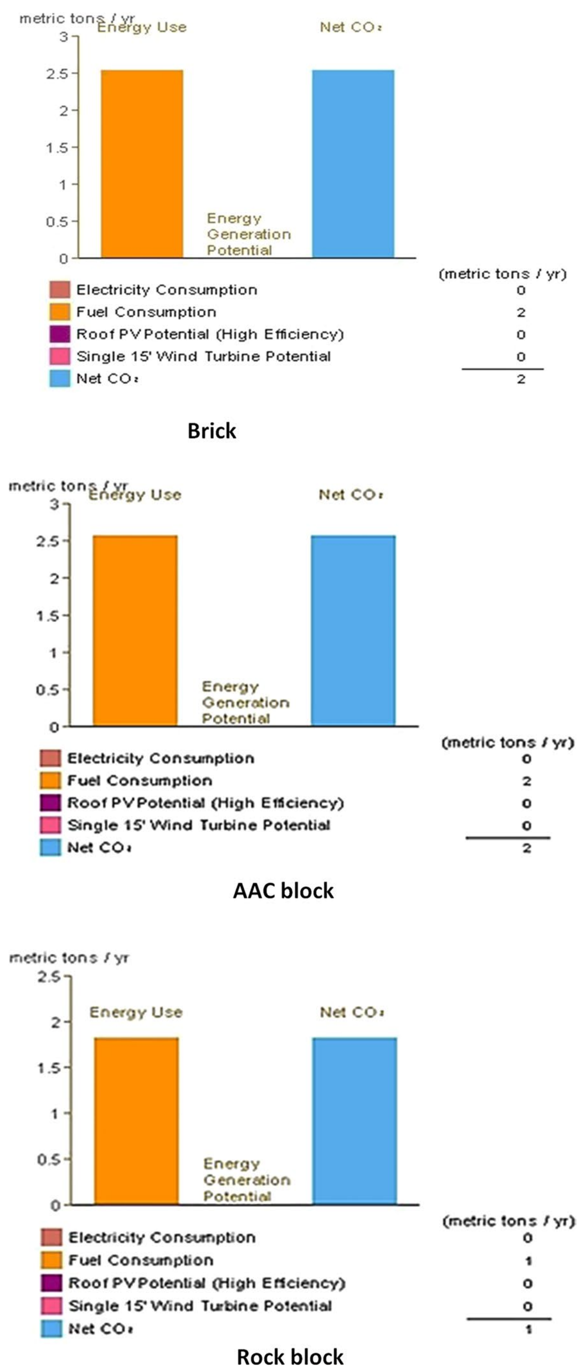


Fig. 8 Annual carbon emission for walls alternatives

the survey was distributed to 200 units, 159 were received representing 79% response rate since not all of them liked to engage with the work.

The second part includes simulation using BIM. The case study project is located in the Diyala governorate in Iraq. It consists of 454 units of residential houses of 120 m^2 area. All the units were fully occupied 3 years ago. They were constructed using concrete blocks for walls and normal reinforced concrete for the roofs. One of the units is modeled and analyzed using BIM to obtain LCEC, CC and CE. Then the same units were simulated, but different materials were used. For walls, normal brick, Autoclaved Aerated Concrete Block (AAC block) and rock block were used as they are all available as construction materials in Iraq.

The same methodology was adopted with the roofs. Three different types were used: lightweight concrete, rib slab with (AAC block) between ribs and rib slab with cork between ribs.

The third part includes a questionnaire with the occupants, but includes the results obtained from the BIM models concerning (LCEC, CE and CC) to select the best alternative from each part and analyzing the results by using AHP technique which is a decision-making method (Saaty 1987). Finally, the model with the proper materials was analyzed to find the final costs.

