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THE EFFECTS OF LOW-E WINDOW GLASS OF BUILDING ON REDUCING CO2 AND ENERGY SAVING IN DUHOK, IRAQ

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ABSTRACT

Nowadays Energy is the main crises in the world due to high demand load of energy for all sector of modern live using smart materials such as Low-E Window glass is most suitable solution for rationalizing energy and reducing the amount of Co2 emission into our environment. Low-E Window can be a large portion of solution since it has a great role in consuming energy and directly related to the amount of Co2 emission. In this research measurement were taken to compare the amount energy consumed in Low-E glass window with ordinary glass. The result showed there is a huge different between them. The result showed that the total difference in solar heat gain was 6246.12W which save 22798.33 kWh/year. The estimated reduction in CO2 was 16186.81 kg.CO2 /year or 16.186 ton. Co2/ year in the building room case in Duhok, Iraq.

KEYWORDS: Low-E Glass, Windows, Emissivity, Thermal comfort and Solar heat gain.

List Of Abbreviations

Abbreviations	Full Form	Abbreviations	Full Form
CT	Coatings	GS	Glass
MSVD	Magnetron Sputter Vacuum Deposition	GHS	Greenhouse
		IGU	Insulated Glass Units
ENC	Energy Consumption	Low- E	Low- Emissivity
EMS	Emissivity	SMT	Smart Windows

1. INTRODUCTION

The global temperature is rising up because of the greenhouse (GHS) effect. There remains little doubt that the building sector is one of the contributors in emitting CO2 to the global atmosphere. This has led

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to a closer examination of energy conservation strategies. Generally, one third of global CO2 emissions, is attributed to the building, which emphasizes the important need for energy savings in consumption in buildings [1].

Every day we loss a large amount of energy. Such energy loss can be minimized by improving existing buildings and striving for smart solutions and energy efficient materials when constructing new houses. The role of window glazing of Low- Emissivity (EMS) on daylighting and energy saving in buildings is very important & substantial.

It is known that the importance of reducing global energy consumption [ENC] cannot be over emphasized due to the finite nature of energy resources and extensive environmental effects such as global warming and climate change [2]. Therefore, considerable attention has justifiably been directed towards energy savings in buildings as they account for up to 40% of total ENC in developed countries. [3].

Both Iraq and Kurdistan of Iraq do suffer from a growing shortage of electrical energy because of an increasing rise in demand. Electrical power generation stations fail to comply with the demand for power because of limited production capabilities and numerous defects. Electric energy that comes from electrical power generation stations is not enough to comply with the demand. Day by day the issue of the electricity crisis, and the alternative solution is using the natural gas and thousands of generators as an energy source in the region. So, every year billion of USD are spending on electricity in the region. One of solution of this issue is using other kind of energies such as renewable energy, or using window films of Low- Emissivity (EMS) [of Low-E] to reduce ENC and increase the performance of the building [i.e. energy savings in buildings]. Figure (1.) illustrated the demand electricity loud and supplied for Duhok governorate at period (1995-2019) for annual values, we can see that there is no sufficient supplied loud in any year over period (2004 to 2019).

1.1 -Theoretical Background About Smart Materials

The phrase "smart windows"[SMT] came into usage because the architect was required to choose the greatest energy-saving components to minimize ENC while also supplying the building with transparency and lighting. The amount of thermal energy that travels through the windows can be reduced by controlling thermal permeability & Control of thermal conductivity. By altering the thermal conductivity of windows, a building can achieve a balance between the interior and the outside by affecting its overall thermal conductivity. In the summer, this lessens the amount of radiation transmitted, and in the winter, it helps Glass (GS) transparency is gradually increased to control eyesight. The diagram shows the general structure of a double silver low-E CT [see fig.2.] [4].

