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Study of eQUEST as a tool for Building Energy Simulation

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Abstract. Building Simulation is widely used for understanding how a building consumes energy and for assessing design strategies aimed at improving building energy efficiency. The present research study uses eQUEST, a popular simulation software. Various simulations are done here to analyze and critically comment on the best design strategies to be used in order to vastly reduce the energy consumption of a Two-storey office building (25000 ft^2 floor area) considering the weather file of Sunder Nagar, Himachal Pradesh. The limitations faced with eQUEST while simulating the modified design are critiqued.

Keywords: Energy simulation; Computational Fluid dynamics (CFD); Energy efficiency.

1. Introduction

Building energy Simulation is defined as the use of software to predict the energy used by a building. Energy models will output building energy use predictions in typical end-use categories like heating, cooling, lighting, plug, and process. Apart from energy units, most software includes utility rates input and can also predict energy costs. Nowadays, designers need tools that answer to very specific questions even during the initial design phase. Through the use of energy simulation software designers can consider specific choices, (e.g., heating and cooling). Designers can also predict the thermal behavior of buildings prior to their construction and simulate the costs of energy in existent buildings in their current conditions, establishing the best thermal retrofitting measures to adopt in the buildings under analysis.

Buildings are consuming roughly one third of the total Energy consumed nationally every year. Much of this energy is used maintaining the thermal conditions inside the building and lighting. Simulation can and has also played a significant role in reducing the energy consumption of buildings. Examples of Building energy simulation programs are: Energy Plus, Energy-10, BLAST, DOE-2, esp-R, TRNSYS, eQUEST etc.

2. Objectives

eQUEST is one of the most popular and widely used building energy simulation programs. The reason for its popularity is the fact that it combines simplified input wizards with detailed simulation tools and has the potential of meeting various needs, both of architects and engineers, such as integrating graphical results with context-sensitive guidance. It is a tool that can be used in the conceptual design stage, when little is known about the building, as well as in the final design stages when most project details have been finalized.

The concept used is to reduce the building energy loads as much as possible and then meet them using the most efficient ways and systems.

An effort has been made to understand the challenges that eQUEST possesses in designing the most energy efficient systems to provide the reduced energy (mostly heating) loads.

In this Project work, simulations for various modifications are carried out. While applying the upgrades, the major challenges faced by eQUEST are observed and documented.

The objectives of this study are as follows:

1. To understand eQUEST software and its potential.
2. To model a simple Office building in eQUEST.
3. To analyze the results graphically.
4. To critically analyze the energy use pattern by changing various design parameters

3. Concepts of Building Energy Simulation

The energy used to heat or cool a building depends on the distribution of temperature within the building, as well as, on the properties of the thermal envelope and the rate of air exchange between inside and outside of the building. The temperature distribution plays an important role, because the rate of heat flow across a window or wall depends on the difference in temperature between the window or wall surface and the air temperature adjacent to the surface. It also depends on the heat transfer coefficient between the inner envelope surface and interior air, which in turn depends on the rate of air movement and degree of turbulence. The

detailed pattern of air movement depends on the mechanical ventilation system, as well as, on the temperature distribution. In turn, the temperature distribution depends on the air movement and of the temperatures on all the room surfaces. This creates a feedback loop – the temperature distribution and boundary conditions depend, in part, on the air movement, which depends (in part) on the temperature distribution and the boundary conditions. Computing this interaction for an entire building requires solving the equations of fluid dynamics and temperature on a fine grid that corresponds to the geometry of the building in question. This approach is referred to as Computational Fluid Dynamics (CFD) and requires substantial computing power and memory (Harvey, 2006, Appendix D). CFD calculates the thermal comfort of a building accurately, but due to extremely complicated nature of the calculations involved, it is not used extensively. Instead, a much simpler approach has been in use. This treats different rooms in a building as a series of boxes. The temperature inside each of these boxes is assumed to be uniform. The heat flow across each surface bounding each box is computed using the following equation: q = temperature difference / thermal resistance = $\Delta T / R$
q (heat flow) has units of watts per square metre (W/m^2).

A finite element model is developed to represent a cracked beam element of length d and the crack is located at

4. Literature Review

Zhu [1] used eQUEST to analyze the effect of various energy-saving measures on building energy consumption conditions and rated the measures according to the Energy Star standard.

