Life cycle cost analysis on glass type of Malaysian office buildings for reducing energy consumption CO_2 emissions

S.Sadrzadehrafiei, K.Sopian, S.Mat, CH.Lim, H.S.Hashim, A. Zaharim

***Abstract*—** The energy saving that can be achieved by applying advanced glazing to a typical office building in Malaysia was evaluated using the simulation software Integrated Environmental Solutions (IES). It was found that application of low-e glazing would lead to a reduction in cooling electricity use by up to 6.4%. The annual cost saving due to application of low-e reverse glazing would be up to 2.1%; single low-e glazing up to 3.1%; and double low-e glazing up to 3.9%. The analysis suggests that the application of expensive advanced glass for the six- story rise office in Malaysia would not be economically viable from the point of view of saving in cooling energy cost.

***Keywords*—**carbon dioxide, Energy saving, IES, life cycles, Office building, life cycles, window glazing

I. Introduction

DUE to increasing concern regarding the huge amounts of energy consumed and the repercussions on the world's environment, many countries are taking measures to enhance energy efficiency in the building sector [1]. As the building sub-sector is a major consumer of both energy and materials worldwide, 8–50% of the total, energy efficient use of energy will play a vital role in reducing energy usage and associated emissions released to the atmosphere[2].

Office development is one of the fastest growing sectors in the construction industry, with office buildings consuming about 70-300 kW h/m^2 of energy, which is 10-20 times higher than in residential sectors [3]. Sadrzadehrafiei et al. [4] conveyed that in a typical mid-rise office building in Malaysia, air conditioners utilized the most energy at 58%, followed by lighting (20%), office equipment (19%), and other (3%) (Fig.1).

In the past three decades, high economic growth in Malaysia causes a dramatic increase in energy consumption.From 1980 to 2009, total electricity consumed and gross domestic product (GDP) increased by 9.2% and 6.2%, respectively [5]. The demand of energy is increasing rapidly in both developing and developed countries which has an effect on increasing energy demand and, consequently, in carbon dioxide release in the atmosphere [6]. Fig. 2 shows the commercial sector energy consumption trend in Malaysia.

According to the United Nations Development Report, Malaysia ranks as the 26th largest greenhouse gas emitter in the world (UNDP, 2007) and based on its growth rate of CO_2 emissions, it appears likely to move up the list quickly [7].

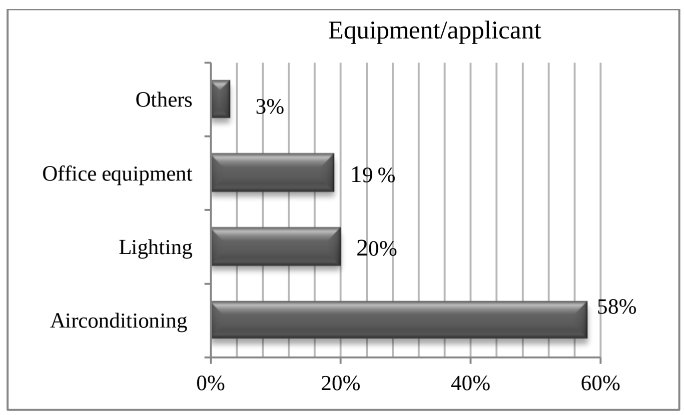

Fig 1. Total energy consumption by all equipments and their breakdown

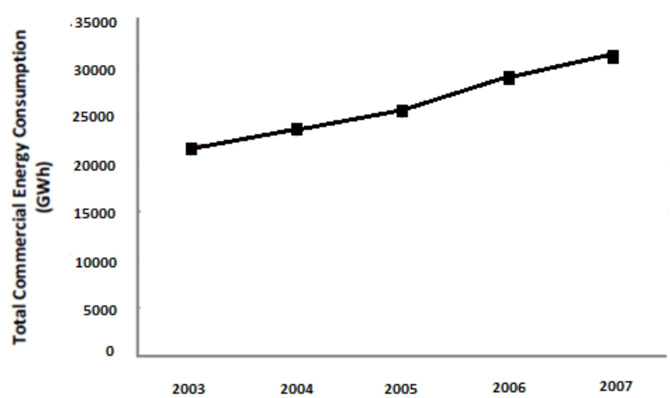

Fig.2.Commercial sector energy consumption trend in Malaysia (EC,2007)

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II. Literature Review

In order to get the higher energy efficiency of a building the appearance of the window system is obliged to improve. Windows are responsible for a disproportionate amount of unwanted heat gain and heat loss between buildings and the environment.