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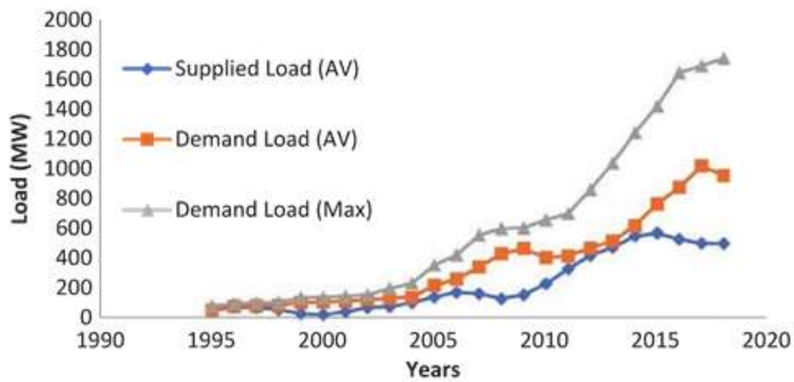

Figure (1) Electricity annual demand louds and supplied louds for Duhok governorate during the period (1995-2019).

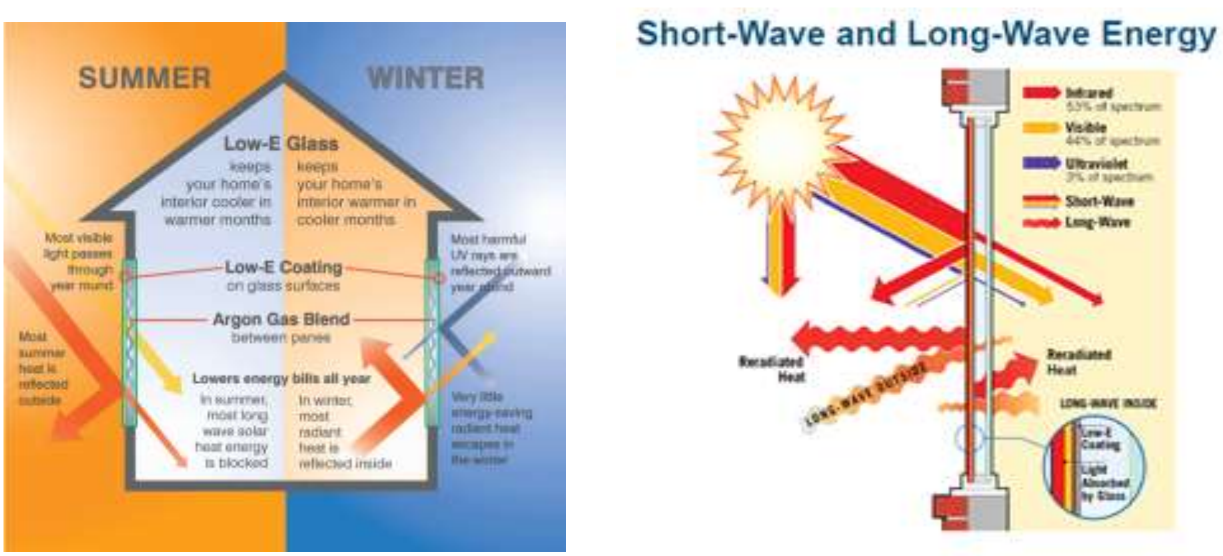

FIG.2. - Low E glass, has a coating applied to it, making windows substantially more energy efficient (a). Low E glass designed to keep in infrared light for colder climates (b). [4].

It is known that Glass (GS) is one of the most common and versatile building materials in use today. This is partly may be due to continuous improvement in solar and thermal performance. One way to obtain this performance is by using low-emission passive coatings and solar control. Low emission passive coated GS is widely used nowadays. So optical and thermal GS performance improvement significantly. Low-E

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CT denote for low emissivity CT. It is a thin layer of CT that is applied to the surface of the GS to improve optical and thermal performance. The nominal "low-E" CT does not represent the optical properties of low-E CT. Low-E coatings are more appropriately understood as "low-e optical filtering" CT. [4]

Emissivity (EMS) is the ratio of heat emitted from a given material compared to that from a blackbody. Or, the ratio of the thermal energy radiated from a material's surface to the thermal energy radiated from a blackbody (a perfect emitter), at the same temperature and wavelength, under the same conditions. A blackbody would have an EMS of 100% and a perfect reflector would have zero value. The EMS of the surface of a material is its effectiveness in emitting energy as thermal radiation. The lower an object's EMS, the better it is at reflecting away heat. Low-e CT works in all seasons and in all climates, always working to slow the transfer of heat. In cold seasons or climates, it reflects heat back into the interior of the building; in warm seasons or climates, it reflects heat back to the outside of the building [5] [see fig.2.]. Emissivity = 1 for an ideal black body surface. And Emissivity = 0 for an ideal white body surface [6]. It is also known that When the EMS of a window CT is low, the window CT is called low-E CT.