Kim et al [2] They observed that **HVAC had the greatest effect on building energy consumption** and **building orientation had the least effect on energy consumption**.

Yu et al. [3] used eQUEST to research the impact of various parameters. Their results showed that **improvements in envelope shielding and external wall insulation could effectively decrease air conditioner energy consumption**, with an energy savings rate of 11.31% and 11.55%, respectively.

Using eQUEST, Sozer [4] examined passive designs that could effectively decrease building energy consumption, ultimately demonstrating that **insulation, shielding, and window type can reduce heating and cooling energy consumption by 40%.**

Radhi [5] researched the building energy reduction effects of using insulation in building walls and showed that **insulation can reduce building electricity use and CO2 emissions by approximately 40%.**

Yin et al. [6] used **eQUEST to detail how double low-E windows with a solar film coating could effectively reduce the annual electrical use and peak demand in commercial buildings**, showing that internal and external solar film coatings reduced cooling loads by 2.2% and 27.5%, respectively.

5. Features of Simulation Tool

5.1 eQUEST as a simulation tool

Software tools that integrate graphical results with context-sensitive guidance are likely to have the most appeal for architects. On the contrary, engineers need software tools that can be used in both the conceptual design stage, when little is known about the building; as well as in the final design stages, when most project details have been finalized. The eQUEST program combines simplified input wizards with detailed simulation tools and thus, has potential to meet these different needs at various stages of the design process. eQUEST is an easy-to-use building energy analysis tool combining a building creation wizard, an energy efficiency measure wizard and graphical results display module with an enhanced DOE-2 derived building energy simulation program. eQUEST is an easy-to-use building energy analysis tool combining a building creation wizard, an energy efficiency measure wizard and graphical results display module with an enhanced DOE-2 derived building energy simulation program.

The building creation wizard takes a user through the process of creating a building model. Within eQUEST, DOE-2 performs an hourly simulation of the building based on walls, windows, glass, people, plug loads, and ventilation. DOE-2 also simulates the performance of fans, pumps, chillers, boilers, and other energy-consuming devices. eQUEST allows users to create multiple simulations and view the alternative results in side-by side graphics. It offers energy cost estimation, day lighting and lighting system control, and automatic implementation of energy efficiency measures (eQUEST, 2008).

5.2 Engine in eQUEST

The simulation "engine" within eQUEST is derived from the latest official version of DOE-2; however, eQUEST's engine extends and expands DOE-2's capabilities in several important ways, including interactive operation, dynamic/intelligent defaults, and improvements to numerous long-standing shortcomings in DOE-2 that have limited its use by mainstream designers.

5.3 Building Blocks of Simulation

Building simulation requires that a model of the proposed building be created that is capable of simulating the important heat flow in the proposed building. Toward this end, the following list summarizes essential components, steps, or building blocks, in a `how-to` description of the process of simulation modelling. Before "building" anything, including a simulation model, one needs to first consider and collect the following:

5.4 Analysis Objectives –

The simulation model should be approached with a clear understanding of the design questions to be answered. One has to focus on the important issues and at the same time, limit the questions. Experience teaches how best to strike this important balance for each new project.

5.4 Building Site Information and Weather Data –

Important building site characteristics include latitude, longitude and elevation, which help the simulation tool to choose the appropriate weather site for the location. Other site characteristics required includes information about adjacent structures or landscape capable of casting significant shadows on proposed (or existing) building.

5.5 Building Shell, Structure, Materials, and Shades –

eQUEST needs information about the walls, roof, and floor of proposed building only in so far as they transfer or store heat. Geometry (dimensions) and construction materials of each of the heat transfer surfaces of proposed building. This will include glass properties of windows and the dimensions of any window shades (e.g., overhangs and fins). eQUEST itself provides users with simple, user-friendly, choices for each of these.

5.6 Building Operations and Scheduling –

This includes information about when building occupancy begins and ends (times, days of the week, and seasonal variations such as for schools), occupied indoor thermostat set points, and HVAC and internal equipment operation schedules. eQUEST has default operations schedules based on building type. **Internal Loads -** Heat gain from internal loads (e.g., people, lights, and equipment) can constitute a significant portion of the energy requirements in large buildings, both from their direct power requirements and the indirect effect they have on cooling and heating requirements. In fact, internal loads can frequently make large buildings relatively insensitive to weather. More importantly, the performance of almost all energy-efficient design alternatives will be impacted either directly or indirectly by the amount of internal load within a building.

