

COST SAVING ANALYSIS OF BUILDINGS USING VARIOUS DOUBLE WINDOW GLASS UNITS OF COMPOSITE CLIMATIC ZONE IN INDIA**G. Kiran Kumar*, T. P. Ashok Babu* & S. Nagaraju****

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Abstract:

Buildings are consuming lot of energy to afford thermal and visual comfort to inside the occupants, due to usage of more enclosures like glass more heat gain will occur into buildings. The main objective of this work is to reduce heat gain passing through various double window glass units to the buildings of composite (Hyderabad) climatic region in India. In these work solar optical properties of glasses namely clear, blue, green and grey glasses are taken from International Green Building Counsel. These window glasses arranged, one glass is placed outside and other glass placed inside to the building, such that total twelve window glass units from DGU1 to DGU12 located in all eight coordinial directions of the building such that total ninety six double window glass units were analyzed. A MATLAB code was developed to find the total solar radiation passing through different double glass window units of Indian composite climatic zone Hyderabad (17.45°N, 78.47°E) from all eight coordinial directions at peak summer and peak winter day were selected as per Indian standards and cost saving annually. From the results in southeast orientation DGU11 is the more energy efficient glass saving 2874.3 Rupees per year, in southwest orientation is saving 2776.15 Rupees per year and in south orientation is saving 2668.25 Rupees per year compared to other orientations, compared to all orientations of composite climatic zone in India.

Key Words: Composite Climatic Zone, Double Window Glass Unit International Green Building Counsel & Solar Optical Properties

1. Introduction:

Buildings are requiring more energy for day lighting, cooling and heating loads to provide thermal comfort to the occupants to inside the buildings. Window glasses are plays a significant role used as a building enclosures to provide visual comfort to the occupants from outside to the inside buildings. Now a day's all commercial buildings complexes and multinational companies used various wide-ranges of glass enclosures to the buildings for good looking in architectural point of view. As for thermal comfort considered if we use extensive glass enclosures as building envelope more heat gain and uncomfortable conditions will occur into the buildings, because window glasses are transparent, so researchers, building engineers are to be focused on different window glasses to keep them as building envelopes to provide day lighting as well as thermal comfort to the occupants without consumption of more energy in buildings.

Previous authors had worked on the different window glasses to find the solar radiation into the buildings. Detailed study of float and tinted glasses of single and double window glass with an air gap filled by air, xenon, krypton gases to find the solar radiation into the buildings by using TRANSYS to different climatic zones in India were reported in [1]. Design and study inward tilt of windows to reduce solar beam radiation to transmit into buildings through clear and brown windows in summer and winter season to Baghdad city in Iraq country were reported in [2]. To find the minimum heat gain into buildings by various wall and window glass material buildings at different window to wall ratios for energy efficient building design to warm and humid climatic zone of Indian city of Mangalore was reported in [3]. A mathematical model was developed to find the global solar radiation on 4mm clear glass window to room and it is compared with experimental results under the exposure of solar radiation was reported in [4]. To minimize the more quantity of direct solar radiation through 3mm clear glass window at different window tilt angles of New Delhi climatic zone was studied in detail [5].

To find out the hat transfer through single Low-E and double Low-E glass windows consider entire wave length region in solar spectrum to change the position of windows and decrease the solar radiation in summer and increase the solar radiation in winter seasons studied to an adiabatic room was done by [6]. To find the direct solar radiation into buildings through the different inward window glass tilt at different Indian latitudes were found by [7]. To analyses the heat transfer through a double-glazed unit with high and low thermal conductivity of internal louvered blind to found thermal transmittance using a biquadratic equation and also with computational fluid dynamics at different places was studied [8]. Influence of various roof construction, sun shields and window glass materials like Low-E glass to keep as a building envelope to residential buildings to reduce energy consumption as well as saving electricity power monthly and annually in Taiwan by EQUEST software were studied in detail [9]. The main objective of this work is to reduce the heat gain passing through different double glass window units at peak summer day and at peak winter day and also cost savings annually of composite climatic region (Hyderabad) in India by using ISHRAE clear sky and intermediate sky model conditions.