Windows actively contribute to heat transmittance between building and the environment and count as responsible for a disproportionate amount of unwanted heat gain and heat loss. In terms of energy saving, windows are generally the weakest link of buildings and one-third of the energy from a typical house loss occurs from windows [8].Application of double-pane windows and coating glass surfaces with low-emissivity materials reported as the ways to reduce heat and energy losses through windows [9].

According to Shen.h et al. [10] glazing systems usually have a significant effect on whole building energy consumption. Atikol et al. [11] conveyed that heat loss through building walls and windows is about 45%, therefore it is possible to save energy through enhancing window performance from a heat loss perspective.

From previous studies on the exterior glass of buildings Milorad Boji [12] analyzed the cooling load reduction and the economics when the single low-e, single low-e reversible, double clear glazing, and double low-e glazing glass types were used. It was found that application of low-E glazing would lead to a decrease in cooling electricity use by up to 4.2%. The saving according to application of clear plus low-e glazing would be up to 6.6%; double clear glazing up to 3.7%; and low-E reversible glazing up to 1.9%. The amount of saving achieved would be depended upon building wings orientation, and rooms' type and place.

Francis Yik [13] in a research paper investigated the effect of application of switchable glazing on energy consumption for space cooling. Using software, EnergyPlus, is found that application of switchable glazing would lead to a cut down in annual cooling electricity consumption by up to 6.6% where the amount depends upon the existence of overhangs, orientation of building wings, sorts and locations of rooms.

Bouden [14] evaluated the energy efficiency of different types of glass in Tunisian weather. In winter, double low-e (one clear + one low-e) + argon was most efficient, while in summer, double glazing (one clear + one reflecting) was most efficient in summer.

From previous studies on mid-rise buildings, Sadrzadehrafiei et al. [4] proposed the application of external wall insulation and double low-e for mid-rise office buildings in tropic climate, Malaysia. Mid-rise office buildings in a hot and humid climate were analyzed to reduce their energy consumption more significantly. It estimated that 180000(KWh) of annual energy consumption can be saved through the application of low-e glazing and insulation. In another study by Sadrzadehrafiei et al. [15], Integrated Environment Solution (IES) simulation software was used to evaluate energy saving achieved by applying advanced glazing to a typical mid-rise office building in Malaysia. It was found that application of advanced glazing would lead to a reduction in annual cooling energy consumption in the range of 3.4-6.4%.

Singh [16] evaluated the energy rating of different window glazing, available in the Indian market.It is determined that savings by a window depend on type of window and its orientation, site location and weather data, dimensions and construction of its walls and roof buildings. The study has been performed for five different climatic zones of India. They advanced energy rating equations for different glazing, buildings and climates by regression analysis.

Kneifel [17] analyzed the energy and cost efficiency, as well as the CO2 emission, of new commercial buildings through integrated design approach. The results showed reduction in energy consumption by about 20-30% and average CO2 emission also decreased by 16%.

III. Analysis Method

A. Overview of the case study

Due to the fact that the main purpose of this work has been to evaluate window and glazing systems in terms of their energy efficiency, CO_2 emission reduction, and LCC to be applied in commercial buildings in the tropic climate, Malaysia, a real office building has been taken as the reference. In this study, an actual building located, Chancellery office building located at University Kebangsaan Malaysia (UKM) in Bangi, Malaysia was selected for the case study. Fig.3 shows its site plan of the actual building in the case study.

The selected building is a six storey building and total floor area of the building is 14484m² its total glass area is 2671 m^2. The glass currently used in the building is 3mm single pane clear glass with the following characteristics: a U-value of 1.06 W/m^2K, solar transmittance of 0.78 and outside reflectance of 0.07. The material composition of the walls, windows, and other elements of the building fabric are described in Tables I and II .As for glazing constructions, layer properties include solar transmittance, absorbance and reflection characteristics.