5.7 HVAC Equipment and Performance –

Good information regarding HVAC equipment efficiency will be important to the accuracy of any energy use simulation. eQUEST assumes default HVAC equipment efficiencies according to California's energy standard. Where possible, equipment efficiencies specific to each analysis should be obtained, e.g., from the building design engineers or directly from equipment manufactures. Most HVAC equipment manufactures now publish equipment performance data on their web sites.

5.8 Utility Rates –

A great strength of detailed energy use simulation using eQUEST is the ability to predict hourly electrical demand profiles that can then be coupled with full details of the applicable utility rates (tariffs).

5.9 Economic Parameters

This facilitates recommend life-cycle economics above simple payback methods of economic analysis. Because energy efficiency investments usually return benefit over the entire life of the building or system, considering their lifecycle impact is most appropriate.

6. Methodology

A two-storey office building is considered by taking the weather file of nearest available location which is Sunder Nagar, Himachal Pradesh. Sunder Nagar lies on 920m above sea level. The climate in Sunder Nagar is warm and temperate. Building Area is 25000 sqft. Heating Equipment used is based on Electric Resistance. Figure 6.1 shows the type of building.

Now, five parameters are considered and the effect of varying each is seen by keeping the other four constant. The parameters are Wall construction material, insulating material, window type, orientation and window area percentage. Table 6.1 shows various cases of simulation trials performed.

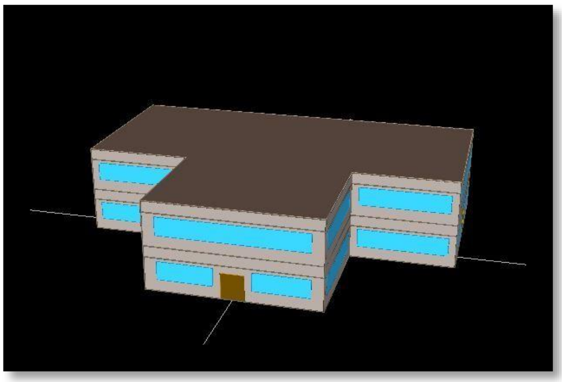

Figure 6.1: Simulation of office Building

Cases Parameters	1	2	3	4	5	6	7	8	9	10
Wall Construction Material	6 in. HW Concrete	6 in. HW Concrete	Brick, 8 in.	Brick, 8 in.	6 in. CMU	6 in. CMU	6 in. CMU	6 in. CMU	8 in. LW Conc. blk	8 in. LW Conc. blk
Insulating Material	2 in. Polyurethane	2 in. Polyurethane	-	-	2 in. Polyurethane	2 in. Polyurethane	1 in. Polyurethane	1 in. Polyurethane	-	-
Window Type	Double	Single	Double	SinglE	Double	Single	Double	Single	Double	Single
Orientation	N,S,E,W	N,S,E,W	N,S,E,W	N,S,E,W	N,S	N,S	N,S	N,S	N,S,E,W	N,S,E,W
Window Area %	0,30,40,45,50	0,30,40,45,50	0,30,40,45,50	0,30,40,45,50	0,30,40,45,50	0,30,40,45,50	30,40,45,50	30,40,45,50	0,30,40,45,50	0,30,40,45,50