2. Solar Optical Properties of Glass Windows:

Generally solar radiation passing through any glass window split into three forms some quantity of radiation passing through glass which is known as transmission and some quantity reflected from surface of glass which is known as reflection and remaining quantity absorbed by the glass known as absorption. These three characteristics are depending on physical and chemical properties and also vary from glass to glass. Table 1 shows the solar optical properties and solar heat gain coefficient of glass windows. These properties are taken from International Green Building Counsel (IGBC). To find the solar radiation passing

through any glass windows it is compulsory to find the solar optical properties of glass windows, these properties will affect the cooling and heating loads of buildings.

Table 1: Solar Optical and Solar Heat Gain Coefficient of Glasses of Thickness 6 mm

Window Glass	T _{sl} [%]	R _{sl} [%]	A _{sl} [%]	SHGC [%]
Clear glass window	77	7	16	81
Blue glass window	48	5	47	58
Green glass window	49	6	45	59
Grey glass window	45	5	50	56

3. Analytical Method:

Solar radiation outside earth's surface in the form of electromagnetic waves i.e. extra-terrestrial radiation in short wave radiation when it reaches the earth's surface it becomes short and long wave radiation. Solar radiation in the form of electromagnetic waves the wavelength region is from 0.2 μm to 10 μm . In that ultra violet region is from 0.3 μm to 0.38 μm , visible region from 0.38 μm to 0.78 μm , near infrared region from 0.78 μm to 2.5 μm infrared region from 2.5 μm to 10 μm . Solar radiation through glazing enters into the building is in the form of direct radiation from the sun, diffuse radiation from the sky and reflected radiation from the ground. To find the total solar radiation i.e. direct, diffuse and reflected ground radiation falling on building enclosures consider solar spectrum region from 0.3 μm to 2.5 μm .

To find these three types of radiation several factors to be considered like hour angle, declination angle, solar altitude, solar azimuth angle, surface solar azimuth angle and angle of incidence of latitude. In this work to find the heat gain through double glass window units with an unventilated air gap 10mm between glasses of composite climatic zone from morning 6:00hrs to evening 18:00hrs at summer solstice and peak summer day and morning 7:00hrs to 17:00hrs at winter solstice as per Indian standards [10-14] in all eight cardinal locations like east, west, north, south, southeast, southwest, northwest and northeast at clear sky and intermediate sky conditions into the buildings.

In this work composite climatic region of Indian city Hyderabad (17.45°N, 78.47°E) was selected and compute the total solar radiation through all double glass window units. Building model of dimensions 4mX4mX3.5m were taken, 40% window to wall ratio i.e. 2.8mX2m dimensions of area of double window glass area considered as per ECBC standards [15], placing in all eight directions like east, west, north, south, southeast, southwest, northeast and northwest place one by one such that total twelve double window glass units from DGU1 to DGU12 as shown in figure 1. These combinations were tried one by one in all eight locations such that total ninety six combinations tried and find the heat gain passing through these combinations of composite (Hyderabad) climatic zone by using ISHRAE clear sky and intermediate sky model at atmospheric conditions.



Figure 1: Double window glass units with an air gap 10mm

The following steps are to find the direct diffuse and ground reflected solar radiation passing through window glass into buildings by using ISHRAE clear and intermediate sky model [16].

Declination angle

$$d_a = 23.45 \sin \frac{360(284 + n_a)}{365} \quad (1)$$

Solar altitude angle

$$\sin \beta = \cos l \cos d_{ia} \cosh + \sin l \sin d_{ia} \quad (2)$$

Solar azimuth angle

$$\cos \phi = \frac{\sin \beta \sin l - \sin d_{ia}}{\cos \beta \cos l} \quad (3)$$

Surface solar Azimuth angle

$$\gamma = \phi - \psi \quad (4)$$

Table 2: Surface Orientations and Azimuths, Measured From South (Ashrae 2001) [16].

