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Prospects of Double Glazed Windows in Buildings: Energy Conservation and Environmental Sustainability

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Abstract The emission of carbon dioxide has great influence on the environment and has a very large part to play in global warming issues. In the building and construction industry, CO_2 is the largest environmental concern. This has prompted research into developing new building systems and technologies, to mitigate the green house gases, which are depleting the ozone layer. Windows are the most vulnerable part of building envelope where the solar energy directly penetrates into the building and the heat gain and loss occurs at this interface. Double-glazed windows are very effective in keeping inside temperature isolated from outside; thereby, saving electrical and thermal energy. In many studies, it has been found that the double glazed windows are more energy efficient than normal Single glazed windows. It has been observed that Double glazed windows are perfect for Indian weather conditions, especially in North India where there are scorching summers and extreme winters. This paper presents an overview of window glazing techniques to optimize the energy savings in buildings. It also discusses the relationship between R-value and double glazed windows and analyses the benefits of the application of double glazed windows for energy conservation in buildings in particular and environmental sustainability as a whole.

Keywords: *double glazed windows, building technology, heat transfer, energy conservation, sustainability*

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1. Introduction

The last three decade has witnessed a severe energy crisis in developing countries especially during summer season primarily due to cooling load requirements of buildings. Increasing consumption of energy has led to environmental pollution resulting in global warming and ozone layer depletion. The energy consumption in buildings is quite high and is expected to further increase because of improving standards of life and increasing world population [1]. According to the World watch Institute, buildings consume about 40% of the world's energy production. As a result, buildings are involved in producing about 40% of the sulfur dioxide and nitrogen oxides that cause acid rain and contribute to smog formation. Building energy use also produces 33% of all annual carbon dioxide emissions, significantly contributing to the climate changes brought about by the accumulation of this heat-trapping gas [2]. In India, the building sector represents about 33% of total electricity consumption, with commercial sector accounting for 8% and 25 % respectively [3]. Therefore, the use of non-renewable energy has also become important in recent years.

Windows are the main part of the building in terms of thermal dissipation, one way to optimize energy consumption and prevent the completion of fossil energy is to design types of windows that waste less energy than does the common kind [4]. A double-glazed window has two panes of glass set into a frame to create two layers of glass with an intervening gas or air pocket to better insulate a room. This window is sometimes referred to as a double-glazed window (Figure 1). An insulating glass unit (IGU) is a type of double-paned (or multi-paned) window [5]. A single-paned window with one sheet of glass is a style of window that served homes for centuries. It's long been known that two exterior surfaces with an internal air pocket provide better insulation than one surface only. But it wasn't until the 1950s that double-paned windows were introduced commercially and then later become common in homes around the 1970s. Double-paned windows are now standard for both new construction and replacement windows. Triple-paned windows are sometimes recommended in environments with harsh weather for maximum insulation [6]. An insulated glass unit (IGU) combines multiple glass panes into a single window system. Most IGUs are double glazed (two panes of glass) with three panes (triple glazing) or more becoming more common due to higher energy costs. The panes of glass in IGUs are separated by a spacer and a still layer of air or gas. The glass is then fitted into window frames, which is made wider to accommodate the two panes [7].

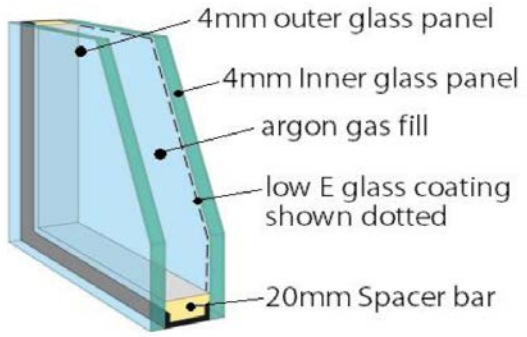

Figure 1. A thermally efficient Double Glazed Window

2. Research Methodology

In this paper qualitative research method has been used. The systematic literature review has been explored through internet and secondary data from relevant published academic literature from journals articles and research papers. The data collection in the qualitative research are the data that comes from a number of case studies that are described descriptively and are supported by illustrations and photographs to reinforce the arguments put forward. The basic concepts and backgrounds are investigated through literature and on-line media, observations to work for qualitative analysis conducted for the impact of double glazed window with reference to climatic design and energy efficiency in buildings. This paper also discusses the relationship between R-value and double glazed windows and analyses the benefits of the application of double glazed windows for energy conservation in buildings

