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Energy Optimization of a One-story Clinic Building In Tehran: An Approach using BIPV Windows

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Abstract: *It is important to optimize energy consumption in different buildings including hospitals and clinics. In this research a one-story clinical building in Tehran with an area of 600 square meters has been simulated in Design Builder software. Thermal loads are calculated in different states including different window types like single glazed, double glazed and BIPV windows. Results indicates that using BIPV windows decreases the heating loads of the building by 5.5%. About 77% of the electricity required for cooling the building is supplied from the produced power of the BIPV windows. Also a annuall reduction of the heat transfer from windows by an average of around 42% is reported due to implementing BIPV windows.*

Keywords: *clinic, building energy, BIPV window, Design Builder.*

1. Introduction

Energy is one of the factors of production in the economic system and any production and service activities are possible through energy consumption. The statistics published by various organizations such as the World Energy Organization regarding the energy consumption in various regions reveal that over 30% of the global energy consumption is in the residential and commercial sectors, a significant portion of which is consumed for heating and cooling in the buildings, particularly in warm and humid areas [1]. Meanwhile, the energy consumption in Iran is far from optimal and has increased significantly over the recent years [2]. Any measure taken to increase energy saving in the buildings must ensure thermal comfort and air quality standards inside the building.

Statistics presented in the studies conducted on healthcare in hospitals indicate that energy consumption per meter square is much higher in hospitals compared to other service initiations, and around 10% of hospitals' current expenditure basket is dedicated to purchasing energy carriers. Given the relatively high number of these centers and their vital need for energy carriers as well as their long working hours (many of these centers work around the clock), the increase in energy carrier prices can increase the expenditure of public medical and healthcare centers of the country by 7000 billion IRR. On the other hand, hospitals have a high capacity for saving energy as well, so that their energy consumption can be reduced by 10% without any special expenditures, while this figure reaches up to 20% in Germany and up to 44% in the Netherlands [2]. There have been many studies considering various solutions for building energy optimization. Here some of them are mentioned including BIPV windows that are the main point of the current research.

In 2017, Lee et al studied the functional performance of vertical BIPV window systems facing south in an administrative building. This study sought to analyze the productivity of the BIPV system under real operational conditions, and reveal the factors contributing to performance decline through annual auditing of south-facing BIVP vertical window system [3].

In 2017, Shukla et al investigated the features of BIPV products including foil, title, module, and BAPV system and glass based on PV performance parameters (efficiency, open-circuit voltage, short circuit current, maximum power, and the filling factor), and their life cycle was examined considering the energy recovery time and GHG emission [4].

In 2020, Abdul Hakim Masloub et al. carried out a study on Building Integrated Photovoltaic (BIPV) optimal performance of windows in administrative buildings of Algeria with a semi-arid climate. This study aimed to investigate the Building Integrated Photovoltaic (BIPV) optimal performance for Overall energy Consumption (OEC) in terms of energy output, cooling, and heating load, and artificial lighting to ensure visual comfort and saving energy in common administrative buildings in a semi-arid climate. Field measurements of the studied office were conducted over a critical period. The respective data were used to simulate a valid OEC model. Comprehensive simulations were carried out using graphic optimization for the primary model as well as the nine existing commercial BIPV modules with various Window-to-Wall Ratios (WWRs), main directions, and deflection angles. Results of site measurements indicated a significantly high energy output compared to the demand for energy. This study revealed that optimal BIPV window design comprised of a double glazed PV module (A), moderate WWR, 20% VLT in the southern façade, and 30% VLT in the east-west axis. Maximum attainable energy savings was 60% in the southern direction using a double glazed PV module (D). On the other hand, PV modules minimize the shining index significantly compared to the primary model. The data extracted from simulations indicated that the percentage of output energy in a three-dimensional model can be used by designers and architects in the initial stages [5].

In this research, first, the consumption of cooling and heating energy of a one-story clinical building in Tehran, and with an area of 600 square meters has been simulated in Design Builder software. To analyze the energy consumption of this building, the effective parameters in the energy consumption of the building such as number of people, type of building materials, type of glass and lighting systems have been selected according to the nineteenth topic of national building regulations in Iran. In order to optimize and reduce cooling and heating loads, changes in parameters related to the type of glass, including BIPV and different glazes are considered as other parameters.

