Effectiveness of energy-saving glazing in various climatic zones of Russia

Elena Korkina\textsuperscript{1,2}, Igor Shmarov\textsuperscript{1} and Matvey Tyulenev\textsuperscript{2}

\textsuperscript{1}Research Institute of Building Physics of Russian Academy of Architecture and Construction Science, Russia
\textsuperscript{2}Moscow State University of Civil Engineering, Yaroslavskoe shosse, 26, Moscow, Russia

E-mail: tulenevm@gmail.com

Abstract. Transmission heat losses through the filling of the apertures are greatest through the entire envelope of the building, therefore, their reduction is of great importance for saving energy for heating. For this purpose, the installation of double-glazed windows with special energy-saving coatings is being carried out. The purpose of this work is to estimate the decrease in heat losses while reducing heat gains when replacing glass packs with energy-saving ones for the whole building. For this purpose, an indicator was introduced that is equal to the ratio of heat loss reduction, taking into account the decrease in heat gains when replacing glass packs with energy-saving ones. This indicator was calculated using the example of a building, presumably located in different climatic zones of Russia. This indicator can be used in economic calculations when evaluating the effectiveness of energy-saving glazing.

1. Introduction

Energy-saving issues in the construction industry are quite important and are contained in many works \[1,2,3\]. Researchers consider the influence of factors such as building materials [4,5,6] and methods [7,8], the influence of incoming solar radiation [9,10,11] and the orientation of the building [12,13], the absence or presence of shading [14] on energy consumption, features of mathematical models [15], etc. One of the most significant factors is transmission heat loss through windows, which account for a large share of all heat losses in a building in Russia [1,3,8,10,16]. In order to reduce transmission heat loss, glazing is installed in the building, which has energy-saving properties [8,16], it reduces heat loss but also reduces heat input from solar radiation [8,10] during the heating period. Some works are aimed at studying the optimal ratio between heat loss and heat gain through windows using energy-saving glazing [16]. To calculate energy consumption for heating and ventilation of a building according to Russian regulations [1,4,16], it is important to know how the amount of these indicators is reduced for the entire building. This work aims to numerically estimate the decrease in heat loss, taking into account the decrease heat input for the entire building when replacing the glazing of windows with energy-saving properties.
2. Analysis of changes in heat loss and heat gain through the glazing of windows

For comparative analysis, the value of heat gains and transmission heat losses through windows are determined first when installing glazing without coatings, \( Q_{\text{irr \ uncoat}} \) and \( Q_{\text{tr \ uncoat}} \), and then when installing glazing with energy-saving coatings, \( Q_{\text{irr \ low \ e}} \) and \( Q_{\text{tr \ low \ e}} \), respectively.

Transmission heat losses for the entire building through light openings \( Q_{\text{tr}} \), MJ/year, are calculated as the sum of heat losses through all window blocks using the formula \( Q_{\text{tr}} = 0.0864 \cdot D_d \cdot \sum_{j=1}^{J} \sum_{n=1}^{N_j} \frac{A_{jn}}{R_{jn}} \) (1)

where \( R_{jn} \) – reduced heat transfer resistance of the window on the facade with orientation \( j \), m\(^2\)·K/W, calculated by [1]; \( D_d \) is the value of the degree-day of the heating period for the building region, °C·days/year.

The definition of heat gains is considered as the sum of heat gains through light openings for all facades using the formula \( Q_{\text{irr}} = \sum_{j=1}^{J} \left[ I_{\text{irr \ ver \ j}} \cdot \sum_{n=1}^{N_j} g_{jn} \cdot \tau_{2 \ jm} \cdot A_{jn} \right] \) (2)

where: \( J \), \( N_j \) – the number of facades and the number of windows on the \( j \)-th facade, respectively, units; \( A_{jn} \) and \( g_{jn} \) – the area and total solar energy transmittance for the light opening, where \( n \) is the index of the light opening located on the \( j \)-th facade, m\(^2\), and relative units, respectively; \( I_{\text{irr \ ver \ j}} \) – the total radiation for the heating period for the \( j \)-th facade, MJ/year·m\(^2\), is calculated [17] by assuming the isotropy of the scattered radiation distribution [18]; \( \tau_{2 \ jm} \) – the coefficient that considers the shading of windows with opaque fill elements, relative units. The calculation is described in detail in Russian regulatory documents and is based on the summation of the values of solar radiation and radiation reflected from the inner faces of glazing [19].