Orientation	Surface azimuth Ψ
North	180
North-East	-135 ⁰
East	-90 ⁰
South-East	-45 ⁰
South	0
South-West	45 ⁰
West	90 ⁰
North-West	135 ⁰

Angle of incidence

$$\cos \theta = \cos \beta \cos \gamma \cos k - \sin \beta \sin k \quad (5)$$

At the earth's surface on a clear day solar irradiance at clear atmosphere is given by

$$I_{DN} = \frac{A}{\exp(B/\sin \beta)} \quad (6)$$

Table 3 shows the predicting hourly solar radiation values of every month of 21st of different climatic regions in India. These values are used to find the direct, diffuse and ground reflected radiation values on any surface.

Table 3: Values of constants a, b and c are obtained for predicting hourly solar radiation in india (Ref 17-19)

Day	A (W/m ²)	B	C
Jan. 21	610.000	0.000	0.242
Feb. 21	652.200	0.010	0.249
Mar. 21	667.860	0.036	0.299
Apr. 21	613.350	0.121	0.395
May. 21	558.390	0.200	0.495
Jun. 21	340.710	0.428	1.058
Jul. 21	232.870	0.171	1.611
Aug. 21	240.800	0.148	1.624
Sep. 21	426.210	0.074	0.688
Oct. 21	584.730	0.020	0.366
Nov. 21	616.600	0.008	0.253
Dec. 21	622.520	0.000	0.243

Intensity of direct solar radiation falling on glass

$$I_{DsR} = I_{DN} \cos \theta \quad (7)$$

Diffused solar radiation from the sky falling on glass

$$I_{dsR} = C I_{DN} \frac{1 - \sin k}{2} \quad (8)$$

Reflected radiation is from the ground surface falling on glass

$$I_{GrD} = (C + \sin \beta) I_{DN} \rho_g \frac{1 - \sin k}{2} \quad (9)$$

Total solar radiation falling on glazing window

$$I_T = (I_{DsR} + I_{dsR} + I_{GrD}) \quad (10)$$

Total solar radiation passing through single glazing window

$$I_{TRSGW} = (I_{DsR} + I_{dsR} + I_{GrD}) \cdot \left(T_{sl} + \frac{U}{h_o} A_{sl} \right) \cdot A_g \quad (11)$$

Total solar radiation passing through double glazing window

$$I_{TRDGW} = (I_{DsR} + I_{dsR} + I_{GrD}) \cdot \left(T_{sl} + U \left(\frac{\alpha_i + \alpha_o}{h_o} + \alpha_i X C_g \right) \right) \cdot A_g \quad (12)$$

Where

$$U = 1 / (1/h_o + dx1/K1 + C_g + dx2/K2 + 1/h_i) \quad (13)$$

Where C_g is the thermal resistance of the air gap between two glasses'

$$C_{ag} = 1 / \left(1.25 + \left(2.32X \left(\sqrt{1 + \left(\frac{t_{ag}^2}{w_{ag}^2} \right)} - \frac{t_{ag}}{w_{ag}} \right) \right) \right) \quad (14)$$

Where (C_g, h_i, h_o values are taken from CIBSE standards [22])

RESULTS AND DISCUSSIONS

A. Heat gain into buildings through double window glass units in both summer and winter seasons of Hyderabad climatic region

Figure 2 shows total solar heat gain passing through double glass window units in all eight directions in summer season of Hyderabad climatic region. From the graphs it is clearly observe that in summer season in south orientation of all double glass window units are gaining less heat when compared to other orientations. In summer season DGU7 double window glass unit is gaining less heat 1.97 kW compared with other window glass units of Hyderabad climatic region due to less solar optical properties and minimum solar heat gain coefficient values.

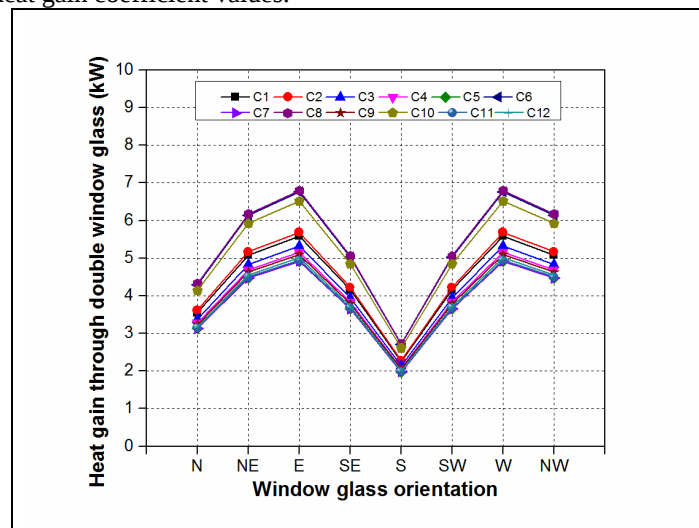


Figure 2: Total heat gain passing through double window glass units from all orientations of Hyderabad climatic region in summer season