2. Materials and Methods

To analyze the energy consumption of this building, the effective parameters in the energy consumption of the building have been selected according to the nineteenth topic of national building regulations in Iran. In order to optimize and reduce cooling and heating loads, changes in parameters related to the type of glass, including BIPV and different glazes are considered as other parameters.

The number of people, the number of equipment, the lighting system, and the performance schedule of the buildings were obtained from the building aligned with the hypothetical data in this study and were entered in the software. The two-dimensional plans of the building floors were first designed in AutoCAD, and the respective file was saved as a .dxf extension and transferred to the Design-Builder software. In the next stage, all the thermal zones of the building can be specified. It must be mentioned that building design and the type of materials used were specified based on a real sample made under ASHRAE standards and national construction rules [6].

Figure 1 demonstrates a scheme of the medical building with one story, an area of 600m2, and medical land use extracted from the Design-Builder software [7].

It has been assumed in the design of this building that it is located in an area where high-rise buildings and the shade of trees did not influence the performance of BIPV windows.

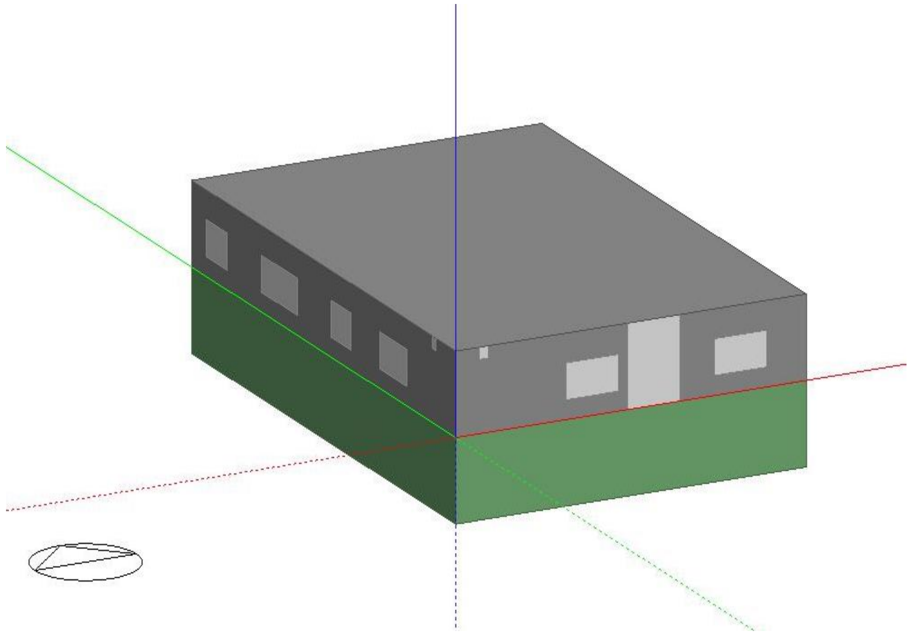

Fig. 1: External view of simulated clinic in Design Builder.

Figure 2 illustrates the sun path at various hours of the day and month in Tehran.