Results and discussion

Occupant survey

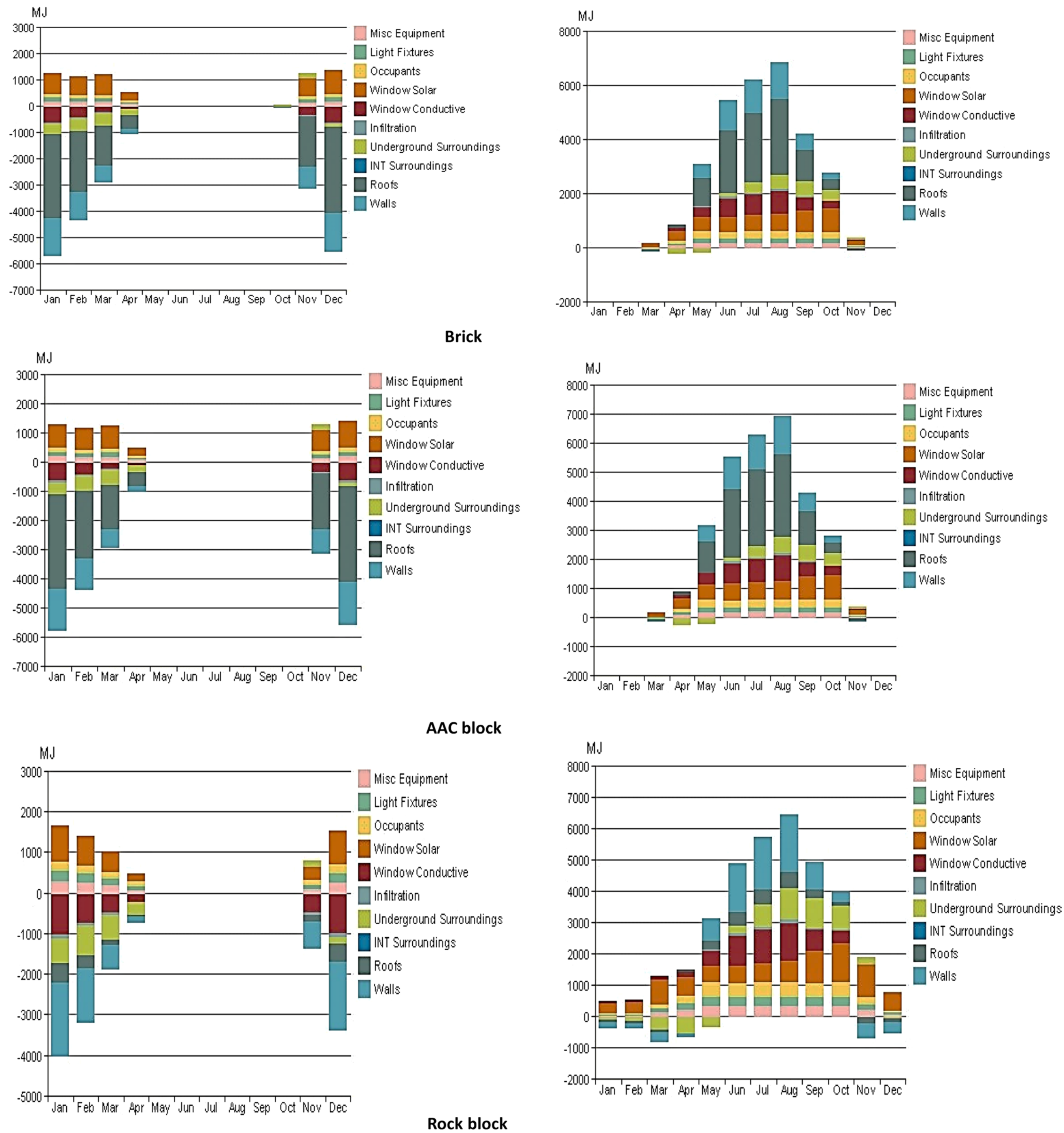
The results obtained from the occupant are shown in Table 1 as mean values for dissatisfaction of occupants/per:

The first part was about the concept of privatization in general whether the privatization is the most dissatisfied problem or the problem existed even before privatization, but it has increased after the beginning of privatization process and starting to get bills according to the new tariff. The results show that the occupants consider the privatization as the major reason of dissatisfaction. However, it seems that the main problem is the insulation ability of the building materials.

Simulation with original materials

The original house (as built house) units were modeled and analyzed using the original building materials (Fig. 2). The simulated house was 120 m^2 in area but the area of construction is equal to 98 m^2. The construction cost for walls and roofs is listed in Table 2.

