STM JOURNALS

International Journal of
Environmental Planning and
Development Architecture

Volume 1, Issue 1, 2023
January—June
DOI (Journal): 10.37591/IJEPDA

https://journals.stmjournals.com/ijepda/

Review **IJEPDA**

Optimization of Window Sizing Based on Different Climatic Conditions

Anshika Jain*

Abstract

Different climatic conditions have an impact on a building's performance. Climate-related factors will also affect how energy-efficient a structure is. As a result, making comparisons between buildings in different climate zones will produce inappropriate results. It is crucial to understand how much a building's energy performance can vary depending on the climate. By running energy simulation on the typical building, the climatic condition ratio is established for various climate zones of India in order to increase the accuracy of building assessment rating tools. The purpose of this paper is to study the effect of the size, position and direction of windows on the amount of energy required for cooling and heating of an indoor room situated in different climatic conditions in India. According to the study's findings, the size of a building's windows is the important and the primary factor responsible for influencing the cooling and heating load requirements and energy efficiency of a building or a single room. By selecting the ideal window size, which for an autonomous façade is between 10% and 50%, one can minimize energy usage by 40% and CO_2 emissions by 30%. An autonomous façade's cooling and heating demand is significantly impacted by orientation. The worst heating and cooling load requirement is at an orientation of 70°E to the south-east. The findings indicate that the south is the optimum direction for the amount of energy needed for winter heating and the north is the best direction for summer cooling.

Keywords: Window-to-wall ratio, optimization criteria of windows, energy efficiency, visual comfort

INTRODUCTION

Numerous research studies have been conducted on the design of energy-efficient buildings. In this regard, windows are shown to have a significant impact on overall energy consumption since they account for more than 10% of the building's energy loads [1].

A study was carried out to find out the effect of size, position, directional orientation of windows and the amount of energy required for cooling and heating an office space room using Ecotect, a computer program offering a wide range of internal functional analysis, which concluded that "the window size of buildings is considered the critical ring and the main parameter affecting the cooling and heating demand of buildings or a single room. About 40% of energy consumption and 30% of CO_2 emission can be reduced by choosing the optimum window size, which is between 10% to 50% for an autonomous façade" [2].

*__Author for Correspondence__
Anshika Jain
E-mail: ar.anshikajain@gmail.com

PG Scholar, Department of Building Engineering and Management, School of Planning and Architecture, New Delhi, India

Received Date: April 03, 2023
Accepted Date: April 24, 2023
Published Date: April 30, 2023

Citation: Anshika Jain. Optimization of Window Sizing Based on Different Climatic Conditions.. International Journal of Environmental Planning and Development Architecture. 2023; 1(1): 33–43p.

RESEARCH GAP

There is a major demand of converting conventional windows into energy-efficient windows in order to achieve maximum energy saving and more comfortable living environment. Windows are directly related to thermal and light comfort, and skin health. In addition, they provide vision, air ventilation, acoustic comfort, and photo-protection and they have biopsychological effects. There is also an increasing trend in their usage as building facades. India is a developing country. Hence, the construction industry is growing at a higher pace in the country. Modernization had led to various changes in outlook and utilization of buildings. One of the important changes that can be witnessed by any passer-by is the façade of modern buildings. Nowadays, glass has replaced approximate 60% of materials that were used in traditional facades.

It is also essential to understand the monetary advantage that the user will gain after investment of their capital. Fully glazed facades are in trend these days which demand highly efficient windows for end user. Reduction in heating and cooling load with the help of these glazing can prove to be beneficial for green buildings also. In the case study we will see how different orientation like north, south, east and west show changes in the heat gain inside the building. This can be helpful in designing of building and placement of glazing for the minimum heat gain in a house.

AIM

The aim of this study was to assess the optimization criteria of window sizes/fenestration and window-to-wall ratio (WWR) as per different climatic conditions in India.

OBJECTIVES

- To identify the factors responsible for optimisation criteria of window sizes
- To study and analyse the criteria of WWR ratio in different climatic zones of India
- To identify the role of window size and orientation on daylighting and energy saving in buildings in India

RESEARCH METHODOLOGY

Research methodology will follow the identification of different types of glazing techniques (Figure 1). Following the techniques, we will study some cases related to Indian environment and their glazing technologies. Also, we will understand the effect of orientation and the heat gain due to glazing with the help of simulation-based case study done on request at the end.

LITERATURE REVIEW

Energy consumption and the corresponding consequences of using energy in building construction and maintaining it are assessed using the life cycle assessment (LCA) technique. When examining the effects brought on by the development of building exteriors, it was found that optimizing WWR had a considerable positive impact on the energy efficiency and has significant environmental benefits.

The impact is reduced by 9% to 15% depending on the window material. The high coefficient of recovery of window materials, including window-frame and glass, is primarily responsible for the environmental advantage connected with the change in building external envelope manufacture. However, the environmental load of WWR varies depending on the window type or orientation during the building's use phase. Office building operations have the greatest negative impact on the environment, but despite the higher environmental cost of producing low-E hollow glass windows compared to single glazing windows, these windows perform better environmentally than other window types [3].