3. Literature Review

Several studies in this field have been performed to measure how to reduce energy consumption in buildings, such as control of air conditioning, sunlight, glass coating, orientation, insulation et. [8]. A number of detailed reviews have been conducted on windows and their overall behavior (when opened or closed) such as their impact on thermal comfort of residents [9], energy consumption by letting the daylight enter into living or working places, which helps to reduce energy consumption by 50-80% [10,11] and finally the effect of chamber number on reducing energy consumption in buildings. In a study, different types of glass and their walls and also difference air type used between the walls were studied. The studied windows included single-glazed windows, 3 mm double glazed with 13 mm air, 3 mm double glazed windows with 13 mm Oregon, double glazed windows coated with light controller with 13 mm air and finally double glazed windows coated with light controller with 13 mm Oregon. Finally, the best type was also introduced [12]. In another study, eight types of double-glazed windows were compared including 6 mm clear windows on both side filled with 12 mm air, 6 mm clear windows on one side and on the other side 6 mm clear window coated with light controller filled with 12 mm air, 6 mm blue window on one side and 6 mm transparent window on the other side filled with 12 mm air [13]. Another research has shown that for a specific climate, energy loss from the pop-up windows is directly related to the percentage surface but not to the direction of windows. However, in terms of solar energy absorption, windows opening towards south do better than those opening towards south [14]. In addition, the influence of smart glasses to increase energy efficiency was noted. Smart windows are made in such a way that turns dark and light as sun light increases and decreases, respectively and as such causes thermal comfort of residents [15].

4. Characteristic Features of Double Glazed Windows

4.1. Spacing between the Glass Panes

The typical space between panes ranges from 6mm to 20mm. A minimum space of 12mm is recommended for optimum thermal performance. Alternatively, for good acoustic control and to reduce low frequency noise such as traffic and aircraft, the optimum air gap recommended is 150mm or over. Note that such large gaps allow convection to occur between the panes and reduce insulating performance. Because the space between the panes in double glazed windows is fully sealed, it acts as an insulator, limiting the transfer of cold air coming into your home. Thermal and acoustic performance can also be increased when gas fills this space. The most popular gas used is argon which has low conductivity properties to improve insulation. Double glazed units include a spacer which is a metal or polymer strip that separates the two panes of glass. Typically, spacers contain a desiccant (drying agent) to remove moisture trapped in the air space [7].

4.2. Glass Typology

A wide range of different glass types, such as low-e and laminated, can be used in double glazing units to further increase energy efficiency and noise control. Low-e glass will further reduce the amount of heat escaping while thicker laminated panes disrupt sounds waves to improve acoustic performance [7].

4.3. Common Problems Associated with Double Glazed Windows

Windows need to be considered as a whole unit. The framing material you choose to complement your glass may enhance its performance or in some cases reduce its energy efficient properties. Standard aluminium window frames readily conduct heat and cold and if not thermally enhanced, may eliminate any benefit from installing expensive double glazing. How well the cavity is sealed and the type of spacer used is also an important factor to consider. If the double glazed unit is not sealed properly or if the spacer does not contain adequate desiccant, it can reduce performance and condensation will appear on cold surfaces [7].

5. Comparison of Single Glazed Windows with Double Glazed Windows

A single glazed window is made using one pane of glass so this means the only thing between your home and the outside temperature is a single pane of glass, and this won't give much insulation. A single glazed window is not very efficient when it comes to heat loss or gain. The double glazed windows use two panes of glass with a vacuumed air gap between them which creates an insulated barrier (Figure 2). Double glazed glass may be laminated or tinted, but otherwise is similar in appearance to a single glazed window. If energy efficiency and insulation against temperature and noise are what you're looking for, double glazed windows are definitely the better option [16].