Figure 3 shows total solar heat gain passing through double glass window units in all eight directions in winter season of Hyderabad climatic region. From the graphs it is clearly observe that in winter season in south orientation of all double glass window units are gaining more heat when compared to other orientations. In winter season DGU1 double window glass unit is gaining less heat 18.66 kW compared with other window glass units of Hyderabad climatic region due to more solar optical properties and maximum solar heat gain coefficient values.

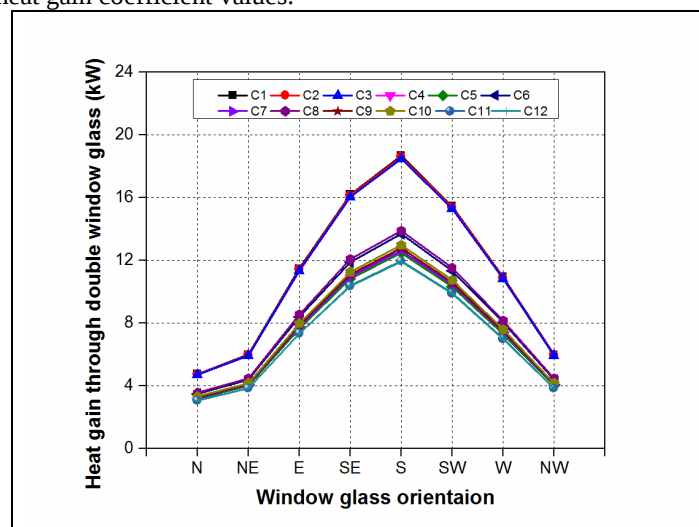


Figure 3: Total heat gain passing through double window glass units from all orientations of Hyderabad climatic region in winter season

B. Cost Analysis Modelling

The net annual cooling and heating cost savings of double window glass combinations in eight orientations were determined to composite climatic region (Hyderabad) was studied. For the computation of net annual cost savings, we followed the procedure [20] as follows

The average daily solar radiation falling on the surface of a place can be computed using Equation (15). In the present study, such computation was made by focusing on two seasons: 1) winter season (consists of September to March) and 2) summer season (consists of April to August). By using an average daily solar radiation and the number of days in each month, the total solar radiation falling on the glass for each season was computed.

The total solar radiation falling on the glass during summer season ($Q_{\text{solar, summer}}$) is given by Eqs. (15).

$$Q_{\text{solar, summer}} = (q_{\text{ds}} \times 30)_{\text{April}} + (q_{\text{ds}} \times 31)_{\text{May}} + (q_{\text{ds}} \times 30)_{\text{June}} + (q_{\text{ds}} \times 31)_{\text{July}} + (q_{\text{ds}} \times 31)_{\text{August}} \quad (15)$$

Where q_{ds} is the daily average solar radiation falling on glass in summer (Direct + Diffuse + Reflected from ground).

The total solar radiation falling on the glass during winter season ($Q_{\text{solar, winter}}$) is given by Eqs. (16).

$$Q_{\text{solar, winter}} = (q_{\text{dw}} \times 30)_{\text{September}} + (q_{\text{dw}} \times 31)_{\text{October}} + (q_{\text{dw}} \times 30)_{\text{November}} + (q_{\text{dw}} \times 31)_{\text{December}} + (q_{\text{dw}} \times 31)_{\text{January}} + (q_{\text{dw}} \times 29)_{\text{February}} + (q_{\text{dw}} \times 31)_{\text{March}} \quad (16)$$