The effectiveness of passive solar energy is greatly influenced by window design, particularly glazing selections. Windows has two sides: a useful side which helps in natural daylighting and a dangerous

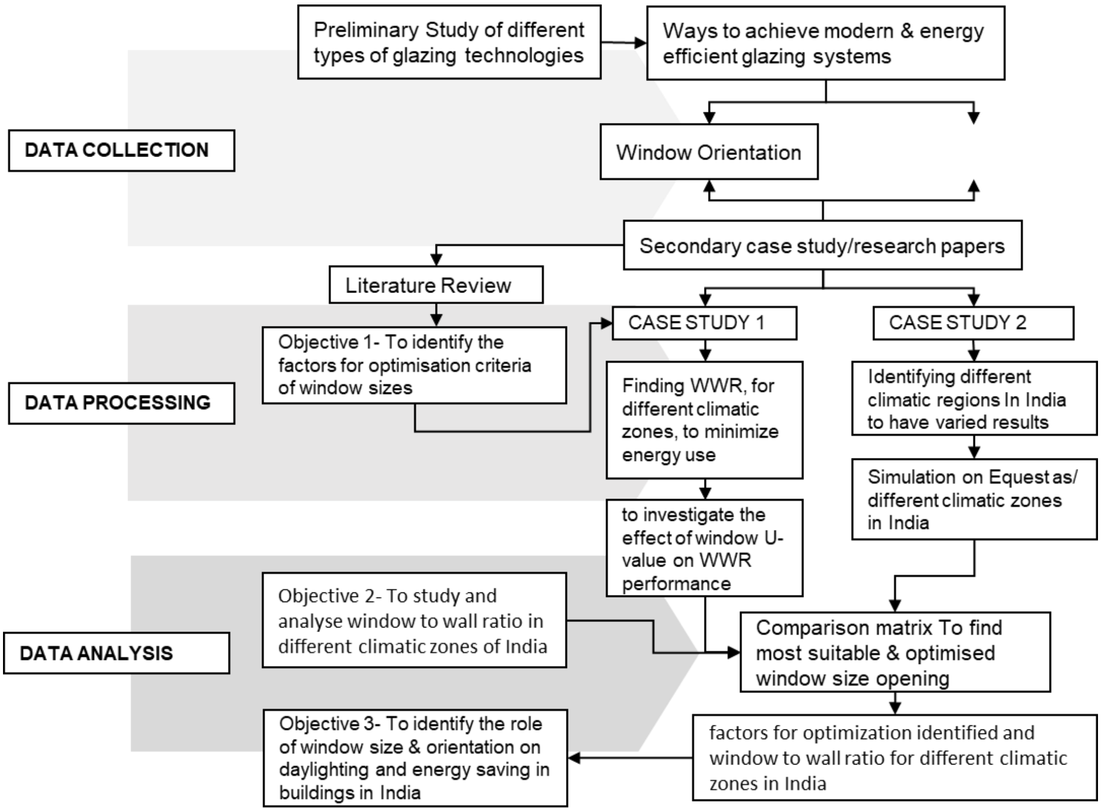


Figure 1. Research methodology. WWR, window-to-wall ratio.

side which adds to the heating loads of a building. During warmer days, heat radiation through windows increases the amount of cooling energy needed to maintain a pleasant temperature. Instead, more heating energy is required to reheat the area in order to maintain indoor thermal comfort and air quality index when hot air moves from inside to outside during cooler hours [4].

The effectiveness of passive solar design is greatly influenced by window design, particularly glazing selections. Windows are like a double-edged knife: they have a useful side and a dangerous side. The impacts of windows' U-value, orientation, and size on yearly heating and cooling energy demand are examined in this research while taking into account both energy and initial investment costs [4]. In contrast to cooling load, the paper demonstrates that heating load is very responsive to window type and size. Additionally, it has been demonstrated that once properly optimized and designed, glazed windows can reduce energy costs by up to 21%, 20%, and 24% cost reduction in percentage. which eventually leads to a significant amount of energy saved. Increased window sizing and WWR on the south facade will result in increased energy losses in all climate zones.

It is advised to reduce the size of the windows on the south facade to a minimum. As a result, the heated space will lose less heat. With the exception of single-glazed windows in all temperature zones, the opportunity to save energy increases as the size of the windows on the south face approaches their maximum value. This happens because, during the hot summer months, windows with low U-values conduct less energy from the outside to the inside of the building. On the other hand, it is best to avoid heat conduction from outside to inside a building during nights in summers, when the ambient temperature is lower than the interior temperature [4].

"Globally, the count of Green Building Rating Systems (GBRS) is rapidly increasing, application of these for confined regions are getting progressively critical for giving a solid assessment on the specified built environments” [5]. The analysis reveals that GBRS lacks a building execution proportion or possibly a framework that demonstrates how the differences result from various climatic factors [5]. This can incite out-of-line building appraisals when contrasting between two buildings in two diverse climatic zones. In this way, it is fundamental to perceive to what degree the climatic conditions can influence a building's performance, is climatic condition ratio.

Window’s Size: Window-to-Wall Ratio

Window area or window size is an essential aspect affecting a building's energy performance. The window size will have a significant effect on the heating and cooling loads of the building itself. Figure 2 illustrates the exact relationship between window size and the area of the room façade. The effectiveness of natural lighting increases with window size. But windows also have a considerable impact on the requirement for heating and cooling, which must be carefully considered [2].

The data show that increasing the window size from 10% to 100% caused a 265.52% increase in overall heating and cooling loads of a building. It has been observed that smaller windows use less energy. Therefore, it is advised to choose an ideal size between 10% and 50% to reduce energy usage [2].

The significant difference between heating and cooling results can be explained as follow:

- *For heating:* the greater the size of window, the greater the amount of heat entering directly from the glass. Thus, less heating energy needed.
- *For cooling:* the greater the size of window, the greater the area exposed to the outside, the greater heat leakage out. Thus, more cooling energy needed.

Window’s Orientation

Another significant factor affecting a building's energy performance is the direction of its windows. The building's orientation will affect how well it heats and cools throughout the winter and summer, respectively. The quantity of energy used for cooling and heating can be significantly affected by the size and position of the windows. Therefore, windows with proper design and orientation can lower the amount of energy used in buildings [6].