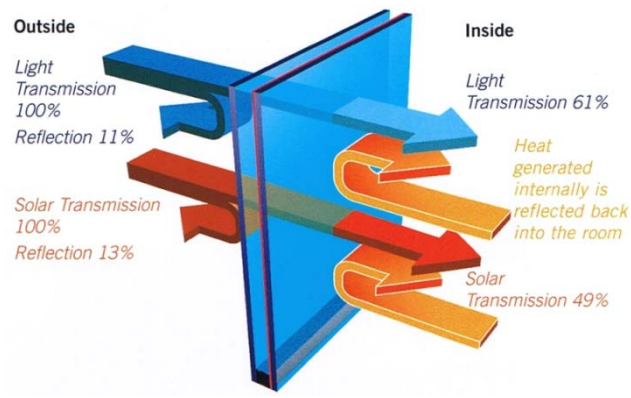

Figure 2. Functioning of 4 mm solar neutral tough and 4 mm elite tough

6. Relationship between R-Value and Double Glazed Windows

The R-values are given to different products to help consumers understand the expected thermal resistance of the material. Though the insulating value of a window can be measured in a number of different ways, the most common is the R-value system. The R-value measures the material's resistance to energy transfer. The higher the R-value number, the greater the resistance and the higher the insulating value of the window. Some windows have a special low-E (low emissivity) insulating film on the glass that bumps up the R-value. The film adds another way to reflect heat energy into or out of the building (Table 1). The thin transparent coatings on the window are comprised of a metal oxide or silver applied to one or more of the glass surfaces to further reduce the energy transmission [6]. A low-E glaze coating on a window reflects ultraviolet (UV) rays to better protect furniture and artwork from fading.

Table 1. R-Value of Single, Double and Triple Glazed windows

No. of Panes	Air/Gas	Coating	R-Value
1	None	None	0.9
2	Filled with 1/2-inch of air	None	2.084
3	Filled with 1/2-inch of air	None	3.226
2	Filled with argon	Low-E (1 coating)	3.846
3	Filled with argon	Low-E (1 coating)	5.433

7. Comparative Analysis of Wall R-Values with Window R-Values

With window R-values reaching nearly 5.5, how does that compare to wall system R-values? A standard two-by-four stud wall with batt insulation and wallboard and wood siding has an R-value of R-12 to R-15, which is considered to be on the lower end compared to other types of materials and sidings. Window manufacturers continue to develop technologies that will allow windows to more closely approach the higher R-value of the walls themselves. Still, walls will always provide better energy efficiency than windows [6].

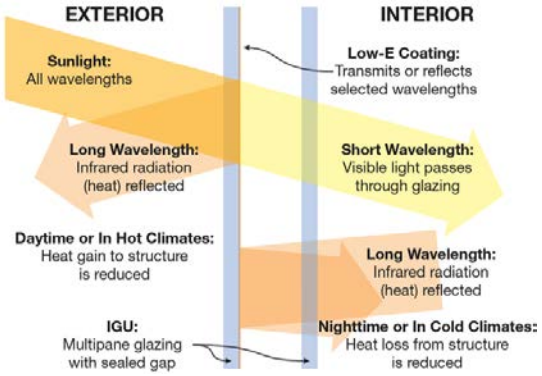

Figure 3. Working performance of double glazed window

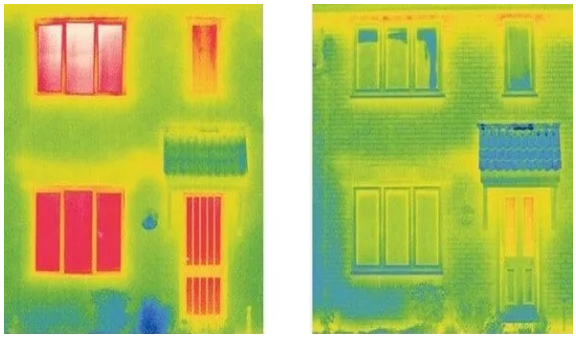

Figure 4. Thermal imaging comparison of single and double glazed window using building simulation software

Figure 3 shows the working performance of double glazed window. The primary purpose of double glazing is to save energy. A calculation system called the U Value is used to measure energy efficiency. That is, it shows how effectively a window (or another part of a structure) retains heat; in other words, the amount of heat energy it gains or losses. The lower the U value, the better: Obviously, the more energy efficient it is, the more energy it saves. For example, a typical U value for single glazing might be 5.6. With double glazing, the U value may vary, from about 1.5 to 2.8, depending upon the characteristics of the glass used, and upon whether the cavity between the panes of glass is filled with argon gas or with air. Figure 4 shows the thermal imaging comparison of single and double glazed window using building simulation software.