Where q_{dw} is daily average solar radiation falling on glass in winter (Direct + Diffuse + Reflected from ground). Then, the decrease in the annual cooling load and the increase in the annual heating load were computed from Eqs. (17) and (18), respectively. Then decrease in cooling costs, increasing in heating costs and net annual cost savings are determined with following Eqs. (19) (20) and (21)

$$\text{Cooling load decrease} = Q_{\text{solar, summer}} \times A_g \times (\text{SHGC}_{\text{CGW}} - \text{SHGC}_{\text{selected glass}}) \quad (17)$$

$$\text{Heating load Increase} = Q_{\text{solar, winter}} \times A_g \times (\text{SHGC}_{\text{CGW}} - \text{SHGC}_{\text{selected glass}}) \quad (18)$$

In the present study, the unit cost of the electricity and natural gas considered are ₹5.12 kWh and ₹32/therm, respectively. The coefficient of performance of the cooling system and efficiency of the furnace are taken as 2.5 and 0.8, respectively. 1 Therm is equal to 29.31 kWh.

$$\text{Decrease in cooling costs} = (\text{cooling load decrease}) (\text{unit cost of electricity}) / (\text{COP}) \quad (19)$$

$$\text{Increase in heating costs} = (\text{heating load increase}) (\text{unit cost of fuel}) / (\text{Efficiency}) \quad (20)$$

$$\text{The net annual cost savings} = \text{Decrease in cooling costs} - \text{Increase in heating costs} \quad (21)$$

Figure 4 shows the graph between double window glass units and annual cost savings in rupees per year compared with double clear glass window unit in north orientation of Hyderabad climatic region. From the graphs it is clearly shown that double window glass unit DGU11 is saving more cost i.e. 1107.23 (Rupees/year) when compared with all other double window glass units in north orientation.

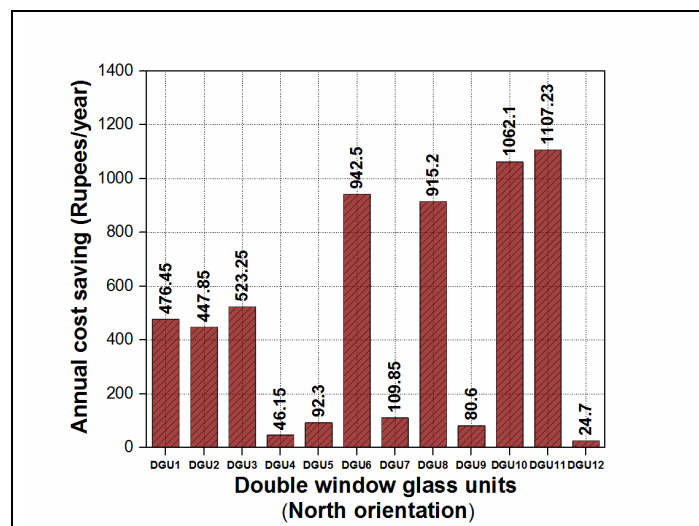


Figure 4: Annual cost savings per year of different double window glass units compared with double clear window glass unit of Hyderabad climatic region in north orientation

Figure 5 shows the graph between double window glass units and annual cost savings in rupees per year compared with double clear glass window unit in northeast orientation of Hyderabad climatic region. From the graphs it is clearly shown that double window glass unit DGU11 is saving more cost i.e. 2013.05 (Rupees/year) when compared with all other double window glass units in northeast orientation.

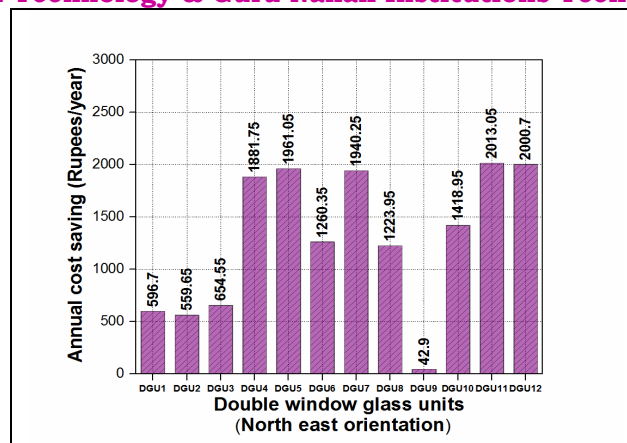


Figure 5: Annual cost savings per year of different double window glass units compared with double clear window glass unit of Hyderabad climatic region in northeast orientation

Figure 6 shows the graph between double window glass units and annual cost savings in rupees per year compared with double clear glass window unit in east orientation of Hyderabad climatic region. From the graphs it is clearly shown that double window glass unit DGU11 is saving more cost i.e. 2691 (Rupees/year) when compared with all other double window glass units in east orientation.