Simulations and tests were used to examine how the building envelope affected energy conservation in the summer. As computing power has increased, computer simulation has been used to investigate the best window size and kinds for reducing building energy usage [7]. A study was done to determine the best way to reduce annual energy consumption by adjusting and modifying building design elements. In cold climates, a bigger glass and WWR surface was needed to absorb solar heat gain for heating, and lowering cooling demands, according to the research. It was discovered that the best results were obtained with a minimum window size at a 15% proportion.

The worst heating and cooling load requirement is at an orientation of 70°E to the south-east. The findings indicate that the south is the optimum direction for the amount of energy needed for winter heating, and the north is the best direction for summer cooling [2].

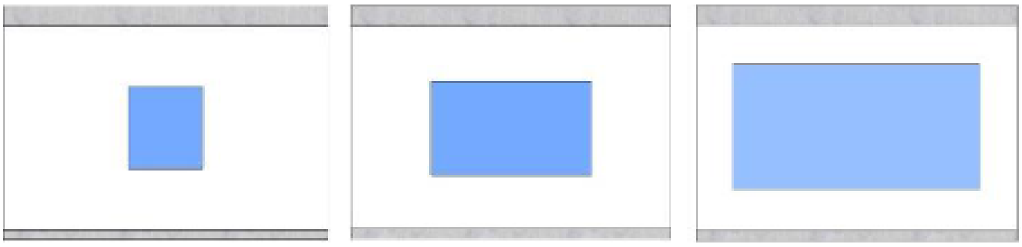


Figure 2. Window-to-wall ratio [2].

The study used Ecotech to analyse the impact of a single window’s four directions on the amount of heating and cooling load. The findings indicate that the south is the optimal direction for the quantity of energy needed for winter heating. This is because heat is stored for a long time and requires less heating because the southern direction is exposed to the sun for such a long time. Because the sun in the western direction gets cool and transmits less solar radiation via the windows, the western direction requires more heating energy. On the other hand, the northern direction is the finest for summer cooling.

Building Case Study 1 (“Optimization of Window-to-Wall Ratio for Buildings in Different Climates: An IDA-Indoor Climate and Energy Simulation Study” [8])

On the basis of the results, it is possible to identify a WWR that reduces the overall energy use. Heating, cooling, and lights were added together to determine total energy consumption. It is noteworthy, nevertheless, that in some climates, heating or cooling accounted for the majority of energy use. In each orientation, several instances were examined, and a certain best value or range was shown. Figure 3 displays the effect of the four main direction on heating and cooling load values for each of the situations under study, while Figures 4 and display the best values for a warm climate and a cold climate (Figure 5), respectively. The information in the tables shows that, in some instances, the size of the fenestration is restricted while, in other instances, a wider WWR range is observed to be efficient.

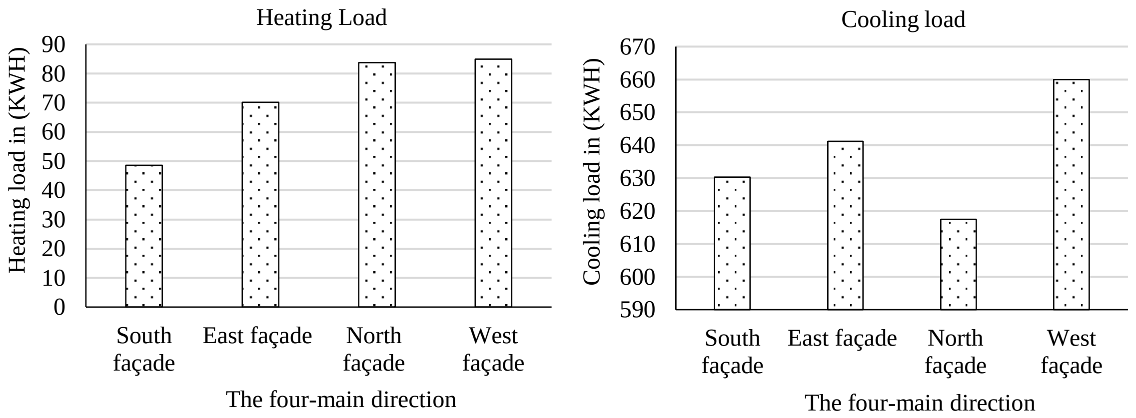
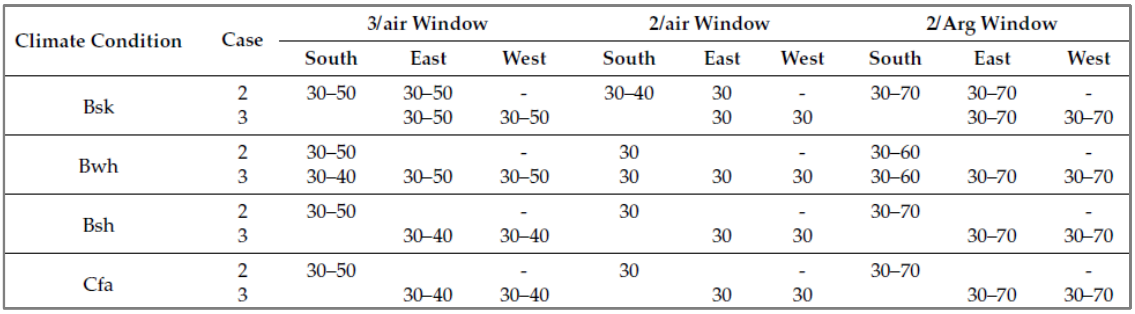
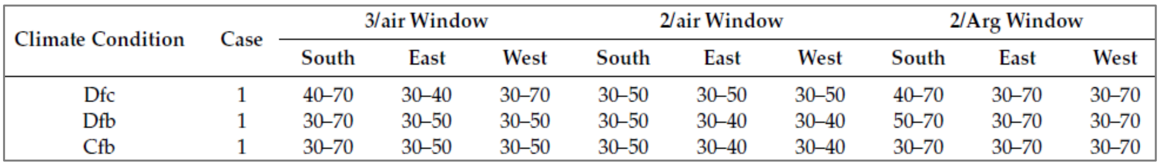


Figure 3. The effect of the four main directions on heating and cooling load [2].