Fig .3. Building site plan

Table I .Composition of the building envelope

Description	Material	Thickness (m)	Conductivity W/(m·K)	Density kg/m³	Specific heat capacityJ/(kg·K)
External wall	Brickwork	0.117	0.84	1700	800
	Plaster	0.02	0.5	1300	1000
Internal Ceiling	Concrete	0.1	1.4	2100	840
	Cavity	0.012			
	Plaster	0.01	0.5	1300	1000
Metal Roof	Steel	0.01	50	7800	480
	Bitumen	0.005	0.5	1700	1000
	Glass wool	0.15	0.04	200	670
Flat Roof	Stone	0.01	0.96	1800	1000
	Bitumen	0.005	0.5	1700	1000
	Concrete	0.15	1.13	2000	1000

Table II. Properties of the selected glass types

Glass type	clear glazing	low-e reverse glazing	Double low-E pane
Thickness(m)	0.003	0.003	0.003
Solar transmittance	0.837	0.63	0.63
Solar reflectance , front side	0.075	0.19	0.22
Solar reflectance at back side	0.075	0.22	0.19
Visible transmittance	0.898	0.85	0.85
Visible reflectance :front side	0.081	0.056	0.079
Visible reflectance : back side	0.081	0.079	0.056
IR hemispherical emissivity: front side	0.84	0.84	0.1
IR hemispherical emissivity: back side	0.84	0.1	0.84
Conductivity (W/m-K)	0.9	0.9	0.9

This study assumed an occupancy level of 9 person per m^2 with a gain of 70W for sensible heat and 45Wfor latent heat per person. A lighting power of 18 W/m^2 and office equipment load; computers, printers and copy machines of 5, 20 and 9 W/m^2 have been used respectively.

The study analyzes in the climatic and solar radiation conditions of Malaysia with Kuala Lumpur weather data. The weather data is used to determine the trend of the monthly dry bulb temperature, wind speed and relative humidity available for thermal environment in selected office building at UKM, Bangi. The geographic coordinates of Malaysia are latitude 3.12^{o}N, longitude 101.55^{o}E, while temperatures are variable and there is high humidity. Malaysia's hottest time is around March, at 27.8^{o}C and annual weather data, maximum dry-wet bulbs are 34.90^{o}C and 26.50^{o}C, respectively [18].

B. Simulation method and assumptions

For the energy simulation, Integrated Environment Solution IES <VE-Pro> was used to predict annual energy consumption of Chancellery office building, using the climatic data from Kuala Lumpur, Malaysia from January to December 2011.

Fig.4 shows the 3D view of the Chancellery office building model developed in IES.This software is a flexible, integrated assessment system that results in productivity and excellence in every aspect of sustainable building design, and is employed by leading sustainable design professionals worldwide [19].

The simulation results of IES have been validated through comparison between field study energy consumption measurement by using power logger and IES simulation results. IES calculates conduction, convective and radiant heat transfer effects using hourly weather data.

C. Selection of the exterior glass for office building

It is possible to reduce the amount of space-cooling energy use in the buildings when the standard type of glass (single pane clear glass) on each of the above types of glass to give an idea of the highest energy saving due to the use of the advance glazing. The Uvalue, solar transmittance and reflectance and visible transmittance and reflectance of glass among its properties were considered, since they have the most affect on energy consumption of building.

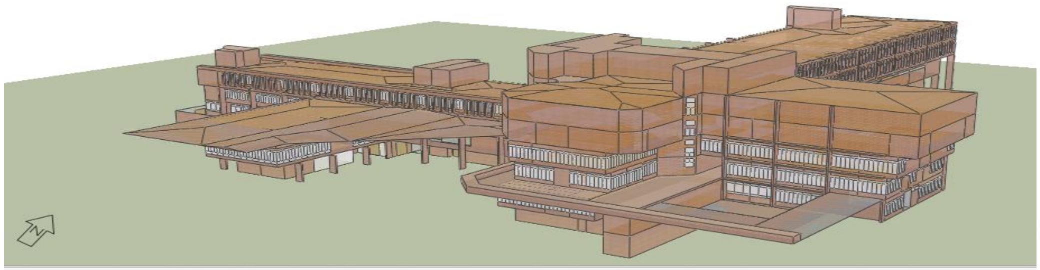

Fig.4. 3D view of the Chancellery office building model developed in IES< VE-PRO> 6.2

In this study, the advanced glazing is assumed to be used in all air rooms, while all non-air-conditioned rooms, including stores and toilets, would just have the ordinary clear glass at windows. Effect of three types of windows has been studied as follows single clear pane glazing, single low-e reverse, and double low-e glazing with the features indicated in Table II. The 16 mm-thick double glazing includes a clear glazing and one pane of low-e glazing and air gap between the two glass panes.

