Thermal Performance Optimization for Residential Buildings in Basra City

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Abstract. The present study investigates many parameters in the design of a residential building consisted of 6 floors with a construction area 240m² located in Basra city. This study aims to reduce electric energy consumption utilized for cooling and heating of the building. The parameters which studied included: the effect of building façade, the exterior color of the external walls, the glazing distribution and the shape of the building. eQuest energy simulation program is used to simulate the annual building energy consumption, the program uses the hourly annual collected weather data. The results show that orientation the building façade toward the north direction is the best in the design of the building. The saving in annual electric energy consumption is about 11%. Moreover, the external color of the building has a strong effect on building cooling and heating energy consumption. By utilizing white exterior wall color, the annual electric energy consumption reduced by about 12%. The results also showed that by utilizing proper glazing distribution the electric energy consumption could be reduced by 3%. When all enhancements were combined an optimum building case were found. For the optimum case, the annual electric energy consumption was reduced by 35% compared to the base building case.

1. Introduction
Emissions of greenhouse gases (GHG) like carbon dioxide are caused by global warming in the environment that considers the most important issue considered nowadays. In developing countries, the percentage of global energy demand consumption is expected to increase from 46 to 58% between 2004 and 2030 [1]. This idea getting more understanding as most of the observed increase in the temperatures since the mid-20th century is achievable due to the increase in chiefly of environmental pollution and increase of the GHG concentrations [2]. As well as the sun is having a direct influence on humans, although it is the basis for every type of energy source on Earth. Solar energy used for different objectives but it has negatively characterized because it overheating some regions of the world. The solar radiation that reaches the Earth is estimated by about 50% of its main strength [3].

The important key to reducing the GHG emissions and change of climate is by reducing electrical energy consumption. Therefore, the construction industry in the world needs to consider passive architectural design for buildings to reduce electric energy consumption.

Furthermore, worry about emissions of GHG has supported researchers to reach for optimization techniques into the design of buildings with less energy consumption. Design teams must apply suitable considerations at the early architectural conceptual design [4].

The sun is the main source of heat and light in the earth it is responsible for life. Understanding the relationship between sun and Earth are very important for location planning, efficient building design, and controlling undesirable heat gains [5].

The energy-efficient buildings are considered one of the important factors since it states the rate of heat transfer in and out of the building. It supplies daylight which decreases the need for artificial
lighting resulting in savings in energy consumption and allows the solar radiation to pass through the building resulting in heat gain.

In Basra city, the summer season is very hot. Midday temperature in June and July can reach as high as 50°C. In the winter, the temperatures range between 10°C and 22°C. Therefore, it is not surprising to know that approximately all buildings in the city require air-conditioning for 8 months of the summer.

In the winter, the temperature reaches in few days a less comfortable level. The building needs for heating and need for uses of domestic hot water, still this problem is much less acute than that compared with cooling in the summer [6]. The air-conditioning equipment is necessary for the building, which gives comfortable live for the human during hot months. As the result, the electrical energy consumption for this equipment is high.

Building an energy model that is a beneficial implement to anticipate loads of electricity, heating and cooling for facilities. The energy usage in a building is dependent on construction, weather, and hours of operation as well as the individual systems that work to cool and heat the building. Models of energy usage must adequately reflect the influence of these factors. Therefore, many researchers studied the thermal performance of buildings to reduce electric energy consumption. Al mudhaffar et al. [7] have been studied the electric energy consumption for a residential building by introducing a basic rule for cooling and heating consumption in the Basra city. Many building parameters are investigated to study their effect on electric energy consumption. The results showed that a house built with thermos- stone causes 5.9% and 12.4% reduction of the annual cooling and heating energy consumption respectively. However, insulating the base- house obtained 23% and 42.8% reduction in cooling and heating energy consumption respectively.

Many factors affect urban design has been studied. Florides et al. [8] have been studied the effect of the shape factor on energy consumption for the cooling and heating of a building. It is supposition was that the best position for a rectangular building is for the longest wall face the south. A building with a 0.5 shape factor (less surface of the wall with a southern orientation) requires nearly 8.2% more energy for heating. This result increases greatly (26.7%) when the roof is insulated.