Climate Condition	Case	3/air Window			2/air Window			2/Arg Window		
		South	East	West	South	East	West	South	East	West
Bsk	2	30–50	30–50	-	30–40	30	-	30–70	30–70	-
	3		30–50	30–50		30	30		30–70	30–70
Bwh	2	30–50		-	30		-	30–60		-
	3	30–40	30–50	30–50	30	30	30	30–60	30–70	30–70
Bsh	2	30–50		-	30		-	30–70		-
	3		30–40	30–40		30	30		30–70	30–70
Cfa	2	30–50		-	30		-	30–70		-
	3		30–40	30–40		30	30		30–70	30–70

Figure 4. Optimal window-to-wall ratio (WWR) range for studied cases in studied climate conditions and orientations in warm climates [8].



Climate Condition	Case	3/air Window			2/air Window			2/Arg Window		
		South	East	West	South	East	West	South	East	West
Dfc	1	40–70	30–40	30–70	30–50	30–50	30–50	40–70	30–70	30–70
Dfb	1	30–70	30–50	30–50	30–50	30–40	30–40	50–70	30–70	30–70
Cfb	1	30–70	30–50	30–50	30–50	30–40	30–40	30–70	30–70	30–70

Figure 5. Optimal window-to-wall-ratio (WWR) ranges for studied cases in studied climate conditions and orientations in cold climates [8].

On the other side, there are some situations where a larger fenestration can be chosen while still having an optimised energy use. When compared to other examples with the same climate and direction, the quantity of energy used is the least inside these optimal ranges or values [8].

Investigations were conducted for given orientations to the south, west, and east. To examine the impact of window U-value on window to wall ratio WWR performance, three different windows with variation in features and solar properties (2/air: clear 3 mm glass for both panes; 2/Arg: outer glass with high visibility and daylight transmittance property; inner glass with daylight transmittance of 48%; and 3/air: 4 mm clear glass for all three panes) were selected. It was determined that in warm climates, a combination of blinds or shades appeared useful. A WWR range of 30% to 50% for the 3/air window, 30% for the 2/air window, and 30% to 70% for the 2/Arg window were found to be ideal for the second and third cases on average in the warm climates of the examined climate conditions. It was observed that the first scenario, in which no blinds or shades were used for the entire year, seemed ideal for colder locations. The use of shades and blinds during the summer and winter did not undergo separate investigations. The variety of the selected climate conditions, each of which is associated with a distinct latitude, is the reason for this [8].

The transmission losses through windows can be outweighed by solar heat uptake in colder climates, which reduces the need for heating during the winter. On the other hand, summertime cooling demand rises; nevertheless, the increase in cooling demand does not have a considerable effect on the total energy use. Therefore, for the colder areas, a greater WWR could be chosen. According to the thermal comfort indices, the ideal WWRs for the 2/Arg window for warm and cold regions are 60% and 70%, respectively, for the south facing exposure. According to the climate, the ideal WWR for the 3/air window in warm regions is 40% or 50%, while in cold climates, it is 70% [8].

With normal ranges of 30% to 70% for the 3/air window and 30-50% for the 2/air window, the southern orientation suggested the potential for a wider ideal range for the colder climates. A recommended range for the 2/Arg window was reported based on each climate condition. It looks perfect for the southern exposure to have a WWR range of 50% to 70% given the Cfb climate condition, which is temperate and completely humid. In Figures 3 and 4, the optimal ranges are displayed. It is possible to draw the conclusion that the selection of WWR is less sensitive for windows with lower U-values based on the simulation data that was gathered. For the south-facing window, the cooling energy, which is clearly a signal that helps to reduce the amount of overall energy use aspect, increases as the function of WWR in all cases, for all the studied windows.

Inferences

Figure 6 depicts the solar heat gained for each of the three situations that were examined when the 2/Arg window was used for the southern exposure. The graphic demonstrates that both the base scenario

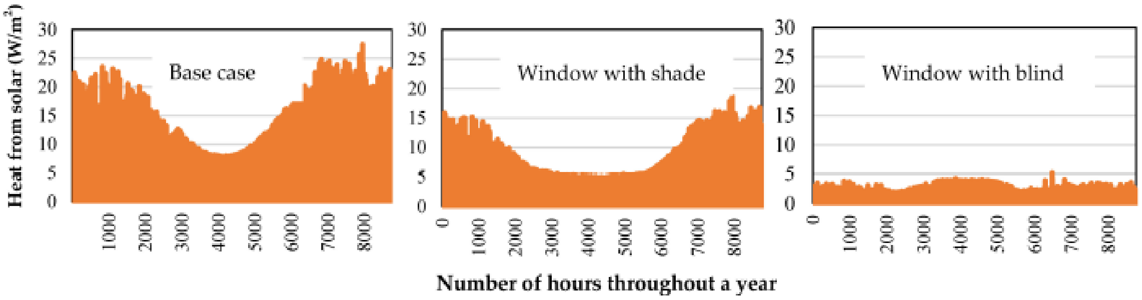


Figure 6. Heat from solar—direct and diffuse for the three studied cases for WWR 30%, for southern exposure, located in Steppe, cold, arid climate [8].

and the second example, the amount of heat received from direct and diffuse solar radiation falls throughout the summer, when cooling energy is most needed. Consequently, it helps to reduce the energy needed to cool the area. When compared to the gain throughout the year, the third instance (window with blind) experiences a modest summertime rise in solar heat gain. However, in the third instance, solar heat gain is somewhat reduced during the winter, which subsequently raises the need for heating.