IV. Results and discussion

A. Energy consumption and CO_2 emission analysis by glass type

On the basis of the building characteristics described above, the annual electricity consumption for mid-rise office building was calculated from the hourly electricity consumption predicted by IES.The annual electricity consumption for building the underlying cause is selected in Fig.4. The annual consumption of electricity for this project has shown, 2255.4(MWh).

By applying the three types of advanced glazing to the case building, the energy efficiency and CO_2 emission were analyzed. Figs 5 and 6 show the results of the comparative analysis of the existing glass and the types of glass selected in this study. Table.III. shows the comparison of the energy consumption of the existing glass and glass types. The electricity usage of single low-e reverse was 2208 MWh lower than that of the existing glass. Accordingly, the amount of CO_2 emission decreased by 24168 kg CO_2 .The electricity usage of single low-e decreased by 69815 kWh .The amount of CO_2 emission was reduced by 36095 kg CO_2. The electricity usage of double low-e decreased by 87310 kWh, and emission was reduced by 45140 kgCO_2. The percentage reductions in the yearly cooling energy consumption and CO_2 emission via applying different types of glazing are shown in Figs.5 and 6, and discussed below:

- The application of advanced glazing will lead to a saving in cooling energy consumption in electricity utilization in the diversity of 3.4 to 6.4%.
- The implementation of low-e reverse glazing would decrease the annually cooling electricity utilization and CO2 emission up to 3.4 % and 2.1% respectively.
- The implementation of single low glazing would lead to saving in the yearly cooling consumption and CO2 emission by 5.1% and 3.1 % respectively.
- Compared to low-e reverse glazing and single low-e glazing, the implementation of double low-e glazing would influence to higher saving in the yearly cooling consumption and CO2 emission by 6.4% and 3.9% respectively..

Among the advanced glazing, the implementation of double low-e glazing in the company of one pane of low-e glazing would yield the highest energy saving

B. Life cycle cost analysis

Benefit-cost analysis is performed to calculate the economic viability of applying all types of advanced glazing under the concern to the typical office building in Malaysia. The analysis was based on a study period of 10years, a real discount rate of 3.5% per annum and an electricity tariff rate of 0.312 (MYR/KWh).

In this study, the cost items for the cost benefit analysis included the purchase and installation costs among the initial investment costs, and the energy usage cost. According to assumption were made for this study, within the lifespan of the building, replacement of the glazing would not take place, the maintenance cost of applying each type of advanced glazing would be same as applying the original clear glazing. Where the electricity price will increase at the same rate as inflation, the life cycle energy cost saving can be evaluated by multiplying the annual cost saving by the present worth factor that equals 8.33. An advance glazing would be regarded as economically viable if the benefit–cost ratio were greater than 1.0 [12].The unit prices for supply and installation of the sorts of glazing deliberate were acquired from quantity surveyors based on recent returned tender prices. By applying three types of glass selected in Table III to the case building, the energy consumption and CO2 emission were analyzed.

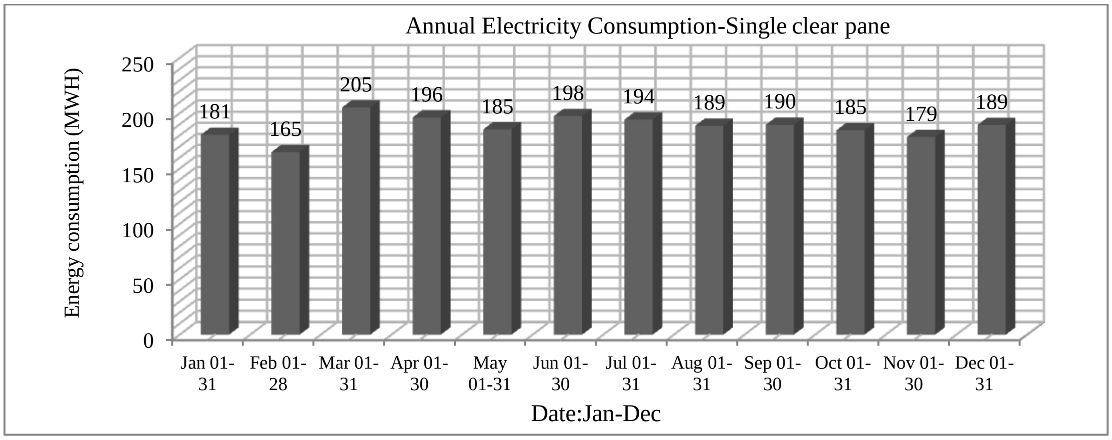

Fig.5. Results of the IES run on Chancellery building energy performance for the base case