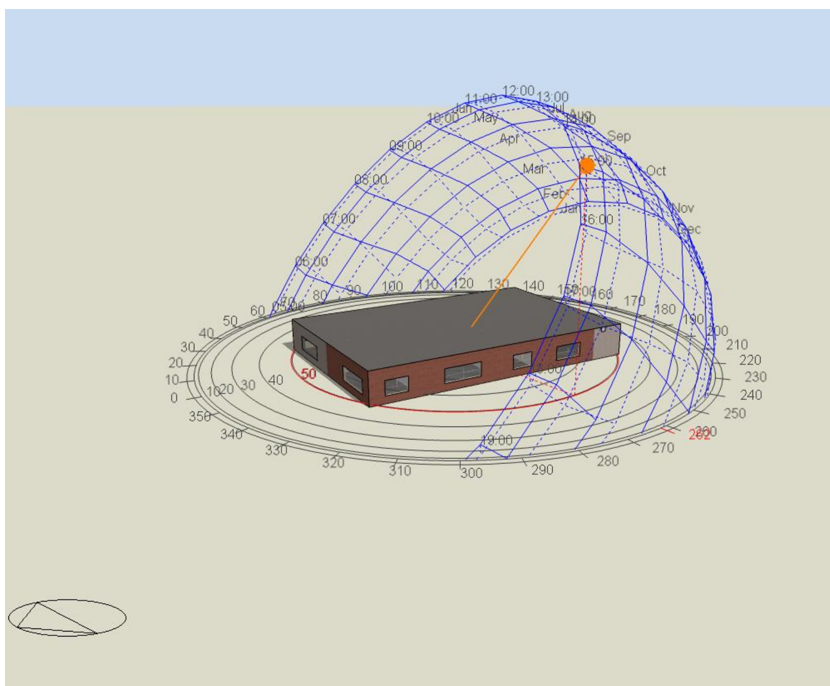

Fig. 2: Sun path in different times for Tehran.

The two-dimensional plane (i.e. the initial design of the building) has been demonstrated in Figure 3. The medical building is made up of nine various zones with the specific land use and regime based on the ASHRAE standard categorized. [6]

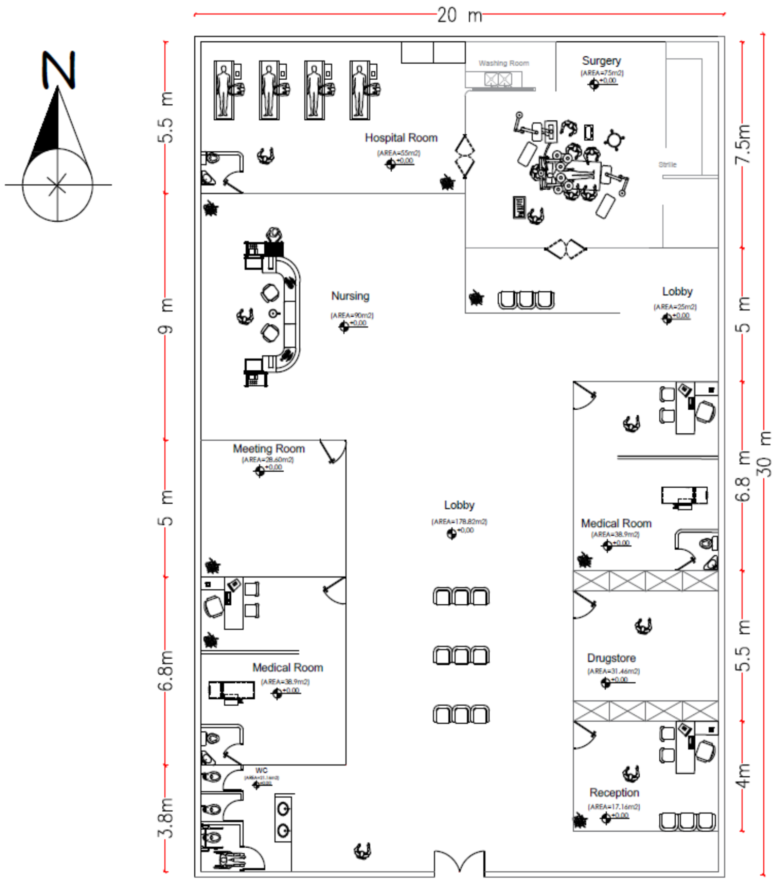

Fig. 3: 2D plan of the clinic.

2.1. General optimization strategies in hospitals

Figure 4 demonstrate that energy waste through the doors and windows amounts to approximately half of the energy loss of a building. The item of windows has been analyzed in the present study. As mentioned earlier, the present study seeks to reduce the energy load required to ensure comfort in a medical building so that the highest energy saving is achieved in the building. and the elaborated results of Design Builder outputs will be presented in the following: the clinic in the initial state and the clinic with BPIV windows .

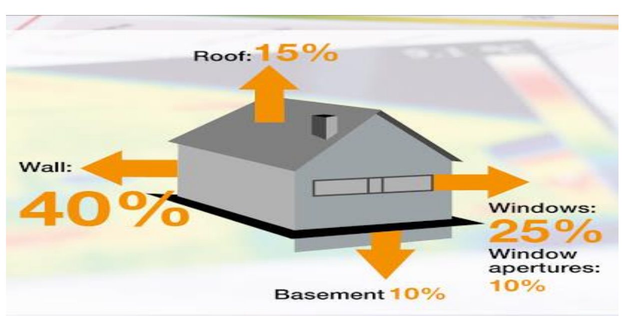

Fig. 4: Energy loss in buildings.