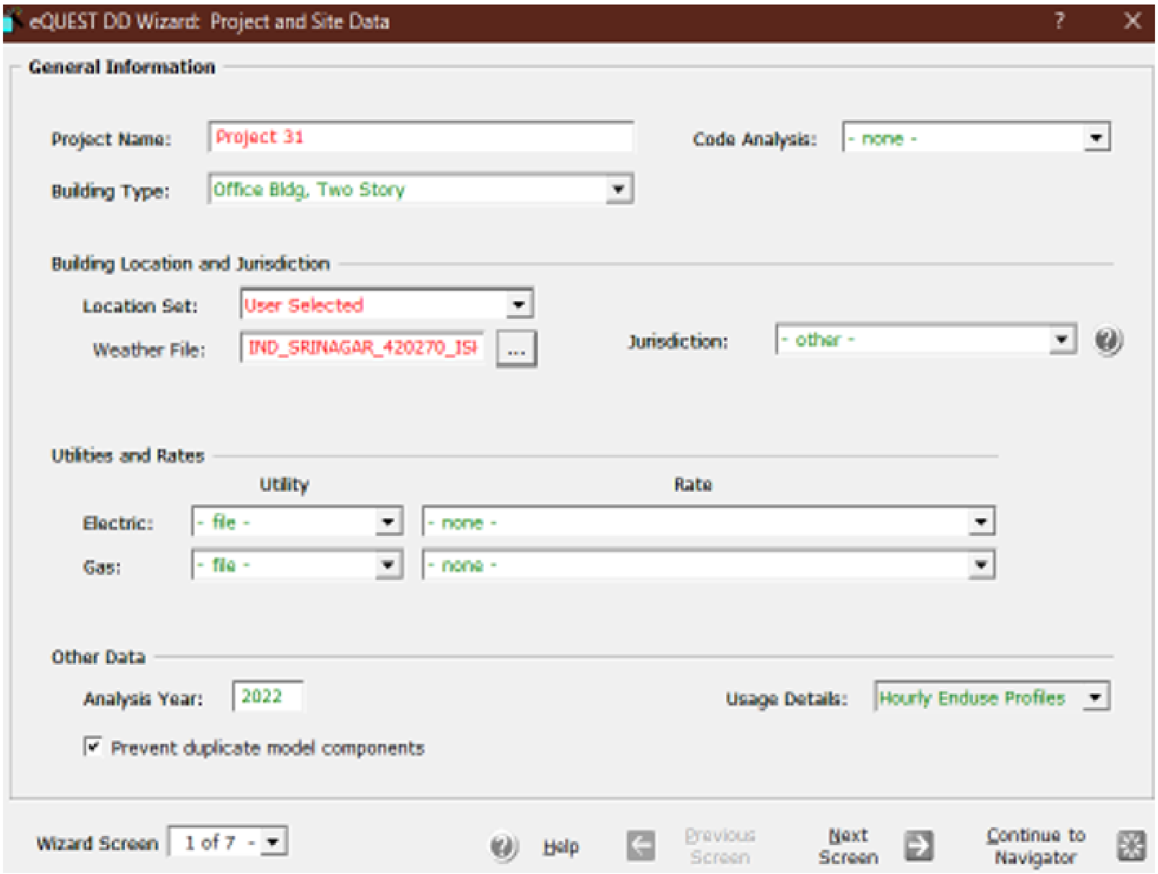
The calculations and studies show that there is no effect of window position of an autonomous façade on the heating or cooling load. More attention must be paid for the windows size and orientation to save energy in the buildings. But the results show that the best direction for the amount of energy required for winter heating is the south and the best direction for the summer cooling is the northern direction.

Building Case Study 2 (Two-Storey Office Building, Equest Simulation)

The simulation is done by selecting five cities for five different climate zones as shown in Figure 7.

1. A two-storey office building is selected in Equest for the simulation and day light control is enabled.
2. Then doors are made opaque so that the light can enter only form windows and no other source as shown in Figure 7.
3. Clear single reflective glass is used and at a time one wall is taken and different percentages 50%, 25%, 15% and 5% are taken while considering the remaining three sides as opaque. Hence 16 values are obtained for each climate zone and these values are compared to the get the most desirable fenestration percentage on each wall faces.

From case study 2, the following inferences can be drawn.



eQUEST DD Wizard: Project and Site Data

General Information

Project Name: Project 31
Code Analysis: - none -
Building Type: Office Bldg, Two Story

Building Location and Jurisdiction

Location Set: User Selected
Weather File: IND_SRINAGAR_420270_ISI
Jurisdiction: - other -