Many researchers were studied how building geometry impact on temperature, wind flux in urbanized canyons. Priyadararsini et al. [9] studied that putting usefully laying a small number of skyscrapers would lead to rising the velocity of wind resulting in decline air temperature. When wind flows from the parallel direction, the speed of the wind was increased by up to 90% and the temperature dipped by up to 1°C. For perpendicular flow, the tower influence was large, with increase ten- times in wind speed and 1.1°C reduction in temperature. This is also supported by a study in Canada to look at the impact of a built skyscraper on a spacious area, which found that the air temperature decreases with an increase in the wind speed [10].

Urban geometry and vegetation have been studied due to its large influence on the urban thermal environment. There have been many research projects examining the mutual and jointed effect of these aspects, planning to found a suitable design method to reach for the comfortable urban environment. Measurement in Hong Kong displayed when increasing the cooling impact of trees can see high SVF sites than low sky view factor (SVF) sites [11].

Alaboud [12] studied improving the indoor thermal performance of residential buildings in Saudi Arabia by using Makkah city as a case study. A normal low-rise residential building was tested and calibrated there results with the simulated results taken from thermal analysis software. The result is supposed to show a similarity between the two results and decrease the energy for the cooling load to as high as 34.5%.

Hasan et al. [13] distinguished two gaps for evaluation of the scale of the residential neighborhood and the scale of the housing unit. The research also addressed the theoretical aspects of planning and thermal design in these areas. In addition, it presented a model for an evaluative method to investigate the negative thermal performance of housing in hot - dry areas on the planning and architectural scales. This research documented the planned and architectural features and aspects of thermal performance and making use of them in setting policies and planning and design directions for housing in hot- dry areas, evaluating concepts and improving the thermal environment. Al-Mansouri et al. [14] pointed out the elements that contribute to energy consumption in the residential building, as it was summed up into three main elements (architectural design, mechanization, and human behavior). The study addressed in
the architectural design the human desire to modern construction as if it were a feature of urbanization without realizing it with the appropriate building materials and climate and social environment.

Al-Youssef et al. [15] studied climate change in summer and winter seasons in Iraq. Therefore, the rate of energy consumption was increased to ensure an appropriate internal environment for occupants, especially during the hot summer season.

The results showed that outer surface of the smart building which includes a set of technologies: (a mobile roof system, concave roof system and smart windows system) improved the thermal performance of the building by the following intelligence as a method that gives the characteristic of the integration of these technologies parallel with local construction buildings via computer simulation program (Ecotect). The research was concluded that the system reduces the annual cooling loads of the building approximately to quarter, which means reducing the drainage of energy expended, as this research encouraged the application of these technologies.

Al- Mosawi et al. [16] studied and reviewed the strategies of green architecture or environmental architecture, which included two main categories. One of them is natural or negative architectural strategies while the other one is related to the technical strategies (effective strategies). Effective strategies focus on using modern technologies in buildings. These strategies lead to obtaining clean energy and comfortable internal structure. For instants using wind, water and sun energy. While the negative strategies depend on design solutions which is far away from modern technologies. Moreover, these types of strategies play a major role in decreasing the consumption of energy. These strategies reviving and adopting on old design strategies that proved their efficiency in responding to climatic requirements without affecting the environment and recommended as a design solution to reduce energy consumption.

From previous architectural studies, it is noted it did not address a special and modern study with a computer program to calculate the effect of the direction of the building, building exterior color, glazing distribution and shape of building on building thermal performance. It is found that the urban planning operation in the Basra city misses the thermal load studies, where thermal comfort as complement and to reducing the consumption of electric energy. The plots of land are placed by urban designer, which are facing all direction without avoiding some of the directions which tend to increase the convection.

Therefore, the study was designed to study six stories hypothetical for a building (residential building with 12 apartments) designed by the second researcher, assuming it is facing the northeast.

2. Simulation Methodology

To carry out our research, a case study of a residential building located in Basra city was employed for the simulations. The effect of changing building orientation is studied while keeping the same construction of the building for wall, roof and floor.