Pyrolytic low-E CT for single-pane glass normally can achieve around 20% EMS, while silver-based sputter CT can achieve 8–2% EMS. Reduced EMS improves a window's insulating properties. Uncoated clear GS has an EMS of 0.84 while a solar control low-E GS might have an EMS as low as 0.02. [7].

There are many factors that may influence the low-e coating selection and placement strategy. These include: a- Heating or Cooling dominated climate. b- Energy performance. c- Building codes. d- Project HVAC requirements. e- Aesthetic objectives. f- Site characteristics. g- Additional design factors.

Types of Low Emissivity Coating

There are 2 main types of low emissivity CT, namely hard low emissivity CT and soft low emissivity CT.
i- Soft-Coat –low-E application happens after the glass is made. The soft coat is more efficient at reflecting heat energy, but also more delicate, applied to GS off-line in a vacuum chamber at room temperature and sealed within an insulated glass units [IGU].

Modern low-e coatings on glass are composed of 12 or more layers of metals and ceramics in a 300 nanometer (0.0003 mm) thick coating, with some layers measuring only one nanometer (one billionth of a meter) in thickness. [7]. Low E glass has one coating, Low E2 has two, and Low E3 has three, etc.

ii- Hard-Coat – which is fused to the surface of the GS while it's being produced. A hard-coat low-E application is done when the glass is in a molten state. The process results in a durable coating that can be used on storm doors and windows.

Both types of low-E Glass, passive and solar control, are produced by two primary production methods – pyrolytic, or "hard coat", and Magnetron Sputter Vacuum Deposition (MSVD), or "soft coat". In the pyrolytic process, the coating is applied to the glass ribbon while it is being produced on the float line. The coating then "fuses" to the hot glass surface, creating a strong bond that is very durable for glass processing during fabrication. Finally, the glass is cut into stock sheets of various sizes for shipment to fabricators. In the MSVD process, the coating is applied off-line to pre-cut glass in a vacuum chamber at room temperature. [6].

Benefits of Energy-Efficient Glass

1-Low infrared heat gain/transfer.2-High natural visible light transmittance. 3-Less artificial lighting. 4-Reduction of long-wave-heat gain/loss. 5-Increased comfort/productivity

1.2 Literature Review

The focus of world attention on environmental issues in recent years has stimulated various responses in many countries. This has led to a closer examination of energy conservation strategies. Generally, one third of global CO2 emissions, is attributed to the building, which emphasizes the important need for energy savings in consumption in buildings [8].

The environmental benefits and the reduction of (CO2) due to saving in electrical energy by window film were calculated and presented by Yousif 2015 [9], and Yousif et al 2013) [10]. Yousif, and Saeed [11].

Last decades many attempts were made to develop building's design and materials to reduce ENC. The invention of smart materials (Low-E glass) and it uses in building increased to develop structural efficiency and reduce ENC. And many developed & developing countries have established regulations aimed at the reduction of building ENC by significantly improving the energy efficiency of buildings [12-14].

Mohamed, 2017 [15]. studied the link between architecture and new materials science, including smart materials (SMT) that have can feel the environment, such as living systems with an analytical study of types of SMT. Many research conclude that materials are a functional element with a method that can be formally adopted and effective at each stage of the design and the use of these materials enhances the sustainability of buildings, so an integrated approach was proposed towards a new model of innovative architectural design [15-18].

Saidam, et.al, 2019] [19]. investigated the impact of the use of SMT in the facades of contemporary buildings through the identification of SMT, types, and importance in architecture and analysis of a series of facades of contemporary buildings and their environmental and technological effects.