The results show that the highest demand for electricity is 1750 K/Wh in August (Fig. 3), which is the hottest month in the year. It means that the concrete blocks and the roof (normal reinforced concrete) have limited insulation ability which increases the demand for more electricity to get comfort inside the house. From the sustainability point of view,



(a) Monthly heating load **(b)** Monthly cooling load

Fig. 9 Heating and cooling loads for walls alternatives

Table 3 Walls alternatives costs

Wall alternatives	LCEC (IQD)	CC (IQD)
Brick	20,091,284	10,366,000
AAC block	16,880,281	11,786,000
Rock block	15,287,808	8187,000

the high demand for energy means higher carbon emission which equals to 5 metric tons/year (Fig. 4) which can affect the environment negatively.

Figure 5 presents the contribution of the different parts of the building in transferring heat to the building. The most conductive members were the walls and the roofs.

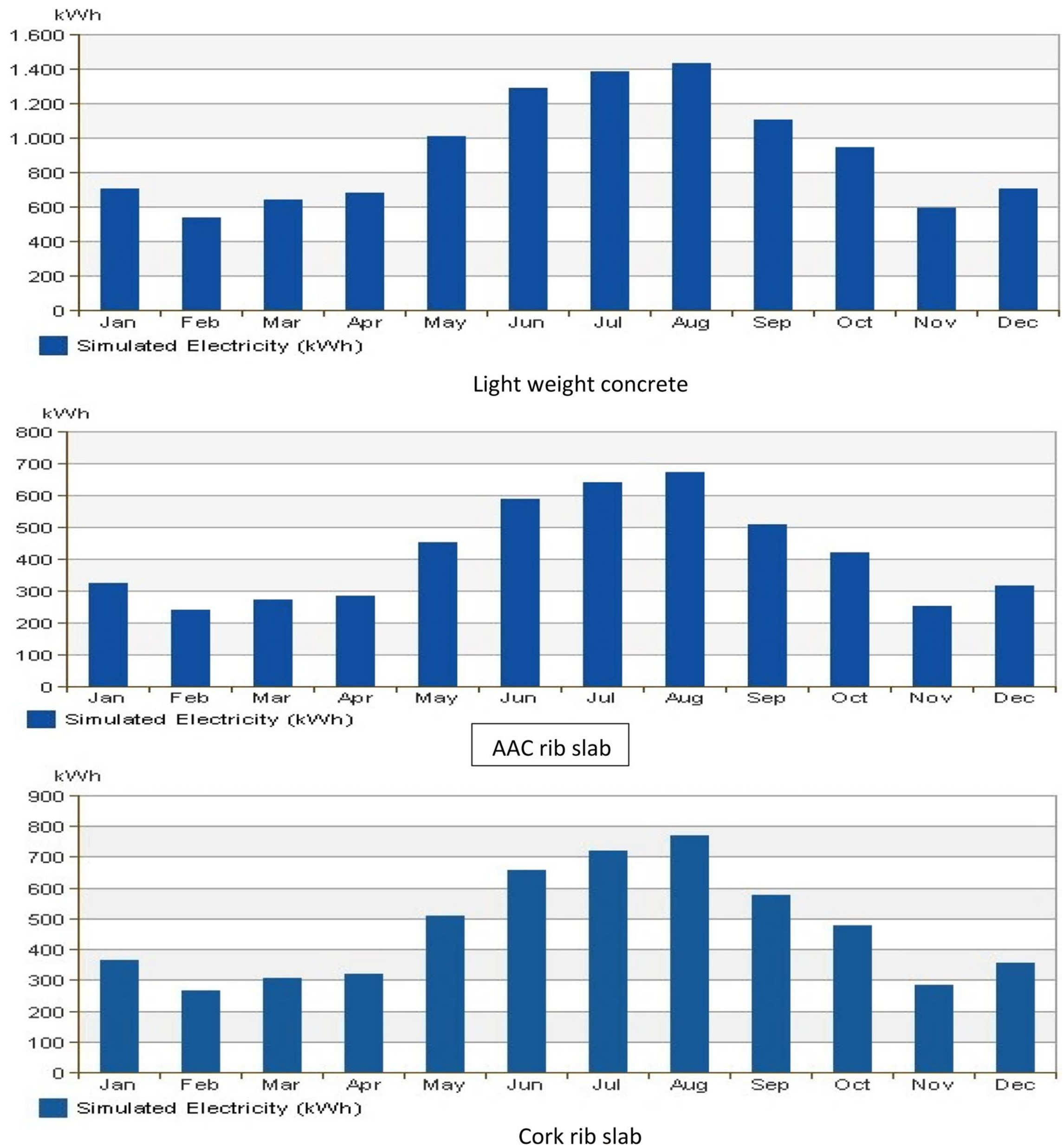


Fig. 10 Electricity consumption for roof alternatives

This means that these parts have high influence on transferring heating and cooling inversely. Therefore, different alternatives were selected to be used in these parts.