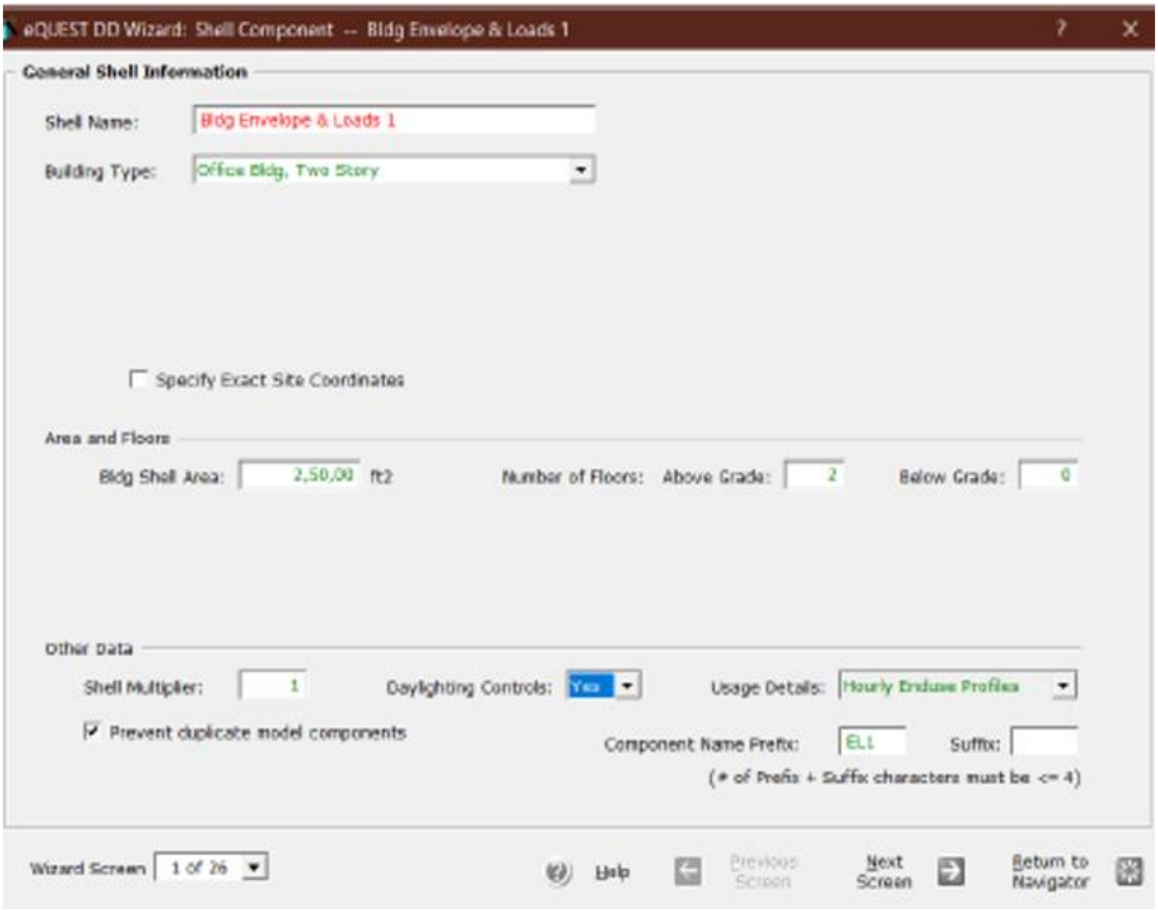
Utilities and Rates

	Utility	Rate
Electric:	- file -	- none -
Gas:	- file -	- none -

Other Data

Analysis Year: 2022
Usage Details: Hourly Enduse Profiles
☑ Prevent duplicate model components