Energy efficiency of windows, whether double or single glazed, is considerably affected by the type and thickness of glass used. Low-e or low emissivity glass has a coating that reduces the amount of ultraviolet or infrared light that passes through it, without blocking the passage of visible

light. Reducing the emissivity improves the insulating ability of the glass. Thus a double-glazed window made with low-e glass will have a lower U value than one made of uncoated glass and will provide an additional reduction in the cost of heating or cooling the building, and also a greater reduction in the building's carbon footprint. Double glazing greatly reduces the amount of heat transmitted through a building's windows, by 20-25% and perhaps as much as 50%. This means that less fuel will be needed to heat or cool the building, saving money for the owner as well as reducing the building's carbon footprint, a very desirable effect [17]. Figure 5 shows the double-glazed windows in ITC Green Centre at Gurugram, India.

Figure 5. Double glazed windows in ITC Green Centre at Gurugram, India

8. Measures to Improve the Efficiency of Windows

No matter how well-designed they might be, double- and triple-paned windows can always be helped along to eliminate energy loss. Some measures, which can help in improving the efficiency of the double glazed windows, are summarized as below [6].

8.1. Using Thermal Curtains

Thick thermal curtains drawn across the windows at night significantly raise the window's overall R-value.

8.2. Adding Window Insulating Films

A thin clear layer of plastic film can be applied to the window trim with adhesive. Application of heat from a hairdryer will tighten the film.

8.3. Weatherproofing

Older windows may have hairline cracks or they are beginning to open up around the framing. Those problems let cold air enter the home. Using an exterior-grade silicone caulk can close up these leaks.

8.4. Replacing Foggy Windows

Windows that are foggy between the two panes of glass have lost their seals and the gas has leaked out. It is usually best to replace the entire window to regain the energy efficiency in your room.

8.5. Covering the Windows

Windows in disused or rarely used areas waste energy, with little benefit to show for it. When the window has little value, it should be considered filling it in with an insulated wall system.

9. Benefits of Double Glazed Windows

Double glazed windows are an ideal energy efficient choice with the added benefit of minimizing noise. The sealed air gap between the two panes acts as an added layer of insulation. This added thermal resistance reduces the amount of heat escaping in winter and keeps your home at a more comfortable temperature. Double glazing has the reverse effect in summer, preventing unwanted heat from coming into the home. This extra insulation lessens your reliance on artificial heaters and air conditioners and can ultimately reduce your energy costs.

When you are close to a window, your comfort is also affected by the temperature of the glass. With double glazing it's harder for the unwanted outside temperature to transfer through, leaving the inside pane close to room temperature. Double glazing also reduces condensation which can result in the unhealthy formation of mould. Sealed double glazing is effective at reducing medium to high frequency noise such as the human voice. A difference in glass thickness between the inner and outer panes will improve sound reduction even further [7]. Double glazed windows are considered a safer option when compared to standard single pane windows. Two sheets of glass are a lot harder to break than one and for even greater security you can specify toughened or laminated glass. Some prominent benefits are summarized as below [16].

9.1. Increased Thermal Efficiency

Significantly reducing heat loss and gain means it is easier to maintain the temperature inside the building. The double glazed windows are more effective insulators than single glazed windows, as they help to stabilize the indoor temperature and provide insulation from the full effects of temperature extremes. Reducing heat loss and gain will keep your home cooler in summer and warmer in winter.

9.2. Improved Energy Efficiency and Power Bill Savings

Double Glazing will significantly reduce the costs of heating and cooling and will help improve the energy rating assessment of your home. Almost half the energy used in Australian homes goes to powering heating and cooling systems, double glazed windows will reduce the need for you to crank up the air conditioner or heater levels to reach a comfortable temperature so you end up using less electricity. The high efficiency of double glazed windows can reduce your heat loss or gain by up to 30% when compared to single glazed windows, significantly reducing your electricity bill.

9.3. Reduced Noise Transmission

Double glazing can help achieve a major reduction in the level of noise that enters your home. The space between the two glass panes in double glazed windows doesn't just insulate from temperature extremes, it also provides great insulation from external noises. With double glazing, the space between the glass panels absorbs more sound energy. This is especially helpful for those who live near airports, have neighbours with noisy pets, or reside in the busiest areas in the city.

9.4. Reduced Condensation

Many homes have a problem with condensation, especially in bathrooms. Condensation occurs when the moist air inside the home is exposed to a cooler surface such as a single glazed window. While condensation is mainly just an annoyance, it does have the potential to cause serious problems, such as mould. Double glazed windows help reduce the likelihood of condensation by removing its main cause, a cold window. The interior glass pane stays close to room temperature, reducing the condensation risk.