Simulation with alternative materials

A search was conducted on the literature to select the proper alternatives for walls and roofs. Then the prices of the alternatives were checked in the Iraqi market. The following alternatives were selected:

(a) For walls, three alternatives were chosen (Fig. 6): ordinary brick 7.5 × 11.5 × 24 cm, Autoclaved Aerated Concrete Block (AAC block) block 20 × 20 × 40 and rock block 20 × 20 × 40.

(b) For roofs, also three types of roofing were selected (Fig. 6): light weight concrete, AAC rib slab and cork rib slab.

The selection of the above alternative materials was based on their availability in the Iraqi market. Brick has been chosen in order to show the difference between the most

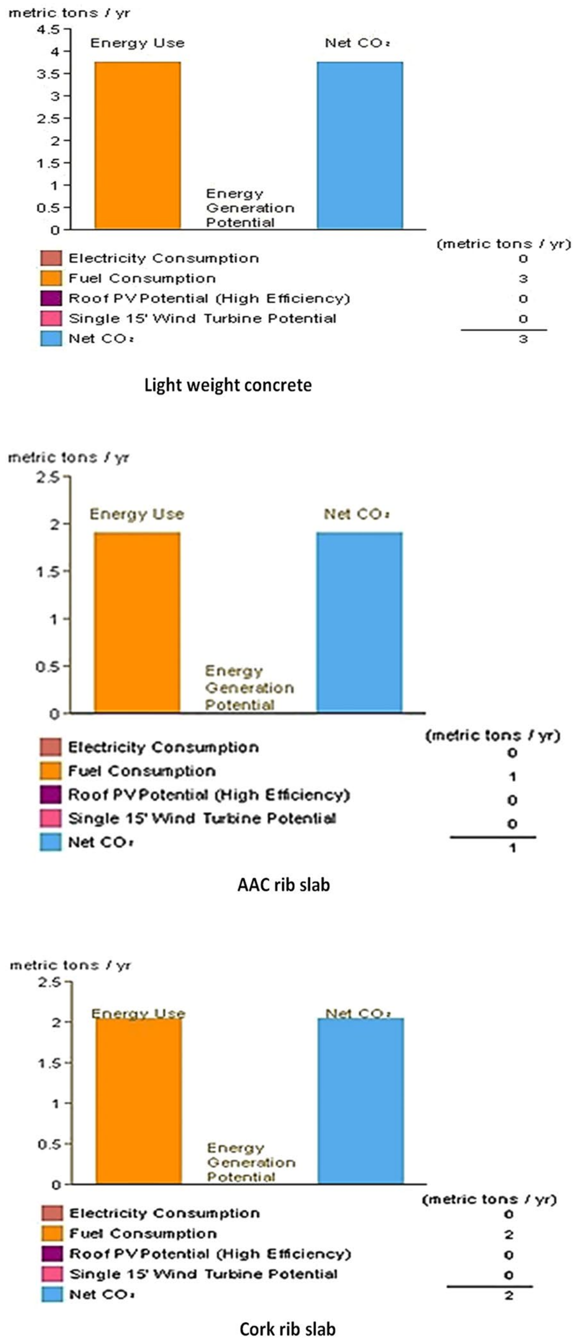


Fig. 11 Annual carbon emission for roof alternatives

Table 4 Roof alternatives costs

Alternatives	LCEC (IQD)	CC (IQD)
Light weight concrete	25,696,341	11,820,000
AAC rib slab	12,083,904	11,793,000
Cork rib slab	13,382,752	8255,100

common used materials in constructing walls and then to see the effect of using better materials in terms of insulation.

Figure 7 shows the simulated electricity consumption for buildings constructed using the selected wall alternatives. They have similar behavior, but they are different in the values according to the material. It can be seen that in summer months the electricity demand is more than winter months that belongs to the region of the project which in the last few years the temperature has increased significantly. The simulated electricity for alternatives is less than the original house but it differs between the materials.