Taha, & Hassan examined the effect of smart low emission GS material on reducing energy consumption for office building in hot arid climate [20]

New materials have been developed that offer superior performance in glazing applications, compared to conventional sheets of GS. According to the International Window Film Association (IWFA), a pane of normal clear GS reflects about 6% of solar radiation, absorbs 5% and transmits the remaining amount. By using these new advanced glazing materials, the above values of reflect and absorb could be controlled. Some examples of these new advanced glazing materials include, transparent insulation materials, such as coated GS, aero-gels & honeycombs electro-chromic materials, and angularly- selective materials [21].

Dussault, et al. [22] examined the energy savings potential of incorporating SMW technologies on a double-glazed window pane of a typical low thermal mass office building in Quebec, Canada.

Yin, et al. [23] investigated the potential of solar window films to reduce the energy consumption of buildings in different climates.

Also, Li, et al. [24]; studied the effect of window films on building ENC.

1.3 Research Objectives

There are many problems effect on architectural design and creation, the progressive field of SMT may help in Application of proper SMT in architecture can influence operation and maintenance of the environment. Applying SMT in architecture to achieve new forms, because refers to important issues such as SMT and regarding the lack of using environmental pollutants.

This research aims to study the Effect of Low-E Glass on reducing energy consumption for building in Iraq-Duhok. The development and implementation of such Low-e glass windows for use in buildings in Duhok City is the primary goal of the research that has been outlined. The aim was reached through the following objectives:

- To comprehend the behavior of Low-E Glass windows.
- To highlight a few impacts of occupant behavior on comfort and energy consumption.
- To demonstrate how building style affects occupant behavior and energy use.

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2. Calculations Based on Theory

The main contributor to building exterior cooling load and the most crucial factor in determining overall thermal transfer values is solar heat gain through windows. The heat gain in a structure also comes from a variety of other sources, including the walls, roof, floor, electrical household equipment, and occupants etc. An approximated equation was used by Al-Naser [25] to model the solar heat gain in a car after exposure for time interval, t. That equation has been modified here in order to fit the case of solar heat gain G1 for a room in a building:

$$G1 \cong \tau\, S\, G_S + \{\rho_{air}\, R_i\, C_{air}\, (\Delta tp.)\} / t + \{\Sigma\, (m_i\, C_i)\}\Delta tp. / t + \varepsilon\, \sigma\, A_i\, (tp._f^4 - tp._i^4) + Ao + a + f\, (tp._f - tp._i) / \Sigma\, (TD_i / TC_i) \quad \ldots\ldots (1)$$

Where:

τ is the glass transmissivity. S is the solar radiation (W/m^2), **G_S** is area of the glass windows (m^2), ρ_{air} is inside room air density (kg/m^3), R_i is the volume of the room interior (m^3), ε is the emissivity. $\Delta tp.$ is the difference between outside and inside room air temperature. C_{air} is the air specific heat capacity (J/kg K). m_i is mass of the heat generating appliances (kg). C_i is their compound specific heat capacity (J/kg K). σ (= 5.6697 x 10^{-8} W/m^{2}K^4) is the Stefan-Boltzmann constant. Ai is the room interior area. $tp._f$ is furniture final temperature. $tp._i$ is furniture initial temperature (K). Ao + a + f is the door, walls and roof area (m^2). $tp._f$ - $tp._i$ is the temperature difference between the door exterior and door interior. TDi is the total thickness of the door, wall and roof (m). TC is the thermal conductivity (W/m.^{o}C).

When Low-E Glass window used, it will act to reduce the solar radiation that will enter the room through the window. This will cause the solar heat gain of the building or room to be reduced to some lower value G2, and the difference in solar heat gain ΔG will be given by:

$$\Delta G = G1 - G2 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots. (2)$$

Eq. (2) was used to calculate the reduction in the solar heat gain in the two cases ordinary glass window and Low-E Glass window for experimental and generalized case.

3. METHODOLOGY

Based on the objective of this study, we determined the application of smart materials in construction industry and architecture design, using analytical-descriptive methods, to investigates low-E Glass material in construction or a building house, and reducing energy consumption, then studies their effect on sustainable environment and reduction of pollution.