9.5. Increased Security and Safety

Double glazing of windows can improve both safety and security in the building. The thickness means they are harder to break than normal windows so they are much safer for small children, and also make break-ins a whole lot harder for would-be thieves. Double glazed windows have many advantages over single glazed windows [16].

10. Material Selection Criteria for Window Frames

Table 2 shows the different types of materials for the window frames of Double glazed windows

Table 2. Different types of materials for the window frames of Double glazed window

Characteristics	Wood	Aluminium	Steel uPVC	Steel uPVC
Cost	Costly	Costly	Cheap	Cheap
Safety	Good	Fair	Good	Excellent
Insulation	Fair	Fair	Poor	Excellent
Corrosion	Good	Fair	Poor	Excellent
Durability	Good	Fair	Poor	Excellent
Thermal Conductivity	Nil	High	High	Nil
Surface Finishing	Good	Good	Poor	Excellent

11. Advantages of Double Glazed Windows

There are numerous advantages of double glazed windows [18]. They are summarized as below:

11.1. Saving in Energy Bills

Double glazing or insulated glazing uses two panes of glass, thereby significantly reducing the amount of heat that enters or exits the building. As a result, the building is cooler during summer and warmer during winter. In effect, the applications of double glazed windows use less of air conditioner and heaters to reach a comfortable temperature, and that ends up using less electricity.

11.2. Boosts Soundproofing

Because the windows are thicker; they are more effective in reducing the noise that can enter the building. This is especially helpful for those who live near airports, have neighbors with noisy pets, or reside in the busiest areas in the city.

11.3. Improves Security

Windows with double glazing are tougher to break and are more difficult to be forcefully opened from the outside. This increases the safety level of your house and burglars will be discouraged from breaking in.

11.4. Reduce the Interior Fading

When furniture and décor are exposed to too much heat, they tend to wear and damage more easily. With less heat making its way into your interiors, your furnishings are better protected.

12. Disadvantages of Double Glazed Windows

There are few disadvantages of double glazed windows [19]. They are summarized as below:

12.1. Traps Heat

This may be an advantage during winter, but during summer this can be a problem. You do have the option to tint your windows, but this will be an additional cost.

12.2. Cannot be Repaired

If the seal of your double glazed windows isn't airtight, condensation can appear between the panes. And since you the windows are already sealed, you can't pull them apart to fix the problem. Instead, you have to replace the whole window and end up paying more.

12.3. Not for Buildings with Older Architectural Styles

A house with an older architectural style might look mismatched if it has your typical modern double glazed windows. But there are some double glazing companies that specialize in making double glazed windows for older homes or retrofitting existing windows, so this may not be too much of a problem.

12.4. Initial Cost is More

Obviously, since there are two panes of glass instead of just one, double glazed windows cost more. But if you

consider the amount of savings you get in the long run and the other benefits too, they may just be a worthwhile investment.

13. Conclusions

Saving fossil fuels and the use of clean sources of energy lead to reduce in building operating costs, protect the environment and people's health. Considering the shortage of fossil fuels, if we consider design criteria based on energy saving strategies, installing the double-glazed windows would be definitely reasonable as these windows save up to 50% in total load of the building it means having more fossil fuels for longer years. In a study, the results indicated that double-glazed windows could save 50% of entire building loads, 0.2% on power consumption, 16.2% on gas and 12.4% on overall households' energy consumption. However, it cannot be ignored that these windows are not really compatible with family economy [20].

In order to achieve the green building concept, it has been recommended to use double glazed windows with uPVC frame and low U value glass (Low E glass). The U value of doubled glazed window is 3.182W/m^2k. The use of VLT (Visibility Light Transmittance) glass should be considered [21]. The doubled glazed windows should be used in the direction of south and south-west side in order to receive maximum solar heat in winters. There may be also further scope of more energy saving by applying triple glazed windows in place of double glazed windows [22]. In today's architecture, it is now essential for architects and building engineers to incorporate these green technologies in buildings as an inherent part of design and architectural expression and they should be included conceptually from the outset [23]. Incorporation of these building technologies would certainly reduce our dependency on artificial means for thermal comfort and minimize the environmental problems due to excessive consumption of energy and other natural resources and hence will evolve a built form, which will be more climate responsive, more sustainable and more environmental friendly of tomorrow [24].

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