Figure 8 shows that the quantity of CO_2 is directly proportional to the fuel consumption, which depends on the insulation of the construction material.

As shown in Fig. (9) the monthly heating and cooling loads for the walls are lower than the original model (the case study). For example, in January the original house with concrete block walls the heating loads that are leaked from walls was (5600) MJ, while for brick, AAC block and rock block were (1400, 1400, 1700) MJ, respectively.

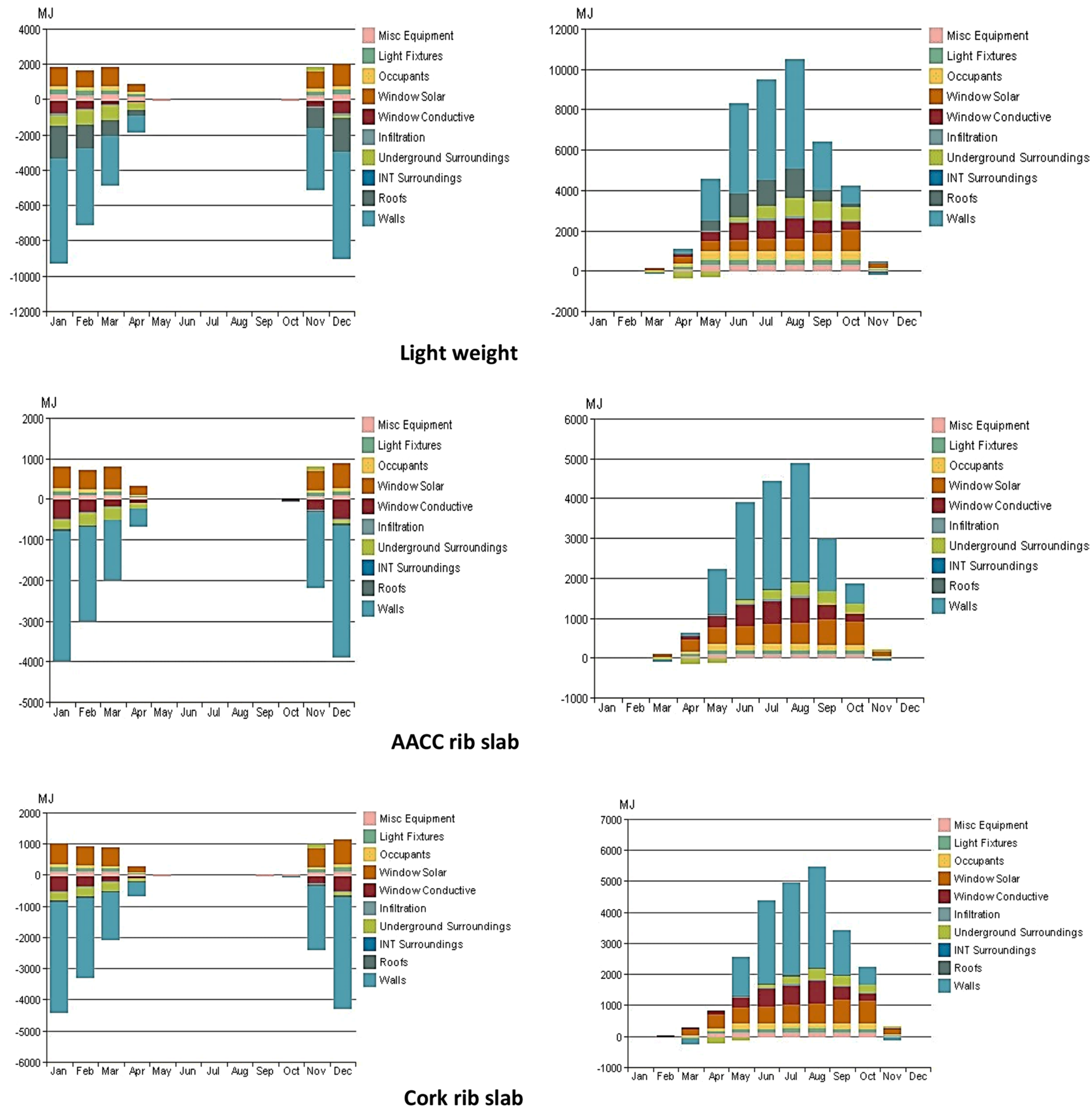
In August monthly cooling loads for the original house was (5200) MJ, while for brick, AAC block and rock block were (1600, 1400, 1900) MJ, respectively. The difference can be seen much better in the Table (3) below:

According to the energy reports, life cycle energy costs and construction cost the rock block, which is manufactured in the north of Iraq, has a significant role in minimizing these, since it has the lowest thermal conductivity.