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The following Physical properties have been measured; transmittance, thermal images of the window GS as well as the low-E Coating GS, temperature, the solar radiation, and light intensity outside and inside 2 rooms in a building house, with low-E Coating GS and without low-E Coating GS.

The transmittance of the window glass as well as the low-E Coating GS have been measured by using the light- meter. The selected wavelengths were between 300 nm to 900 nm (using color filter). The solar radiation for both inside and outside of 2 rooms were measured by Voltcraft PL-110SM Solar Radiation Measuring Instrument. Its measurement ranged from 0 - 1999 W/m². The temperature of the outdoor/indoor was measured by ordinary thermometer.

thermal images were got through the using the dedicated FLIR Camera.

Case Study-1 for Small Chamber

In a small chamber of dimensions (15 cm * 15 cm * 15 cm) and each with window (15 cm * 15 cm). The picture of the small chamber is shown in Figure1

Figure-3- Using a small chamber for test.

Case Study-2 for Two Rooms

For generalized case, the study was carried out in two rooms (with dimensions: Width= 4 m, height= 3 m, length=4.5 m) in a house in center of Duhok city in north of Iraq.

The area of each window is (3.2 m *2.5 m) of Low-E window glass of one room and the other with ordinary window glass the building house consists of 2 floors. The picture of the building house is shown in Figure 4. Experimental calculation has been calculated for two rooms in order to know solar heat gain in two rooms.

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Figure 4 testing two rooms in a building house.

4. RESULTS AND DISCUSSION

4.1 Thermal Vision

Case Study-1 for the Small Chamber-1

Figure 5 shows Thermal Vision or thermal photo for both Low-E Glass & ordinary glass. When The max. temperature was 49.4 0C. This show the ability of low-E Glass vs ordinary glass to absorb heat, and navigate between multiple viewing modes and color palettes.

Case Study-2 for Two Rooms

Figure 6 shows Thermal Vision or thermal photo for both Inside room & outside room of Low-E Glass. When The max. temperature was 31.8 0C for Inside room. The max. temperature was 35.6 0C for out-side room. This shows the ability of low-E Glass to absorb heat, and navigate between multiple viewing modes and color palettes depending on temperature.

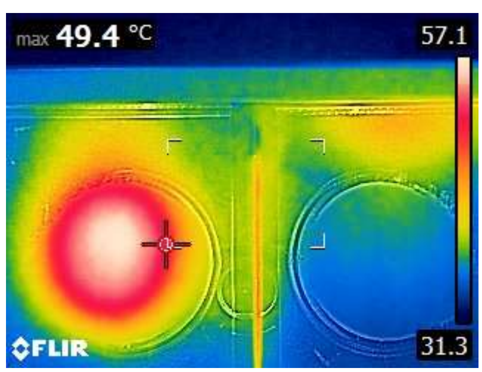

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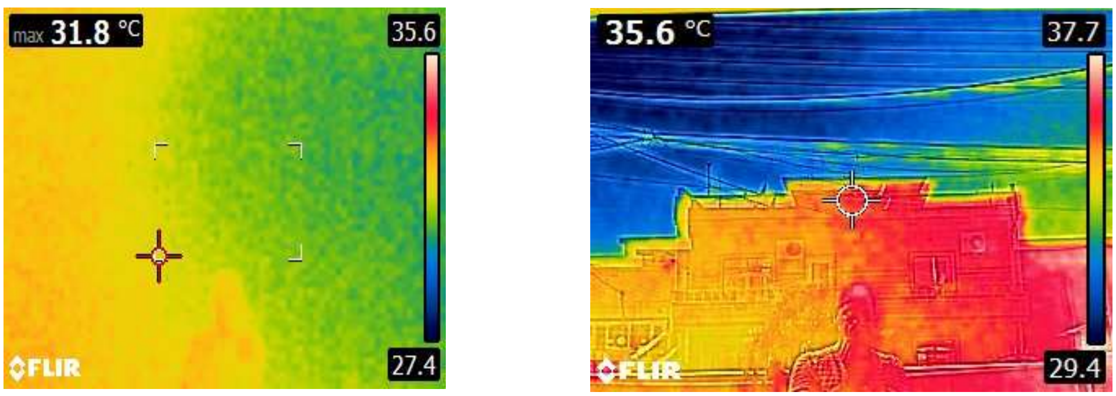
Figure 5 Thermal Photo of low-E glass [right] vs ordinary glass [Left] Together with Color Temperature Plots.