2.1 The Model Definition

The building contains six floors, where every floor has two residential flats with an area of 100 m². The ordinary number of people per flat is four with are one storage in every flat. The building model and plan is shown in figure 1 (a) and Figure 1(b). The characteristics of the building are shown in Table 1.

| Characteristics       | Description                                |
|-----------------------|--------------------------------------------|
| Location              | Basra (Lat. 30° 34´N, Long. 47° 47´ E)      |
| Plane shape           | Rectangular                                |
| Orientation           | Front Elevation Facing the North East       |
| Area                  | 240 m²                                     |
| Wall exterior color   | dark                                       |
2.2 Building Energy Simulation program (eQuest)

It is an hour-by-hour energy simulation software. After compiling a building description, it produces a detailed simulation of the building, as well as an estimate the energy consumption.
2.3 Weather Data Documents
The study transacts with the Gulf area, with its characteristic desert climatic conditions, and adopts hourly values for a full year in Kuwait weather file. Basra city is not available in from building energy simulation program weathers files, to check the validity of the procedure, a comparison is made between weather file. Data for Kuwait with the weather data get from Basra airport [18]. The results show that the weather file of Kuwait is nearly identical to the weather file for Basra city [19].

2.4 Energy Simulation
The transfer function method [20] gets its potential for approximation the load in cooling for residences on an hour-by-hour source and to calculate resultant conditions that can be estimated in that place for many system types, control schemes, and working timetable.

When a \( f(t) \) is signified at a standard intervals \( \Delta t \) and its importance are \( f(0) \), \( f(\Delta) \), \( f(2\Delta) \), ...... \( f(n\Delta) \) the Laplace transform is given as [21]:

\[
\tau(z) = f(0) + f(\Delta)z^{-1} + f(2\Delta)z^{-2} + \cdots + f(n\Delta)z^{-n} \tag{1}
\]

Where \( \Delta = \) time interval, hour
\( Z = Z-\) transform variable that equal to \( e^{s\Delta t} \)
The preceding polynomial in \( z^{-n} \) is called the continuous function \( \tau(t) \) of the \( z \) – transform .

Due to the emitted component of heat and the connection with heat storage effect, the sensible load of cooling at the time \( (t) \) can be connected to the sensible gains heat and preceding cooling loads in the arrangement of the function of time \( f(t) \), which can be extracted as a \( z \)– transform. The cooling load of the space is calculated by the transfer function technique depending on three ways. First, the heat from roofs, walls and floors are calculated if it is gains or loss. Second, the solar, as well as heat gains, are taken into directly for the planned hour. Third, the room weighting factors or transfer function factors are applied to transform from cooling load to the heat gains, or the heating loads from heat losses [22]. They can be calculated and the coefficient of the transfer function by [21]:

\[
Q_{rs,t} = \sum_{i=1}^{I} (v_0 q_0 + v_1 q_1 + v_2 q_2 + \cdots) - (\omega_1 Q_0 + \omega_2 Q_2 + \cdots) \tag{2}
\]

Where: \( I \) is the number of heat gain elements.
\( \Delta \) is the interval of time.
\( t- n\Delta \) is the time .
\( q_{rs,t} \) is the load of space heating.
\( Q_{rs,t} \) is the load of space cooling.
\( v_0, v_1, v_2, \cdots, \omega_1, \omega_2 \) are the weighting factors.

The eQuest program is utilized to do the simulation in this research. The eQuest program has the ability to simulate a wide range of data and measures energy conservation in buildings. It has been tested for accuracy by many researchers [7], [18].

3. Results and Discussion
3.1 Effect of orientation of the building
The main factor that interposes in the design is the orientation of the building. Figure 2 shows the annual consumption of cooling energy for different orientations of building. It can be seen that north direction has a minimum annual consumption of cooling energy about 95.44 MWh and the northeast direction has an annual consumption of cooling energy consumption about 103.50 MWh. It is found that if the orientation of the building is changed from northeast to the north, the annual cooling energy consumption reduced by about 8%.