Wizard Screen 1 of 7 -



General Shell Information

Shell Name: Bldg Envelope & Loads 1

Building Type: Office Bldg, Two Story

☐ Specify Exact Site Coordinates

Area and Floors

Bldg Shell Area: 2,50,00 ft2

Number of Floors: Above Grade: 2

Below Grade: 0

Other Data

Shell Multiplier: 1

Daylighting Controls: Yes

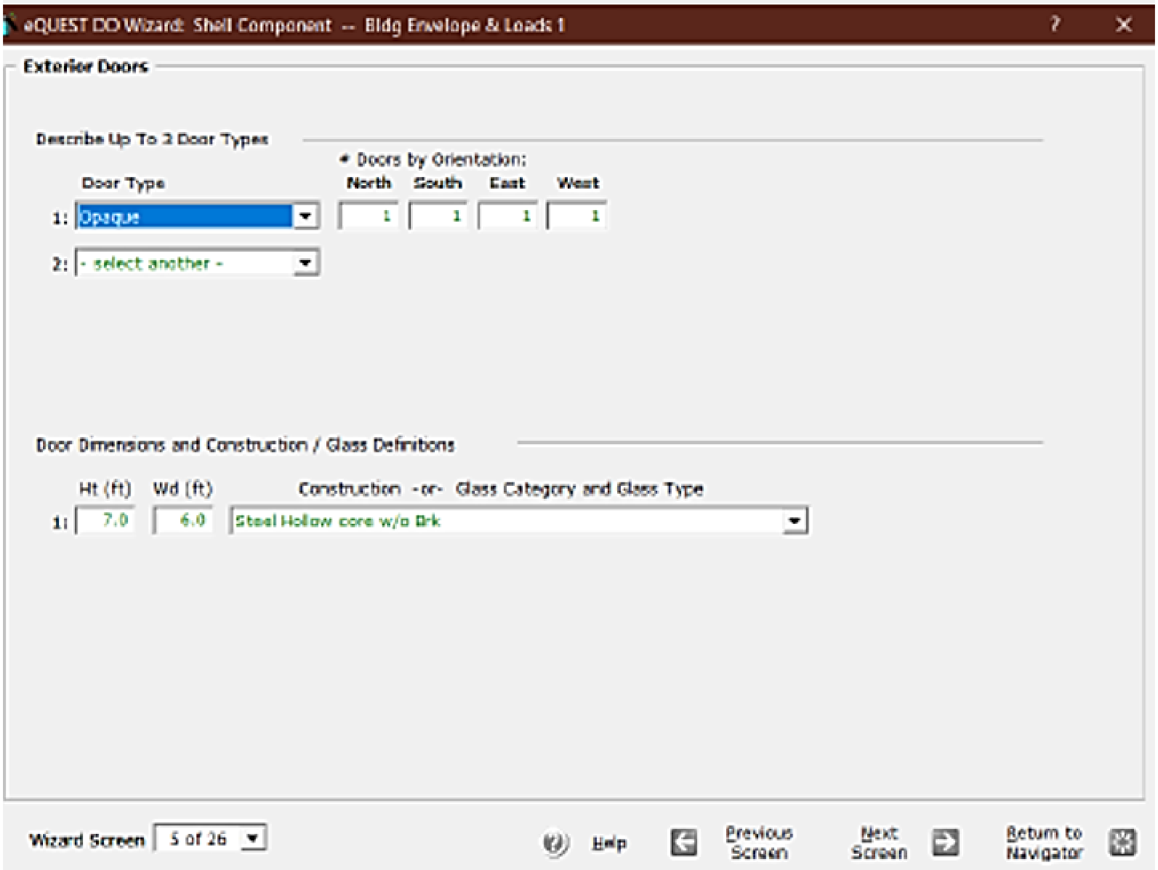
Usage Details: Hourly Enduse Profiles

☑ Prevent duplicate model components

Component Name Prefix: EL1

Suffix:

(# of Prefix + Suffix characters must be <= 4)



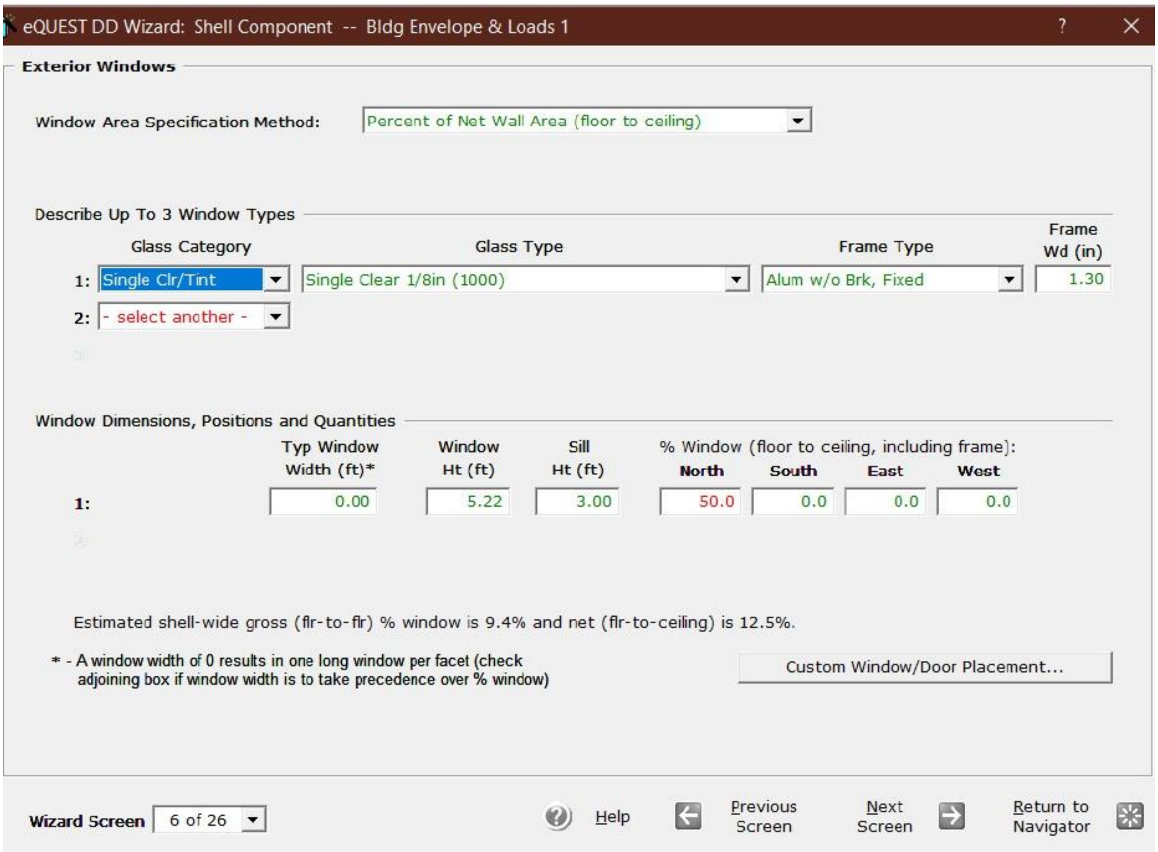
Exterior Doors

Describe Up To 3 Door Types

	Door Type	North	South	East	West
		# Doors by Orientation:			
1:	Opaque	1	1	1	1
2:	- select another -				

Door Dimensions and Construction / Glass Definitions

	Ht (ft)	Wd (ft)	Construction -or- Glass Category and Glass Type
1:	7.0	6.0	Steel Hollow core w/o Brk



Exterior Windows

Window Area Specification Method: Percent of Net Wall Area (floor to ceiling)

Describe Up To 3 Window Types

	Glass Category	Glass Type	Frame Type	Frame Wd (in)
1:	Single Clr/Tint	Single Clear 1/8in (1000)	Alum w/o Brk, Fixed	1.30
2:	- select another -			

Window Dimensions, Positions and Quantities

	Typ Window Width (ft)*	Window Ht (ft)	Sill Ht (ft)	% Window (floor to ceiling, including frame): North	South	East	West
1:	0.00	5.22	3.00	50.0	0.0	0.0	0.0

Estimated shell-wide gross (flr-to-flr) % window is 9.4% and net (flr-to-ceiling) is 12.5%.

* - A window width of 0 results in one long window per facet (check adjoining box if window width is to take precedence over % window)

Custom Window/Door Placement...