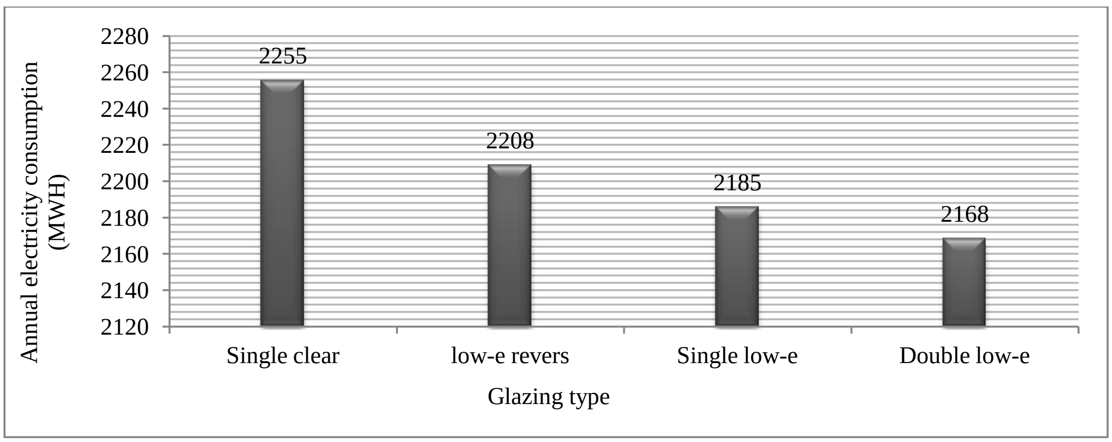

Fig.6.Annual energy consumption and different types of glazing

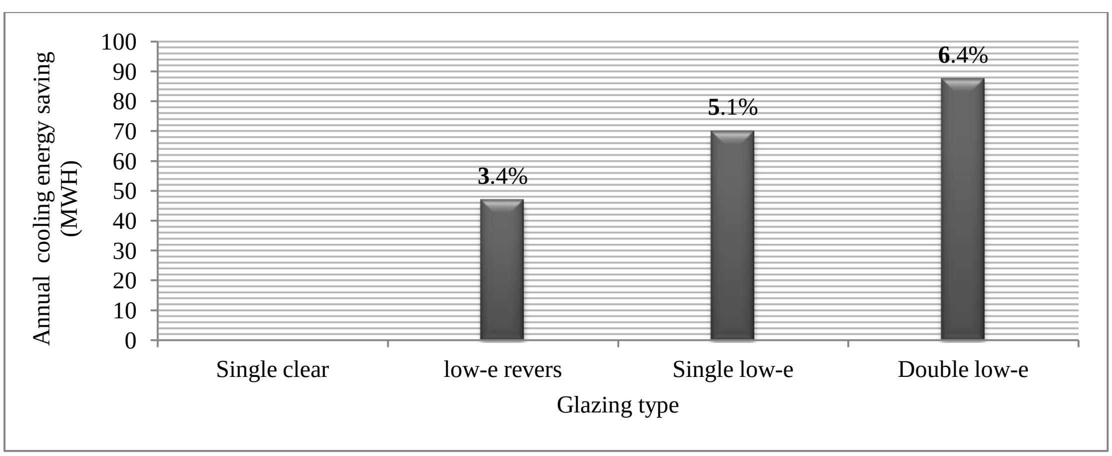

Fig.7.Annual energy saving and different type of glazing

Figs 8 and 9 show the results of annual and life cycle cost saving cost saving of selected types of glazing . The annual energy consumption by single low-e reverse was 46747 kWh lower than that of the existing glass and LCC saving over 10 years was RM 121443. The economic profit after 10 years through application of single low-e was RM 181372. The annual cost saving by double low-e glazing was RM 27241 and LCC saving over 10 years was RM 226822. The benefit–cost analysis showed that among the types of glazing studied, single low-e reverse and single low-e glazing have the benefit–cost ratio greater than one, 1.37 and 2.05 respectively, whilst double low-e glazing would not be economically viable options (Table. V).This analysis shows that the application of expensive advanced glass for the six- story rise office in Malaysia would not be economically viable. As it can be seen in Fig.9, application of double low-e glazing resulted in the highest life cycle cost saving of 32%, followed by single low-e and single low-e reverse by 25.8 % and 17.3% respectively.

