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ENERGETIC PERFORMANCE OF WINDOWS

BY

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Abstract. The aim of this paper is to analyse the influence of windows in Bucharest climatic zone of the România through the simulation of the energy balance in a dwelling. This simulation may provide a comparing way for the energy saving design in the future buildings and some suggestions for the architects to adopt the optimal type of window according to local conditions. We give an overview of how windows are modeled in *the Window6 Simulation Program*. In this paper, several kinds of windows are introduced and compared using *the Window6* and *ISOVER Software.* In addition, the potential energetic efficiency of four representative windows in Bucharest city of the România are analysed and compared using *the CASAnova Software*. Example results of calculation are shown too.

Key words: windows, thermal transmission, solar heat gain, visible transmittance, air leakage, heat loss, energy consumption simulation.

1. Introduction

The increasing running cost of heated buildings, the energy consumption and the pollution sources are why it is so important to understand how buildings use energy.

The windows are the weak parts of building envelope concerning of the energetic efficiency and the indoor comfort. The windows are responsible for the solar heat gain inside and for 10…25% of the heat loss from heated ambient.

The solar heat gain through fenestration is one of the sources of space cooling load in a building. In the summer time, it is important to minimize the solar heat gain through windows by shading without reducing the natural illumination, and in the winter time, it is necessary to increase the fraction of solar radiation entering the room without causing any glare. In the climate areas which need both cooling in summer and heating in winter, the decreasing of cooling loads by shading may increase heating loads and *vice- versa*. It is important to determine the optimal shading system of windows.

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U-factor rating measures the effect of windows on building energy use; *the lower the U-factor is, the lower the amount of heat loss is*. *U*-factor is affected by conductivity and the airflow around the window, and the emissivity of the glass; *the lower the conductivity and emissivity of the glass are, the lower the rate of heat loss and the lower the U-factor are.*

High-performance window and glazing systems are now available: a double or triple glazing, specialized transparent coatings, insulating gas sandwiched between panes, and improved frames concerning of lower heat loss, less air leakage, and warmer window. surfaces which all improve the comfort, minimize the condensation risk, reduce heat transfer, and cut the energy loss through.

2. Window Program

The American National Fenestration Rating Council (NFRC) has developed a window rating system based on whole window performance in order to help the alleviation of confusion associated with. The NFRC rating accurately accounts for all product components and presents window information in a concise and easy-to-understand format.

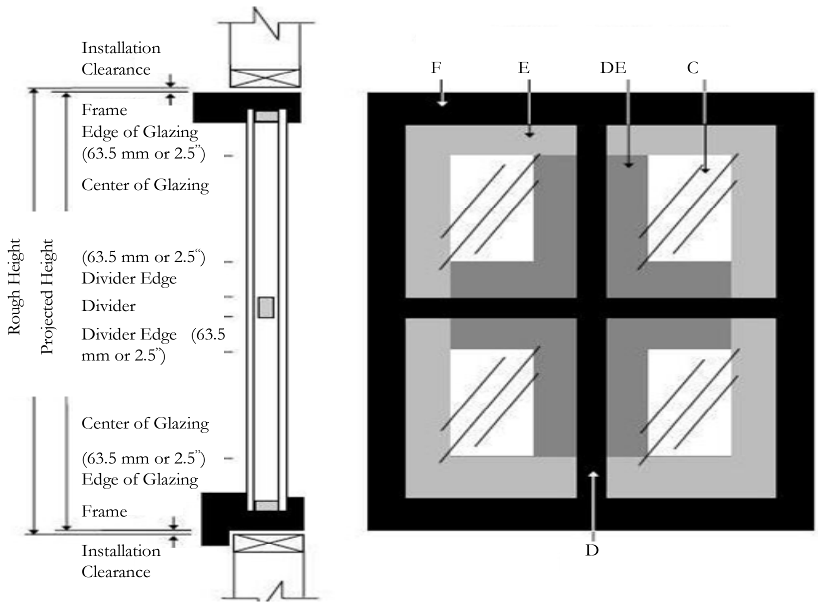

Fig. 1. – Total window assembly

The windows have two *U*-factor ratings [1]: one for the center of the glass and one for the total window assembly (Fig. 1). Center-of-glass *U*-factor is the one for the glass alone. Total window assembly overall *U*-factor is the factor for edge-of-glass and frame effects and it accounts for heat flow through the glass itself, the edges that occur in the unit, and the window frame and sash. NFRC rating is for the whole window. The windows should be compared with an overall *U*-factor rating.