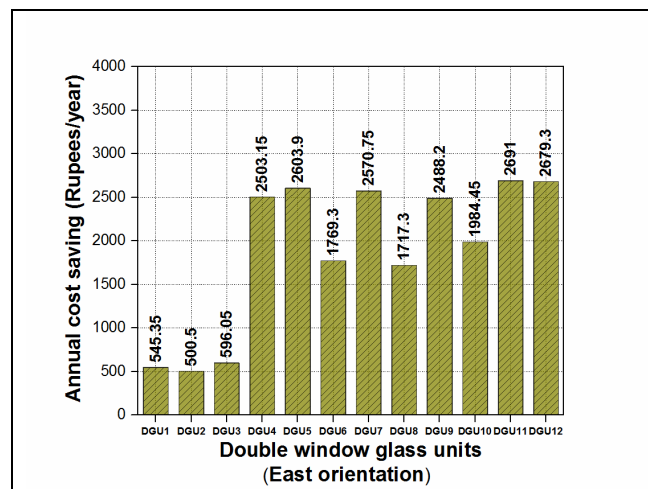


Figure 6: Annual cost savings per year of different double window glass units compared with double clear window glass unit of Hyderabad climatic region in east orientation

Figure 7 shows the graph between double window glass units and annual cost savings in rupees per year compared with double clear glass window unit in southeast orientation of Hyderabad climatic region. From the graphs it is clearly shown that double window glass unit DGU11 is saving more cost i.e. 2874.3 (Rupees/year) when compared with all other double window glass units in southeast orientation.

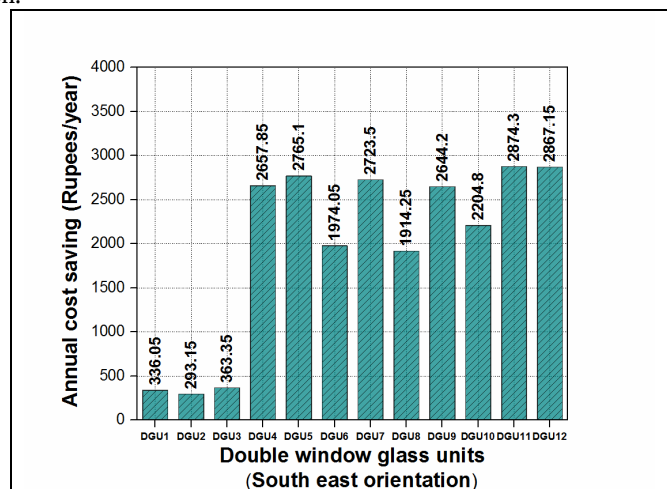


Figure 7: Annual cost savings per year of different double window glass units compared with double clear window glass unit of Hyderabad climatic region in southeast orientation

Figure 8 shows the graph between double window glass units and annual cost savings in rupees per year compared with double clear glass window unit in south orientation of Hyderabad climatic region. From the graphs it is clearly shown that double window glass unit DGU11 is saving more cost i.e. 2668.25 (Rupees/year) when compared with all other double window glass units in south orientation.