Metals, such as Silver and Aluminium, have thermal EMS of <0.05, while standard clear GS comes in at around 0.9, making it one of the higher EMS materials out there. standard GS with its thermal EMS of 0.9, allows 90% of thermal energy to pass through it, reflecting the remaining 10%. Clearly then, window GS needs some help in reflecting heat back into the home. Window GS needs some help in reflecting heat back into the room. Low E glass is essentially standard clear GS with a microscopic, transparent CT on its surface that is better at reflecting heat than the GS itself, creating a composition that has a lower EMS than standard GS.



a-Inside the room **b-Outside the room**

Figure 6- Thermal Photo of low-E Glass window out-side the room [right] vs Inside the room [Left] together with Color Temperature Plots

Glass with a low E coating therefore keeps the room warmer by reflecting a higher proportion of the heat back into the room, and can keep us cooler by reflecting solar thermal energy from outside.

4.2 Transmission Spectra

Transmission spectral data for 6 mm low iron glass of double low- Emissivity coating, using color filter (Colors, R, O, Y, G, B). is shown in Figure 7. Max. Transmission was about 20%.

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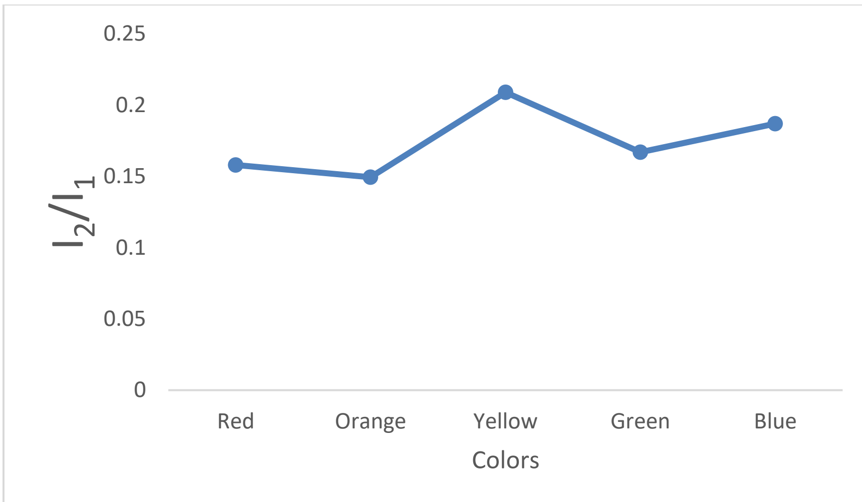

Figure 7. Transmission spectral for 6 mm low iron glass of double low-E Coating, using color filter (Colors, R,O,Y,G,B).

The comparison tested window glass results of Transmission spectral data for 6 mm low iron GS (91% Visible light Transmission -VLT), a double silver low-e CT (81% VLT), a triple silver low-e CT (77%), and an ideal CT (75% VLT), are shown in Figure 8.[26]