As shown in Fig. 10 and comparing the results with the original simulated unit the alternatives simulated electricity were less, for the original house simulated electricity was (1750) KW/h, while for light weight concrete, AAC rib slab and cork rib slab were (1410, 660, 760) KW/h, respectively. The minimum alternative is the AAC rib slab.

From Fig. 11 it can be seen that the lightweight concrete has the highest carbon emission and this matches the results in Fig. 10, since more energy demand means more carbon emission to the air, but all of them are still less than the original unit. Table 4 presents the roof alternative costs.

The selection of the rib slab alternatives was according to the work of Ibrahim et al. (2017) since it was conducted in the same area of this study. The simulation results including energy consumption and cost of construction were too close to what was presented by Ibrahim et al. (2017), which reflects BIM results reliability. The cost of construction for cork rib slab is less than the others while the life cycle energy cost of the AAC rib slab is the lowest (Table 4 and Fig. 12).



(a) Monthly heating load

(b) Monthly cooling load

Fig. 12 Heating and cooling loads for roof alternatives

Table 5 Relative importance for the standards of walls and roofs (occupant's opinion)

Elements	CC (%)	LCEC (%)	CE (%)
Walls	51.35	39.05	9.6
Roofs	58.15	29.45	12.4

AHP results

The questionnaire of the occupants were analyzed using AHP technique. It is a method of arranging decision alternatives and selecting the best alternative when the decision maker has multiple objectives or criteria on which the decision is based (Saaty 1991). The relative importance

Table 6 Final weights for all alternatives

Elements	Alternatives	Weights
Walls	Brick	0.0702
	AAC block	0.3925
	Rock block	0.5371
Roofs	Light weight concrete	0.1865
	AAC rib slab	0.4218
	Cork rib slab	0.3917

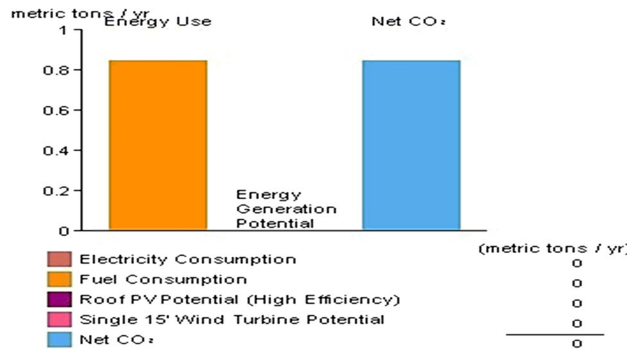


Fig. 14 Annual carbon emission for the suggested model

for each standard are shown in Table 5. It is clear that the occupants concerns were mainly focused on the construction cost of roofs. The final weights for walls and roofs alternatives in terms of total cost are shown in Table 6. Accordingly, the final choosen alternative for walls was rock block and for roofs was AAC rib slab.

The analysis results (Figs. 13, 14, 15 and Table 7) for the suggested model using walls of rock block and roofs of AAC rib slab showed better outcomes than the as built model since LCEC is reduced significantly.

The adopted procedure has the benefit to select the members that have the highest effect on the losses of cooling in summer months, and heating in winter months, by examining the report of energy simulation for the building, and trying to get benefits of this to minimize losses. This ensures better indoor comfort, less energy demand, fewer bills and less carbon emission.

Conclusions

The authors tried to reduce the impact of the new electric tariffs in rising electricity bills in Iraq by suggesting new building alternatives which can help in controlling the building temperature and reducing the electricity demand by suggesting new building alternatives. BIM was used to simulate the buildings and provide the electricity demand and AHP was used to analyze the results. The selection of alternatives was based on the availability of the materials in Iraq and their insulation properties to minimize additional construction costs in addition to reducing the resulting carbon emission.