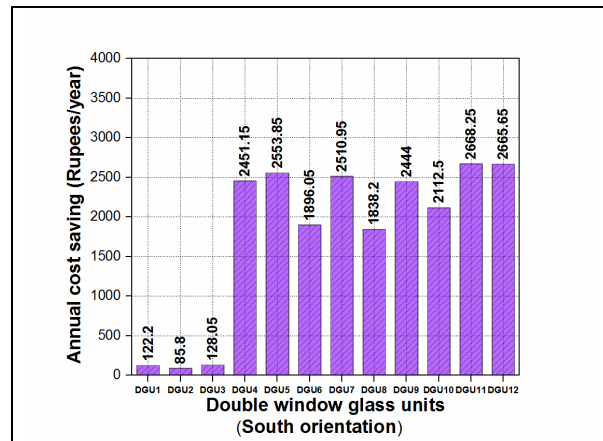


Figure 8: Annual cost savings per year of different double window glass units compared with double clear window glass unit of Hyderabad climatic region in south orientation

Figure 9 shows the graph between double window glass units and annual cost savings in rupees per year compared with double clear glass window unit in southwest orientation of Hyderabad climatic region. From the graphs it is clearly shown that double window glass unit DGU11 is saving more cost i.e. 2776.15 (Rupees/year) when compared with all other double window glass units in southwest orientation.

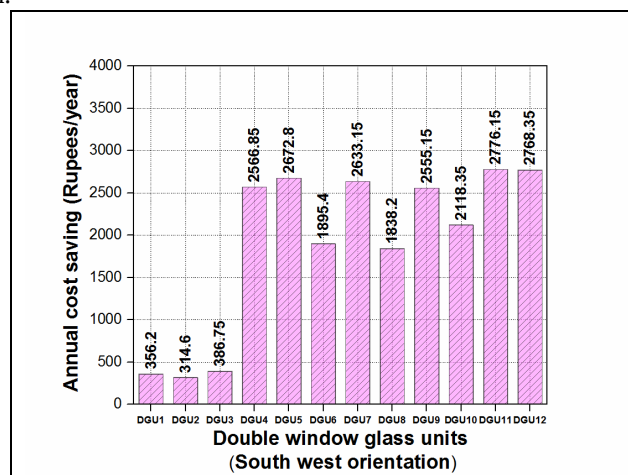


Figure 9: Annual cost savings per year of different double window glass units compared with double clear window glass unit of Hyderabad climatic region in southwest orientation

Figure 10 shows the graph between double window glass units and annual cost savings in rupees per year compared with double clear glass window unit in west orientation of Hyderabad climatic region. From the graphs it is clearly shown that double window glass unit DGU11 is saving more cost i.e. 2621.45 (Rupees/year) when compared with all other double window glass units in west orientation.

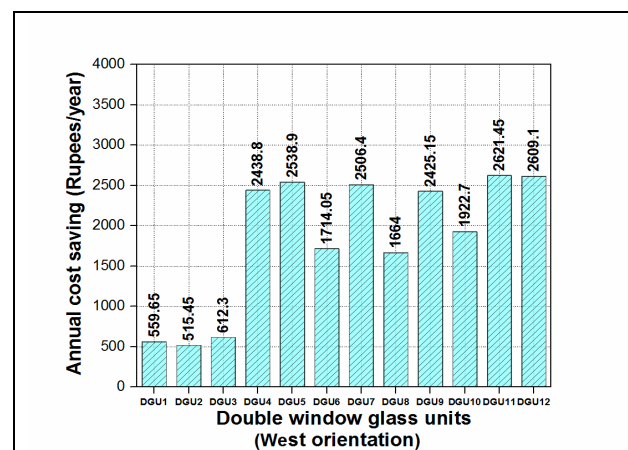


Figure 10: Annual cost savings per year of different double window glass units compared with double clear window glass unit of Hyderabad climatic region in west orientation

Figure 11 shows the graph between double window glass units and annual cost savings in rupees per year compared with double clear glass window unit in northwest orientation of Hyderabad climatic region. From the graphs it is clearly shown that double window glass unit DGU11 is saving more cost i.e. 2013.05 (Rupees/year) when compared with all other double window glass units in northwest orientation.