Table 6.1: Table showing various cases of Simulation trials performed

7. Results and discussions

1. In Case 1, 6-inch hollow wall concrete as construction material, 2-inch Polyurethane as insulating material, Double glazed window type is kept constant and for all the orientations North, South, East and West Window area percentage is varied from 0 to 30 to 40 to 45 to 50. Variation of energy at different orientations by varying the window percent is shown by graph 7.1.
2. In Case 2, 6-inch hollow wall concrete as construction material, 2-inch Polyurethane as insulating material, Single glazed window type is kept constant and for all the orientations North, South, East and West Window area percentage is varied from 0 to 30 to 40 to 45 to 50. Variation of energy at different orientations by varying the window percent is shown by graph 7.2.
3. In Case 3, Brick masonry of 8 inch as construction material, no insulating material, Double glazed window type is kept constant and for all the orientations North, South, East and West Window area percentage is varied from 0 to 30 to 40 to 45 to 50. Variation of energy at different orientations by varying the window percent is shown by graph 7.3.
4. In Case 4, Brick masonry of 8-inch as construction material, no insulating material, Single glazed window type is kept constant and for all the orientations North, South, East and West Window area percentage is varied from 0 to 30 to 40 to 45 to 50. Variation of energy at different orientations by varying the window percent is shown by graph 7.4.
5. In Case 5, 6-inch Concrete masonry Unit as construction material, 2-inch Polyurethane as insulating material, Double glazed window type is kept constant and for the orientations North and South Window area percentage is varied from 0 to 30 to 40 to 45 to 50. Variation of energy at different orientations by varying the window percent is shown by graph 7.5.
6. In Case 6, 6-inch Concrete masonry Unit as construction material, 2-inch Polyurethane as insulating material, Single glazed window type is kept constant and for the orientations North and South Window area percentage is varied from 0 to 30 to 40 to 45 to 50. Variation of energy at different orientations by varying the window percent is shown by graph 7.6.
7. In Case 7, 6-inch Concrete masonry Unit as construction material, 1 inch Polyurethane as insulating material, Double glazed window type is kept constant and for the orientations North and South Window area percentage is varied from 0 to 30 to 40 to 45 to 50. Variation of energy at different orientations by varying the window percent is shown by graph 7.7.
8. In Case 8, 6-inch Concrete masonry Unit as construction material, 1 inch Polyurethane as insulating material, Single glazed window type is kept constant and for the orientations North and South Window area percentage is varied from 0 to 30 to 40 to 45 to 50. Variation of energy at different orientations by varying the window percent is shown by graph 7.8.
9. In Case 9, 8-inch Light weight concrete block wall as construction material, no insulating material, Double glazed window type is kept constant and for all the orientations North, South, East and West Window area percentage is varied from 0 to 30 to 40 to 45 to 50. Variation of energy at different orientations by varying the window percent is shown by graph 7.9.
10. In Case 10, 8-inch Light weight concrete block wall as construction material, no insulating material, Single glazed window type is kept constant and for all the orientations North, South, East and West Window area percentage is varied from 0 to 30 to 40 to 45 to 50. Graph 7.10 displays the variations at different levels.

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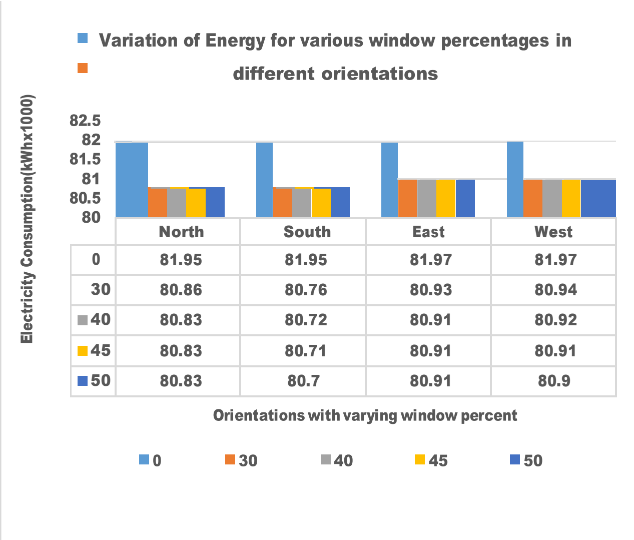
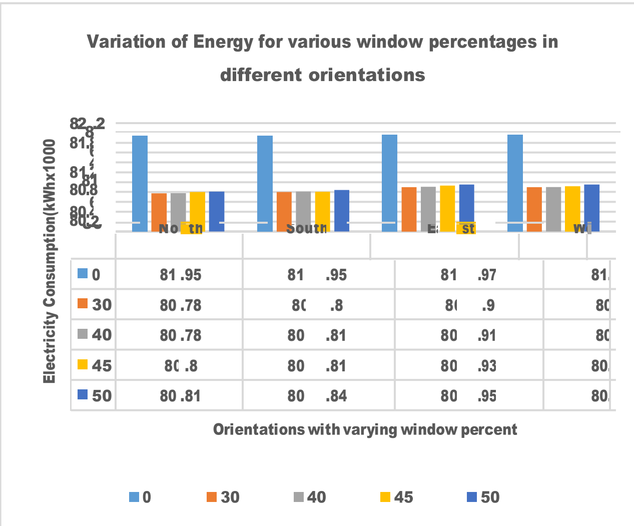
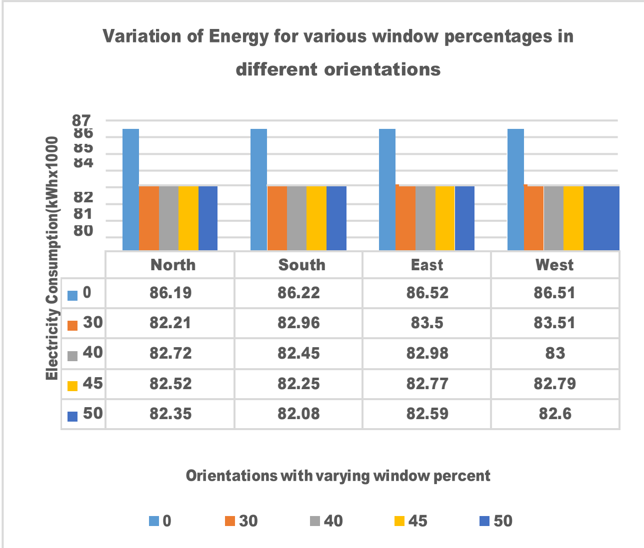