**Figure 2.** Annual consumption of cooling energy for different orientation of building.
Figure 3 shows the annual consumption of energy of heating for different orientation of the building. The northeast direction has an annual consumption of heating energy of nearby 3.05 MWh and the north direction has 2.37 MWh annual consumption of heating energy for the cold season. Hence, the annual consumption of heating energy decreased by about 22% if the orientation of the building changed from northeast to north direction.

Figure 3. Annual consumption of heating energy for different orientation of the building.

Figure 4 shows the annual consumption of electric energy in a different orientation. It can be seen from this figure that the total annual consumption of electric energy for northeast direction was 143 MWh and for the north direction was 127 MWh, hence 11% of the annual consumption of energy is saved. The results show that the north direction is the best orientation when compared with other directions.

Figure 4. Annual consumption of electric energy for different orientation of the building.
3.2 Effect of building exterior wall color

After finding the best building orientation, many other parameters could also help in the reduction of consumption in energy. One of these parameters is changing the color of the external walls. Figure 5 shows the annual consumption of cooling energy for different exterior wall colors. It can be seen that the building white walls have minimum annual consumption of space cool energy which is about 78.95 MWh and the building with dark walls has a maximum consumption of cooling energy which is about 95.69 MWh. The annual consumption of cooling energy could be saved by about 17% if the building's exterior walls color changed from dark to white color.

![Figure 5. Annual consumption of cooling energy for different exterior wall colors.](image)

Figure 6 shows the annual consumption of heating electric energy for different exterior wall colors. It is found that the dark wall exterior color is the worst case for the hot season, but it is the best case for the cold season. The result shows that if the wall exterior color is changed from dark to white the annual consumption of space heat energy increased from 2.36 MWh to 3.25 MWh, this leads to increase consumption of heating energy by about 27%.

![Figure 6. Annual consumption of heating energy for different exterior wall colors.](image)
Figure 7 shows the annual consumption of total electric energy for the different exterior wall colors. It can be seen from this figure that the minimum consumption of energy was obtained by using white color and the maximum consumption of energy was for the case with dark color. If the wall exterior color is changed from dark to white the annual consumption of electricity energy changed from 127.99 MWh to 112.27 MWh, this could save about 12% of the total energy consumption of electric. Although there is an increase in consumption of heating energy by using the white color, the white exterior wall color wall is desirable because it saves more of the consumption of electric cooling energy. This agreement with [19].

![Electric Energy Consumption vs Color](image)

**Figure 7.** Annual consumption of electric energy for the different exterior wall color.

### 3.3 Effect of glazing distribution on building walls

Windows and window – treatments have a big effect on cooling and heating loads. Therefore, a careful important chosen of glazing, the orientation of windows could help the designers to achieve a significant reduction in cooling loads. In this section, the effect of glazing distribution on external walls is studied. The percentage of the glazed - wall area of the building is studied for different distribution as shown in Table 2.

**Table 2.** Effect of different glazing distribution in the wall of the building

| Case No. | Glazing distribution |
|----------|----------------------|
| 1        | 12% E/W, 5% N/S      |
| 2        | 12% N/S, 5% E/W      |
| 3        | 12% S/W, 5% N/E      |
| 4        | 12% S/E, 5% N/W      |
| 5        | 12% N/E, 5% S/W      |
| 6        | 12% N/W, 5% S/E      |

Fig. 8 shows the annual consumption of cooling energy for different glazing distribution. It is found that the maxim annual consumption of cooling energy was found when the glazing distribution was (12% S/E, 5% N/W) which is about 75.67 MWh and the minin consumption of cooling energy was for (12% N/E, 5% S/W) which is about 73.42 MWh. If the glazing distribution is changed from (12% S/E, 5% N/W) to (12% N/E, 5% S/W) 3% of the annual consumption of cooling energy could be saved.
Figure 8. Annual consumption of cooling energy for different glazing distribution.

Fig. 9 shows the annual consumption of heating energy for different glazing distribution. It is found that the maximum annual consumption of heating energy when the glazing distribution was (12% N/W, 5% S/E) is about 5.53 MWh and the minimum energy consumption of annual heating was when the glazing distribution was (12% N/S, 5% E/W) is about 4.77 MWh. 14% of the consumption of heating energy could be saved if the glazing distribution changed from (12% N/W, 5% S/E) to (12% N/S, 5% E/W).