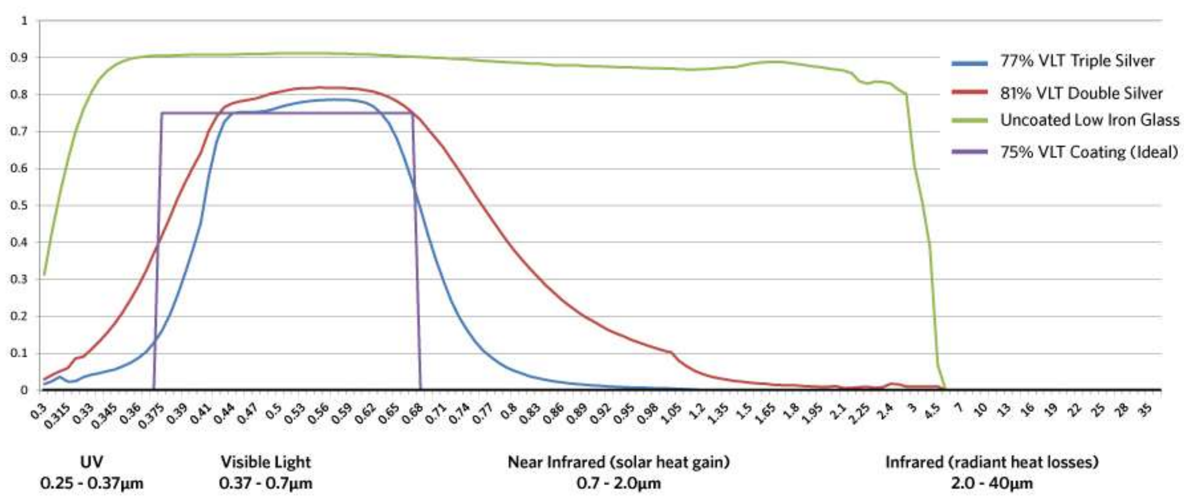

Fig. 8. Transmission spectral for 6 mm low iron for 6 mm GS (91% Visible light Trans. -VLT), a double silver low-e CT (81% VLT), a triple silver low-e CT (77%), & an ideal CT (75% VLT),

While the ideal coating is not technically feasible, it passes all visible light neutrally while selectively reflecting ultraviolet, near infrared solar gain, and infrared radiant heat very effectively. According to Kirchhoff's law of thermal radiation, the emissivity of a surface is equal to its absorptivity. So, emissivity = 1 for an ideal surface with maximum thermal radiation (i.e. an ideal black body surface). And Emissivity = 0 for an ideal surface with zero thermal radiation (i.e. an ideal white body surface).

4.3 Calculations of Solar Heat Gain

Following are the final results of calculations of reduction in solar heat gain.

Case Study-1 for the Small Chamber-1

Total difference in solar heat gain will be: □G= 9.168 W.

Case Study-2 for a Two Rooms

For a large-scale practical case, if a Low-E Glass window is applied to the windows of containing of total net glazing area of 8 m2. In this case the Total difference in solar heat gain will be: ΔG = 6246.12 W.

4.4 Calculations of the Reduction in Co2 Emissions.

Case Study-1 for the Small Chamber-1

According to the calculations and analysis regarding to solar heat gain, we can calculate the reduction in CO2emissions. Modifying building envelope by Low-E Glass will significantly reduce energy required for heating and cooling. The total energy consumption of heating, ventilation and air-conditioning (HVAC) systems will reduce by total difference in solar (heat) gain.

In the case of experimental total difference in solar heat gain □G will be 9.168 W which save about 33.46 kWh/year. The estimated reduction in CO2 is 23.75 kg.CO2/year in the case study. This was calculated by using a factor of 0.71 kg.CO2 for every kWh [27].

Case Study-2 for a Two Rooms

Likewise, For the Building room case:

Total difference in solar heat gain □G will be 6246.12W which save 22798.33 kWh/year. The estimated reduction in CO2 is 16186.81 kg.CO2 /year or 16.186 ton. Co_2/ year in the building room case.

Therefore, Low-E Glass have a relatively good potential to impact GHG emissions when compared to other mains, especially when cost is taken into account. Hence, it is one of the most effective measures that can be considered.

5. CONCLUSION

The use of Low-E window glass has many benefits. It is the best transparent and heat isolated materials for building window. Low-E window glass can control the amount of solar heat gain thus we can use Low-E window glass to maintain our building warm atmosphere in winter and mild atmosphere in summer. Also, Low-E window glass can keep our environment clean reducing the large amount of Co2 emission.

For the case study (small chamber) the estimated total difference in solar heat gain ΔG was 9.168 W, which save about 33.46 kWh/ year. The estimated reduction in CO_2 was 23.75 kg.CO_2/ year.

And for the Building room case, the total difference in solar heat gain ΔG was 6246.12W which save 22798.33 kWh/year. The estimated reduction in CO2 was 16186.81 kg.CO_2 /year or 16.186 ton. Co_2/ year.

So, Low-E glasses demonstrate an effective means of reducing GHG emissions when used in retrofitting existing buildings.

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