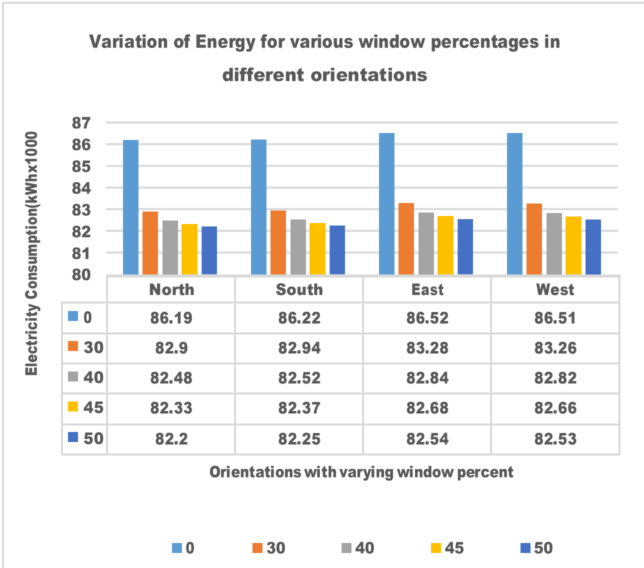
Graph 7.1: For 6 in. HW conc., 2 in. polyurethane and Double-Glazed window type