BIPV windows have been used instead of regular windows in all directions of the building in this study so that their influence on reducing the consumed energy is investigated and analyzed. The occupancy area of the window exposed to sunlight is 60.234m^2.

3. Results

Figures 5 and 6 compares the heating and cooling loads of the building in the initial and BIPV included window states in Tehran, respectively.

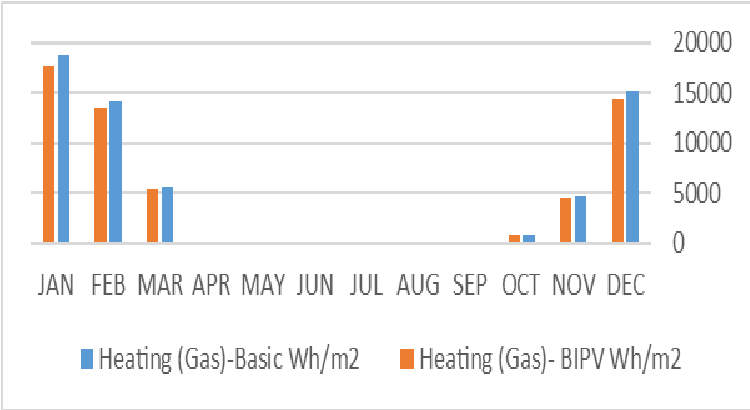

Fig. 5: Heating and cooling loads of the building in the initial states.

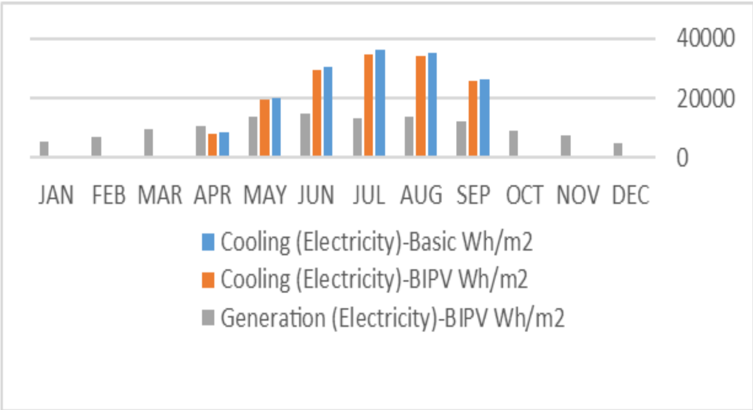

Fig. 6: Heating and cooling loads of the building including BIPV windows.

Comparison of the data obtained from figures 5 and 6 reveals that using BIPV windows decreased the heating loads of the building by 5.5%. About 77% of the electricity required for cooling the building was supplied from the produced power of the BIPV windows.

Figure 7 compares the heat transfer from the building windows for the initial state (single glazing) and BIPV window implemented state. Positive values indicate the heat received by the building and negative values represent the heat lost from the building.

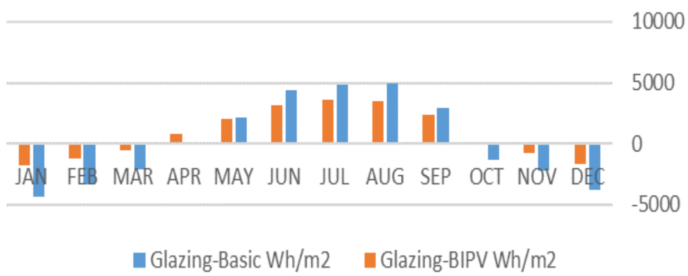

Fig. 7: Heat transfer of the building for glazing windows type.

Comparison of the data obtained from the figure 7 reveals that BIPV windows reduce the heat transfer from windows by an average of around 42% annually.

4. Conclusion

Comparison of the results reveals that BIPV windows can cover around 77% of the cooling needs of the building by generating power. Considering that Tehran has a warm and arid climate and the difference between power and natural gas expenditures, the use of BIPV technology can contribute to energy consumption reduction significantly, particularly in peak consumption hours. However, it is important to consider items such as installment and operation expenditure, the ease of use and maintenance, and accessibility in the market to ensure cost-effectiveness.

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