Then, considering the formulas (1) and (2), the difference in heat loss, taking into account heat gains when using glazing without energy-saving coatings and with them, is calculated according to the formulas, respectively:

\[
Q_{\text{tr \ uncoat}} - Q_{\text{tr \ low \ e}} = 0.0864 \cdot D_d \cdot \sum_{j=1}^{J} \sum_{n=1}^{N_j} \frac{A_{jn}}{R_{jn \ uncoat}} - \sum_{j=1}^{J} \left[ I_{\text{irr \ ver \ j}} \cdot \sum_{n=1}^{N_j} g_{jn} \cdot \tau_{2 \ jm} \cdot A_{jn} \cdot g_{jn \ low \ e} \right]
\] (3)

Then, the proportion of reduction of transmission heat loss without reducing heat gain after the replacement of glazing from the value of the transmission heat loss excluding heat gains to the replacement of insulating glass is defined as:

\[
e_Q = \frac{Q_{\text{tr \ uncoat}} - Q_{\text{tr \ low \ e}}}{Q_{\text{tr \ uncoat}}} \cdot 100\%
\] (5)
This indicator is the value that shows a real decrease in heat loss when using energy-saving glazing relative to the heat loss before using energy-saving glazing. However, this indicator depends on the architecture of the building and on the climatic characteristics of the area in which the building is located. This value should be adjusted when calculating energy savings for heating and ventilation of the building from the replacement of the glazing with energy-saving ones.

### 3. The example of a comparative calculation

The effectiveness of replacing glazing with uncoated glass with glazing with a coating that has energy-saving properties, consider a single-section building, presumably located in Moscow, $D_d = 4551$ °C·day/year, Krasnodar $D_d = 2537$ °C·day/year, Krasnoyarsk $D_d = 6221$ °C·day/year, Salekhard $D_d = 8978$ °C·day/year. The choice of cities is due to their different climatic characteristics. For example, Moscow has a humid temperate continental climate. In Krasnodar, the climate is transitional, from temperate continental to humid subtropical, with mild winters without stable snow cover, which affects the amount of reflected radiation. Krasnoyarsk, which belongs to Eastern Siberia, has a continental climate. In Salekhard, which belongs to Western Siberia and is located on the Arctic circle, the climate is cold, bordering between subarctic and moderate, and the heating period lasts from September to May. The building's facades are oriented in four main directions. It is assumed that each facade has the same thermal characteristics and configuration of window blocks in the amount of 100 units. The calculated value is $\tau_2 = 0.62$ relative units, the window area is $A = 2$ m$^2$. Table 1 shows the calculated values of the solar factor, $g$, and the center heat transfer coefficient for glazing, $U_0$, without and with energy-saving coatings, determined according to the manufacturer’s data.

| Characteristics of glazing | $g$, rel.un. | $U_0$, W/m$^2$·°C |
|---------------------------|-------------|-----------------|
| Triple, argon             | 0.68        | 1.8             |
| Triple, low-e, argon      | 0.63        | 0.6             |

According to the results of calculations, the given heat transfer resistances of these Windows when installing glazing without coatings and with energy-saving coatings are $R = 0.63$ and 1.2 W/m$^2$·°C, respectively. When calculating the reduced heat transfer resistance of window blocks, the heat transfer resistance of the covers was taken according to the manufacturer, equal to 0.77 W/m$^2$·°C.

### 4. Results and discussion

When calculating heat gains and heat losses for the building section under consideration, the following values were obtained, presented in table 2 for different building locations.

| Characteristics of glazing | Heat loss, MJ/year (index “uncoat”) | Heat gain, MJ/year (index “irr”) | Difference, MJ/year |
|----------------------------|------------------------------------|---------------------------------|---------------------|
| Moscow, latitude: 56° north| 480000                             | 296000                          | 184000              |
The calculated values of the $E_Q$ and $e_Q$ indicators are shown in table 3.

**Table 3. Values of heat loss reduction indicators taking into account the decrease in heat input $E_Q$ and without taking into account $e_Q$.**

| City         | $E_Q$, % | $e_Q$, % |
|--------------|----------|----------|
| Moscow       | 96       | 42       |
| Krasnodar    | 148      | 42       |
| Krasnoyarsk  | 84       | 41       |
| Salekhard    | 80       | 41       |

As can be seen from the calculations, the real benefit in reducing heat loss from the replacement of glazing, calculated taking into account the decrease in heat availability, significantly exceeds the benefit calculated without taking into account heat loss reduction for all the considered dislocations of the building in different climates. The building located in Krasnodar, whose climate is close to that of New York and Milan, has the highest benefit in reducing heat loss. The smallest of the cases considered are for cities in Western and Eastern Siberia. For a building supposedly located in the temperate climate of Moscow, replacing the glazing with energy-saving ones is certainly beneficial.

In addition, the use of energy-saving glazing in these cases almost eliminates heat loss through the windows in the building due to heat input.

**5. Conclusion**

Thus, to assess the reduction of heat loss and heat gain for the entire building entered the ratio to reduce heat loss taking into account the reduction of heat gain during the replacement of glazing on energy saving, as well as the indicator does not take into account reduction in heat gain.

It should be noted that this indicator cannot be considered separately as an energy-saving characteristic of the window, because it depends on the orientation of the building’s facades, on the architecture of the building and on the climatic characteristics of the area in which the building is located.
The calculation of these parameters was carried out and the efficiency of replacing the glazing with energy-saving ones for the considered climatic zones was obtained.

The indicator can be used with the selection of windows in their replacement by energy-saving and in the calculation of energy-saving effect due to the replacement of glasses in a building in a climate.

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