Graph 7.2: For 6 in. HW conc., 2 in. polyurethane and Single Glazed window type



Graph 7.3: For 8 in. common Brick and Double-Glazed window type



Graph 7.4: For 8 in. common Brick and Single Glazed window type

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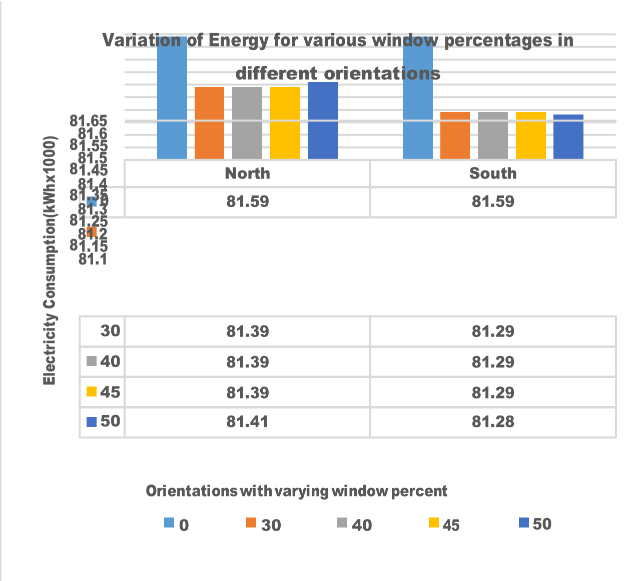
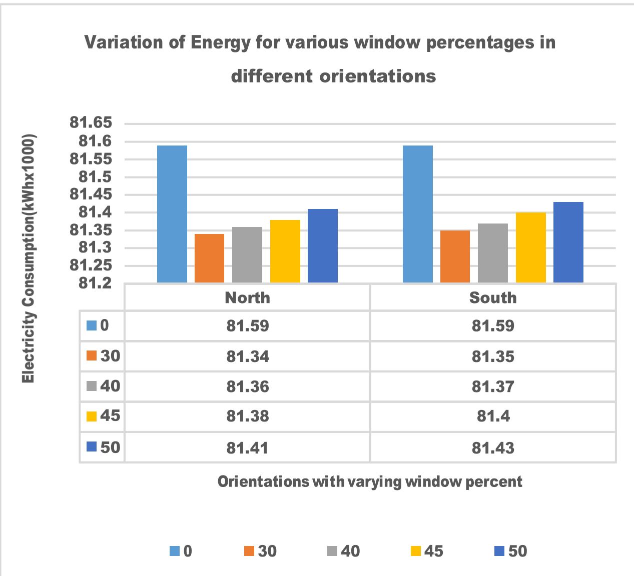
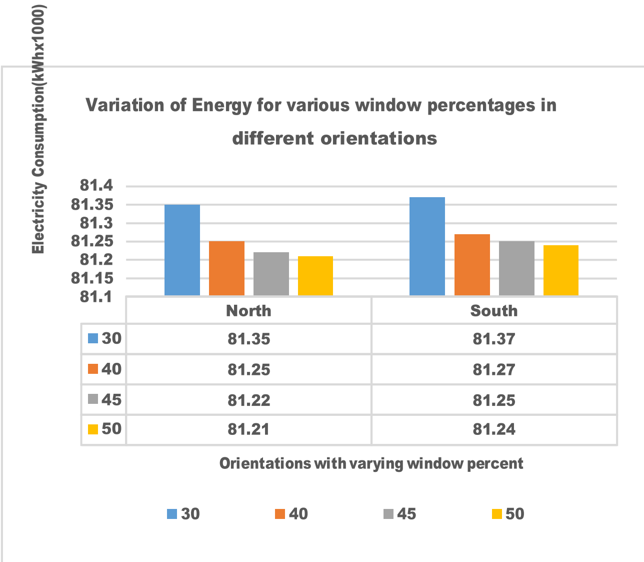


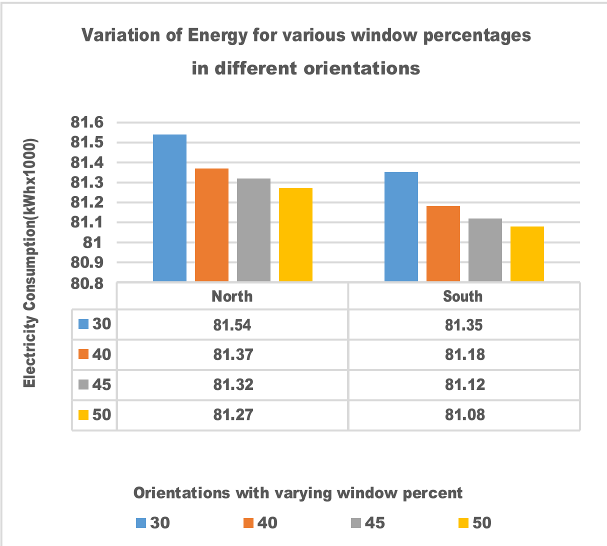
Graph 7.5: For 6 in. CMU, 2 in. polyurethane and Double-Glazed window type