Table III. Comparison of the energy consumption of the existing glass and glass types

Glass Type	Cooling Energy consumption (MWh)	Emission (Kg CO2)	Cooling Energy Saving (KWh)	Emission Reduction (Kg CO2)
Single clear	1361	1166091	0	0
Single low-e reverse	1315	1141923	46747	24168
Single low-e	1291	1129996	69815	36095
Double low-e	1274	1120951	87310	45140

Table IV. Life cycle cost saving benefit-cost ratio

Glazing type	Unit price (RM/m2)	Difference in unit price (RM/m2)	Total cost of glazing ,difference (RM)	Annual energy cost saving (RM)	LCC saving (RM)	LCC saving/Cost
Single clear(Base case)	48	0	0	0	0	
Single low-e reverse	80	32	88352	14585	121443	1.37
Single low-e	80	32	88352	21782	181372	2.05
Double low-e	226	178	491458	27241	226822	0.46

Fig.8. Annual cost saving and different type of glazing

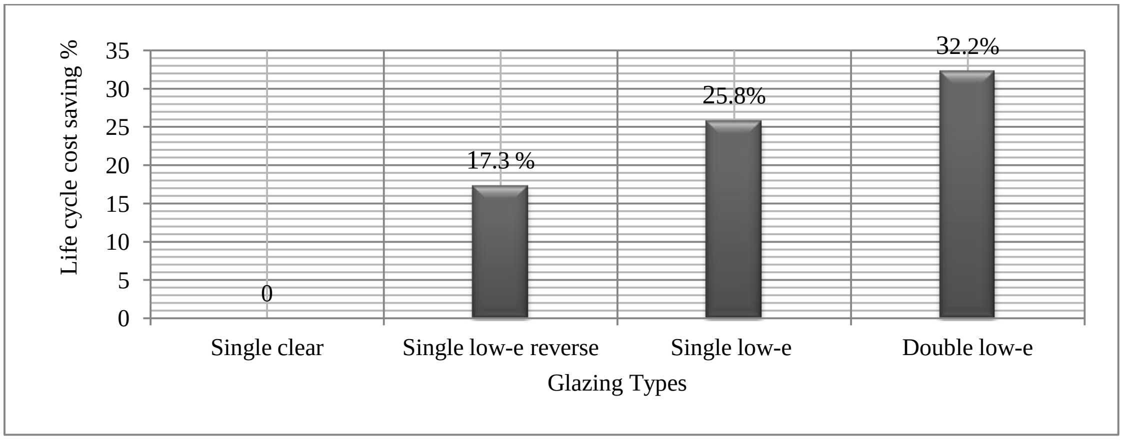

Fig.9. life cycle cost saving and different type of glazing

V. CONCLUSION

This paper examined advanced glazing rate savings over a 10-year life period and calculated emission reduction intervals for different types of glazing. In this study the types of glass installed in existing office building in Malaysia and the three types of advance glazing were selected. The energy and CO_2 emission reduction, and LCC if these types of glass were to be used were analyzed, and the results were compared to those for the existing glass. The results can contribute in the selection of economically efficient glass. The results showed that the energy consumption and the CO_2 emission of all three types of glass became lower than those of the existing glass. The energy consumption and CO_2 emission of double low-e glazing smallest, followed by single low-e and single low-e reverse , in that order.

The life cycle cost saving due to the application of these glazing types was found to be:

- Single low-e reverse glazing—up to 2.1%.
- Single low-e glazing—up to 3.1%.
- Double glazing —up to 3.9%.

The benefit–cost study showed that the single low-e pane and single low-e reverse would be marginally economically viable but double low-e glazing would not be. The high cost of double low-e glazing types is the major reasons that make these types of glazing not viable.

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