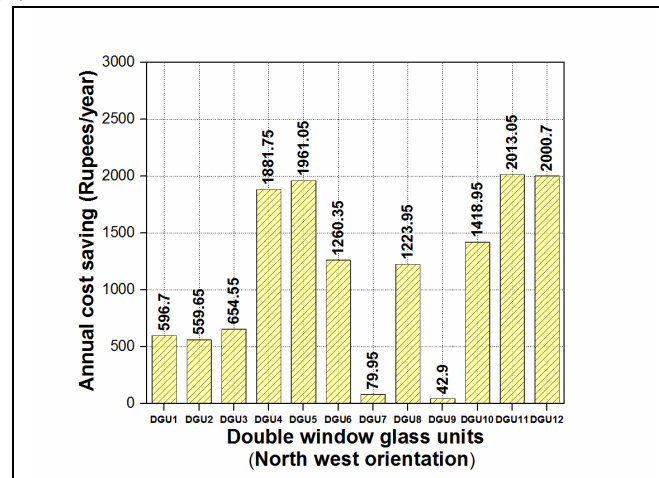


Figure 11: Annual cost savings per year of different double window glass units compared with double clear window glass unit of Hyderabad climatic region in northwest orientation

5. Nomenclature:

A_g	$[m^2]$	Area of the glass
A	$[W/m^2]$	Solar radiation in absence of atmosphere
B	$[-]$	Atmospheric extinction coefficient
C	$[-]$	Sky diffuse constant
C_g	$[m^2]$	Conductance of the air gap
d_a	$[^\circ]$	Declination angle
h	$[^\circ]$	Hour angle
h_i	$[W/m^2K]$	Inside convective heat transfer coefficient
h_o	$[W/m^2K]$	Outside convective heat transfer coefficient
k	$[^\circ]$	Angle of window glass from vertical
l	$[^\circ N^\circ E]$	Latitude
n_a	$[-]$	Number of days
I_{DN}	$[W/m^2]$	Solar radiation at normal incidence
I_{DsR}	$[W/m^2]$	Direct solar radiation from the sun
I_{dsR}	$[W/m^2]$	Diffuse radiation from the sky
I_{GrD}	$[W/m^2]$	Ground reflected radiation
I_T	$[W/m^2]$	Total incident solar radiation
t_{ag}	$[m]$	Thickness of the air gap
w_{ag}	$[m^2]$	Width of the air gap
U	$[W/m^2K]$	Over all heat transfer coefficient
I_{TRSGW}	$[W/m^2]$	Total solar radiation through single glass window
I_{TRDGW}	$[W/m^2]$	Total solar radiation through double glass window
T_{sl}	$[%]$	Solar transmittance
R_{sl}	$[%]$	Solar reflectance
A_{sl}	$[%]$	Solar absorbance
SHGC	$[%]$	Solar heat gain coefficient
Greek letters		
λ	$[nm]$	Wavelength
$\Delta\lambda$	$[nm]$	Wavelength interval
S_λ	$[W/m^2]$	Relative spectral distribution of the solar radiation
$\tau(\lambda)$	$[%]$	Spectral transmission
$\rho(\lambda)$	$[%]$	Spectral reflection
$\alpha(\lambda)$	$[%]$	Spectral absorption
α_i	$[%]$	Solar absorbance of the inside glass
α_o	$[%]$	Solar absorbance of the outside glass

β	$^{\circ}$	Solar altitude angle
γ	$^{\circ}$	Surface solar azimuth angle
θ	$^{\circ}$	Solar incidence angle
Φ	$^{\circ}$	Solar azimuth angle
ρ_g		Ground reflectance factor
Abbreviations		
CGW		Clear glass window
BLGW		Blue glass window
GGW		Green glass window
GrGW		Grey glass window
DCGW		Double clear glass window
SDGW		Selected double glass window

6. Conclusions:

The Present work reveals that the total solar radiation gain into the buildings through different double window glass units from DGU1 to DGU12 of Hyderabad climatic zone in India both summer and winter seasons and cost saving annually were studied. Form the results it is conclude that

- ✓ In summer season from south orientation DGU7 window unit is gain minimum solar radiation passing through it due to its less solar optical properties and in winter season DGU1 window unit is gain maximum solar radiation compared to all other double window glass units compared with other orientations because it is having more solar optical properties.
- ✓ From the annual cost saving graphs from southeast orientation DGU11 is the more energy efficient glass saving 2874.3 Rupees per year, in southwest orientation is saving 2776.15 Rupees per year and in south orientation is saving 2668.25 Rupees per year compared to other orientations, compared to all orientations of composite climatic zone in India.

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