The results showed excellent ability of using BIM with AHP for selecting the best construction materials to minimize the electricity demand. High electricity demand was recorded for the as built buildings in cooling and heating and the greatest losses in loads were from the roofs, then walls. It is recommended to use rock blocks for walls and AAC rib slab for roofs. In addition, it is very important that the Iraqi government adopts some programs to improve the sustainability awareness among Iraqi citizens and encourage investment companies and contractors to pay more attention to the thermal insulation system in the building industry.

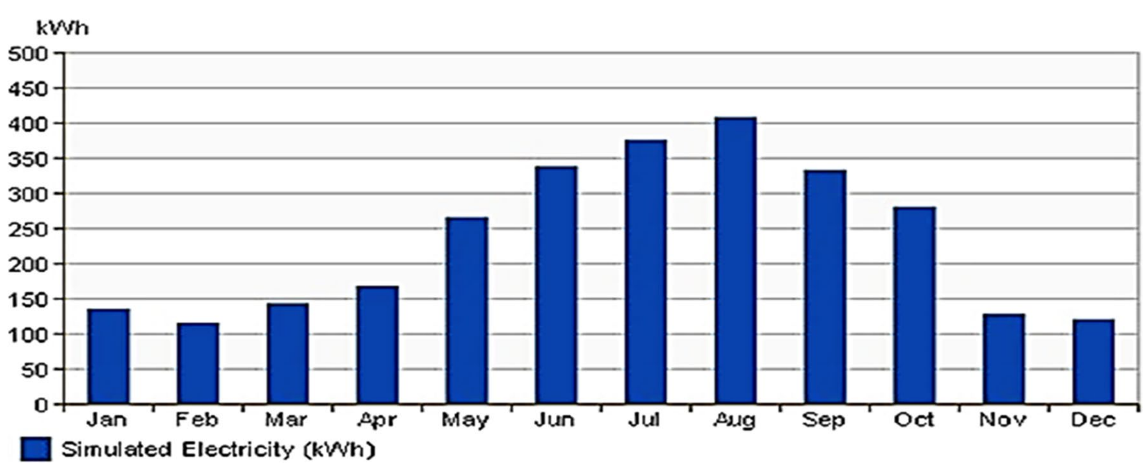
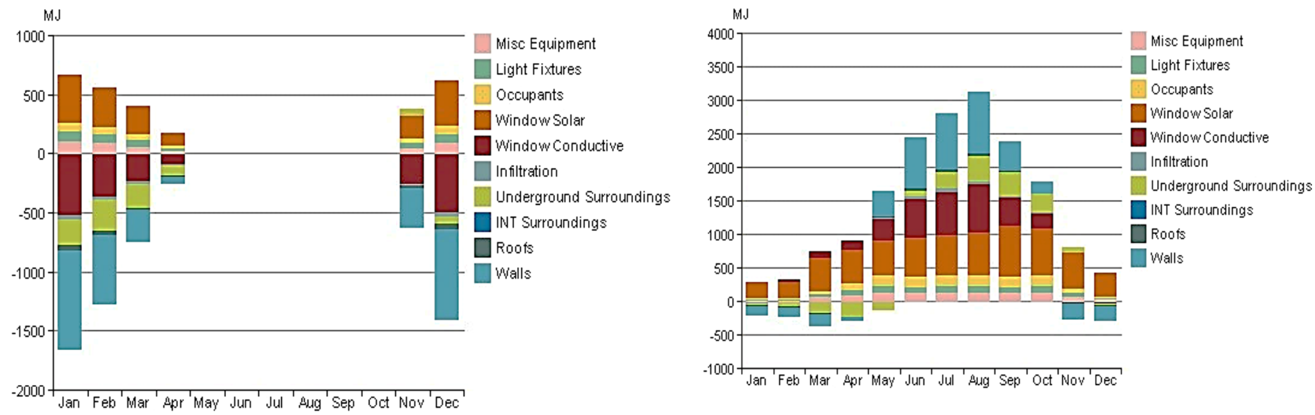


Fig. 13 Simulated electricity for the suggested model



(a) monthly heating load

(b) monthly cooling load

Fig. 15 Heating and cooling loads for the suggested model

Table 7 Comparison between costs of as built and the suggested model

	LCEC (IQD)	CC (IQD)
As built model	32,421,500	16,379,000
Suggested model	6,275,200	16,442,000

Compliance with ethical standards

Conflict of interest There is no conflict of interest.

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