Graph 7.6: For 6 in. CMU. 2 in. polyurethane and Single Glazed window type



Graph 7.7: For 6 in. CMU ,1 in. polyurethane and Double-Glazed window type



Graph 7.8: For 6 in. CMU,1 in. polyurethane and Single Glazed window type

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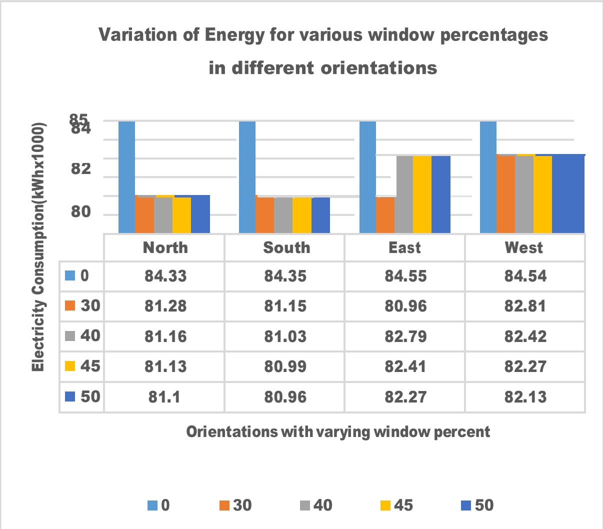
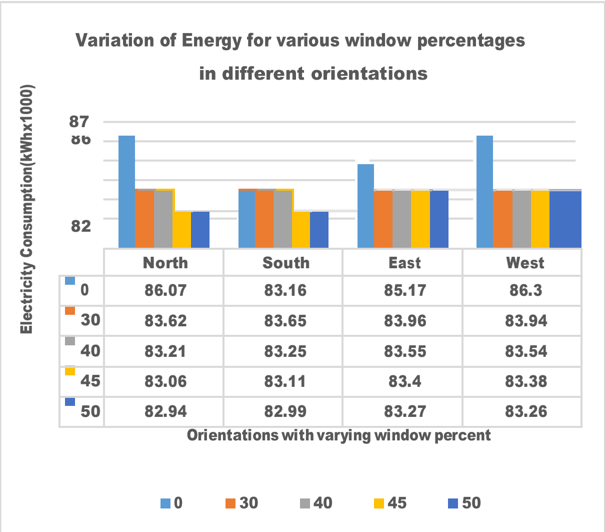


	North	South	East	West
0	84.33	84.35	84.55	84.54
30	81.28	81.15	80.96	82.81
40	81.16	81.03	82.79	82.42
45	81.13	80.99	82.41	82.27
50	81.1	80.96	82.27	82.13

Graph 7.9: For 8 in. LW conc. Blk. and Double-Glazed window type



	North	South	East	West
0	86.07	83.16	85.17	86.3
30	83.62	83.65	83.96	83.94
40	83.21	83.25	83.55	83.54
45	83.06	83.11	83.4	83.38
50	82.94	82.99	83.27	83.26

Graph 7.10: For 8 in. LW conc. Blk. and Single Glazed window type

8. Conclusions

After observing the energy consumption in all the 156 simulations and its variation with the variation of different parameters shown by the graphs following conclusions have been drawn-

1. 6-inch Hollow Wall concrete gives lesser energy as compared to 6-inch CMU keeping the insulating material same (2-inch polyurethane).
2. Double glazed windows give lesser energy compared to single glazed windows.
3. In more than 50% of the trials South orientation gives lesser energy compared to North, East and West.
4. It can be said that Energy at 50% window area is minimum.

References

[1] Y. Zhu, Applying computer-based simulation to energy auditing: A case study, Energy and Buildings 38 (2006) 421–428.

[2] H. Kim, A. Stumpf, W. Kim, Analysis of an energy efficient building design through data mining approach, Automation in Construction 20 (2011) 37–43.

[3] J. Yu, C. Yang, L. Tian, Low-energy envelope design of residential building in hot summer and cold winter zone in China, Energy and Building 40 (2008) 1536–1546.

[4] H. Sozer, improving energy efficiency through the design of the building envelope, Building and Environment 45 (2010) 2581–2593.

[5] H. Radhi, can envelope codes reduce electricity and CO2 emission in different types of building in the hot climate of Bahrain, Energy 34 (2009) 205–215.

[6] R. Pacheco, J. Ordonez, G. Martinez, Energy efficient design of building: A review, Renewable and Sustainable Energy Reviews 16 (2012) 2012.

[7] R. Yin, P. Xu, P. Shen, Case study: energy savings from solar window film in two commercial buildings in Shanghai, Energy and Building 42 (2012) 132–140.