Wizard Screen 6 of 26

Figure 7. Simulation – Equest (studio exercise).

Temperate Climate

Bangalore is chosen for temperate climate (Table 1). When the model is simulated the desired wall-to-window percentage is found to be north 50%, south 5%, east 5% and west 15%.

Composite Climate

Delhi is chosen for composite climate (Table 2). When the model is simulated, the desired wall-to-window percentage is found to be north 50%, south 15%, east 5%, west 5%.

Table 1. Temperate Climate - Bangalore ideal WWR percentage.

Temperate	**Bangalore**				
	50%	25%	15%	5%	
North	230.41	229.87	229.74	229.69	50%
South	235.62	231	228.73	226.45	5%
East	238.63	234.34	232.3	230.39	5%
West	243.48	235.68	230.24	230.88	15%

Table 2. Composite Climate - Delhi ideal WWR percentage.

Composite	**Delhi**				
	50%	25%	15%	5%	
North	234.48	234.62	234.68	234.99	50%
South	242.61	238.53	234.14	235.78	15%
East	247.94	241.3	238.27	235.87	5%
West	241.54	237.77	239.31	235.46	5%

Warm and Humid Climate

Goa is chosen for warm and humid climate (Table 3). When the model is simulated, the desired wall-to-window percentage is found to be north 25%, south 5%, east 5% and west 5%.

Hot and Dry Climate

Ahmedabad is chosen for hot and dry climate (Table 4). When the model is simulated, the desired wall-to-window percentage is found to be north 5%, south 5%, east 5% and west 5%.

Cold Climate

Srinagar is chosen for cold climate (Table 5). When the model is simulated, the desired wall-to-window percentage is found to be north 5%, south 25%, east 25% and west 15%.

The minimum combined area of such openings, excluding doors and including frames, shall not be less than [9]:

1. One-tenth of the floor area for dry hot climate;
2. One-sixth of the floor area for warm and humid climate;
3. One-eighth of the floor area for intermediate climate; and
4. One-twelfth of the floor area for cold climate, regardless of the area of openings obtained.

CONCLUSIONS AND RECOMMENDATIONS

It is found that one of the most significant factors determining the demand for heating and cooling in buildings is the size of the windows.

Examples of computations demonstrated that a sizable portion of the total load is the need for cooling. Therefore, it is important to carefully analyse the impact of window size, orientation, and shape on the

Table 3. Warm and Humid Climate - Goa ideal WWR percentage.

Warm and humid	**Goa**				
	50%	25%	15%	5%	
North	266.87	263.05	262.68	262.33	25%
South	272.19	267.36	266.52	263.15	5%
East	268.22	267.69	265.25	262.83	5%
West	280.62	271.61	267.58	263.37	5%

Table 4. Hot and Dry Climate - Ahmedabad ideal WWR percentage.

Hot and Dry	**Ahmedabad**				
	50%	25%	15%	5%	
North	256.4	255.34	254.97	253.03	5%
South	263.53	255.5	251.77	250.11	5%
East	263.92	259.16	255.61	253.42	5%
West	271.32	261.9	257.95	254	5%

Table 5. Temperate Climate - Bangalore ideal WWR percentage.

Cold	**Sri Nagar**				
	50%	25%	15%	5%	
North	193.26	186.09	180.24	179.36	5%
South	186.19	182.3	181.82	179.23	25%
East	181.2	179.78	182.82	182.9	25%
West	193.26	186.09	180.24	179.36	15%

overall heating and cooling load requirement of an autonomous façade when designing an upgraded autonomous façade for office buildings. The results show that the best direction for the amount of energy required for winter heating is the south and the best direction for the summer cooling is the northern direction.

The factors required for optimization of window opening sizes are as follows:

- Orientation effect; facade side
- Window opening and sizing
- Day lighting requirements and energy efficiency required
- Horizontal/vertical shading devices
- Window-to-wall ratio (WWR) effect (varies as different climatic zones)
- U-value effect and solar heat gain coefficient (SHGC) value of the glass used
- Passive and natural ventilation; cross-ventilation
- Amount of heat absorbed by wall/surface.

REFERENCES

1. Sawyer K, project manager, technical editor. Windows and Building Envelope Research and Development: A Roadmap for Emerging Technologies. Washington, DC: Office of Energy Efficiency and Renewable Energy, Department of Energy; 2014.
2. Eljojo AK. Effect of windows size, position and orientation on the amount of energy. J Eng Res Technol. 2017; 1 (1): 1–8.
3. Su, Zhang X. Environmental performance optimization of window–wall ratio for different window type in hot summer and cold winter zone in China based on life cycle assessment. Energy Buildings. 2010; 42 (2): 198–202.
4. Jaber S, Ajib S. Thermal and economic windows design for different climate zones. Energy Buildings. 2011; 43 (11): 3208–3215.
5. Alyami SH. Critical analysis of energy efficiency assessment by international green building rating tools and its effects on local adaptation. Arab J Sci Eng. 2019; 44: 8599–8613.
6. Wang HH, Guo R, Xiao QL. Energy saving effect of building envelope in summer. J Central South Univ Technol. 2012; 19 (5): 1370–1376.
7. Al-Homoud MS. Optimum thermal design of office buildings. Int J Energy Res. 1997; 21: 941–957.
8. Sayadi S, Hayati A, Salmanzadeh M. Optimization of window-to-wall ratio for buildings located in different climates: an IDA-indoor climate and energy simulation study. Energies. 2021; 14 (7): 1974.
9. Ebekozien A, Aigbavboa C, Ayo-Odifiri SO, Salim NA. An assessment of fire safety measures in healthcare facilities in Nigeria. Property Management. 2020 Dec 14;39(3):376-91.