Figure 9. Annual consumption of heating electric energy for different glazing distribution.

Fig. 10 shows the total annual consumption of electric energy for different glassing distribution. It can be gotten from a figure that the maximum annual consumption of electric energy is found when the glazing distribution was (12% S/E, 5% N/W) and the minimum annual consumption of electric energy is found when the glazing distribution was (12% N/E, 5% S/W).
3.4 Effect of building shape

In this section, the effect of changing the building shape with keeping the same area for all cases. Three building shapes were studied which included: square, rectangle and triangle. The orientation of the building for this test was the north direction.

Figure 11 shows the effect of changing the shape of the building on the energy consumption of annual cooling. It is found the maximum consumption of energy for cooling was obtained for the triangle building which is about 106.49 MWh and the minimum the energy consumption of annual cooling is obtained for the square building which is about 81.50 MWh. If the building shape is changed from rectangular to square shape the annual consumption of cooling energy could be saved by about 7%.

Figure 11. Annual consumption of cooling energy for different shape of the building.

Figure 12 shows the effect of changing the shape of the building on the annual consumption of energy cooling. It is obtained that if the building is triangle has the maximum consumption of heating energy
which is about 7.01 MWh and the rectangle building shape has the minimum annual consumption of heating energy about 3.19 MWh.

![Figure 12. Annual consumption of heating energy for different shape of the building.](image)

Figure 12 shows the effect of the shape of building in the consumption of electric energy. It is found the maximum consumption of electric energy in the triangle building about 164.11 MWh and the square building has a minimum annual consumption of electric energy is about 118.69 MWh. If the building design is changed from rectangle shape to square shape, 1% saving in electrical consumption is obtained. The result reveals that obtained the rectangle shape is best in the design of building than square shape because it provides a decrease in the cold energy in the cooling season when compared with annual cooling and electric energy consumption. This agreement with [8].

![Figure 13. Annual consumption of electric energy for different shape of the building.](image)
3.5 The Optimum Building Case

Having gained some insight into the individual effects of various parameters on the thermal performance. It is now appropriate to combine all these factors in order to produce the best improvement to obtain the optimum building case. Figure 14 shows the monthly consumption of electric energy comparison between the base and optimum building case. Total consumption of electric energy consumption saved by 35% for the optimum building compared to the base building.

The annual consumption of electrical energy in a unit area is equal to 76.20 kWh. Thus, a standard number is obtained a standard number for the annual consumption of electric energy per square meter. Therefore the results of this research can be generalized to any other building in Basra with any possible area. This standard number can be adopted for the design of any residential building and reject any design that exceeds the amount of energy consumed to preserve the energy supplied to the building. Moreover, reduce the amount of carbon dioxide discharged to the atmosphere. This depends primarily on the cooperation of the architect and refractory engineers in designing buildings with less consumption of energy. In future studies, this standard number can be reduced by changing the designs of building materials, the colors used, and the necessary shading of buildings, landscaping, and windows.

4. Conclusion

The work discussed in this study to improve the thermal performance of a residential building in Basra city that can be abbreviated in the following points:

- The best orientation of the building is the north direction. If the orientation of the building is changed from the northeast direction to the north direction, the energy of annual consumption of cooling energy will be decreased by 8% and the of the annual consumption of heating energy by 11%.

- Building exterior color is an important factor in building thermal performance. As the results showed that white color is the lowest in convection. If the color of the external wall changed from dark color to white color the annual consumption of cooling energy was reduced by 17% and the total annual consumption of electric energy could be decreased by about 12%.

- The best glazing distribution was to raise the window region in the north and south directions and reduce the window region in the east and west directions.
• The rectangle shape was the best design of the building compared to the square or triangle shapes. It could save about 31% of the annual consumption of heating energy for square-shaped.

• When all the above enhancements were combined, then an optimum case could be obtained. The optimum building case could save about 35% of the annual consumption of electric energy compared to the base building case.

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