The mechanisms that need to be considered include conduction through glazing and framing elements, solar gain by transmission and absorption, natural ventilation, and infiltration. The optical, solar and thermal properties of transparent components and materials are the essential parameters to perform accurate simulations.

Thermal Transmittance of the window [12], [13] will be computed by the following relation:

$$U = \frac{1}{R} = \frac{\sum U_j A_j}{\sum A_j} \le U_{max} \tag{1}$$

where: R is the thermal resistance of the assembly, in [$m^2.{}^0C.W^{-1}$], A_j – the area of each j part of the assembly, [m^2]; U_j – the thermal transmittance of each part j of the assembly, [$W.m^{-2}.{}^0C^{-1}$]; U_{max} – maximum value of thermal transmittance, [$W.m^{-2}.{}^0C^{-1}$] (Fig. 2).

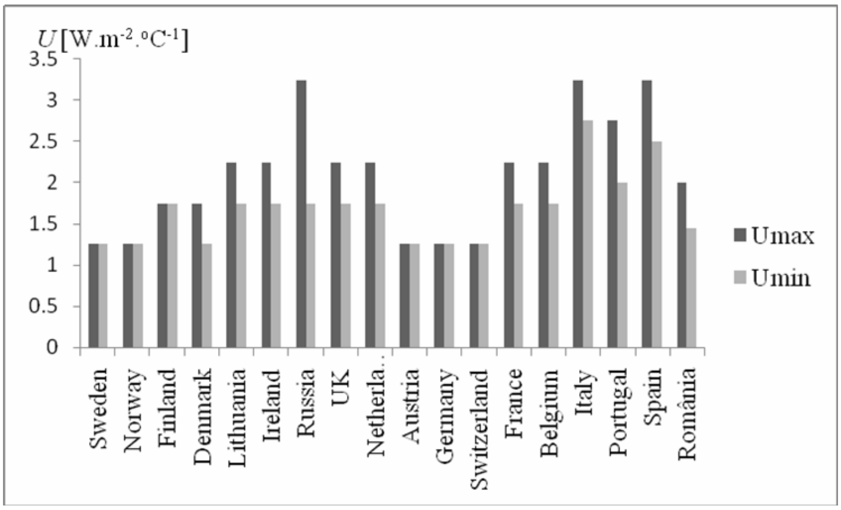

Fig. 2. – Thermal transmittance of the windows by [12, 13]

Heat transfer across a fenestration product is a function of the temperature difference between inside and outside and the incident solar radiation on, and the window area, thermal transmittance and solar heat gain coefficient. Instantaneous heat flow rate through the window will be computed by the relation:

$$Q = UAD\theta + \mathrm{SHGC}AI_r \tag{2}$$

where: U is the thermal transmittance, [$W.m^{-2}K^{-1}$]; A – the area of fenestration product, [m^2]; $\Delta\theta_{e(i)}$ – the outside (inside) air temperature difference, [^0C]; SHGC – solar heat gain coefficient; I_r – direct solar radiation, [$W.\ m^{-2}$].

We give an overview of how windows are modeled in the *Window6 simulation program* [10]. The important features include layer-by-layer input of custom glazing, ability to accept spectral or spectral-averaged glass optical properties, incidence angle-dependent solar and visible transmission and reflection, iterative heat balance solution to determine glass surface temperatures, calculation of frame and divider heat transfer.

Window6 Software calculates the thermal and optical performance indices of the total fenestration product:

a) Thermal Transmittance *U*-factor,
b) Solar Heat Gain Coefficient (SHGC),
c) Visible Transmittance (VT),
d) Condensation Resistance Index (CR),
e) Air Leakage.

The SHGC refers to the fraction of solar radiation that passes through a window assembly and warms the inner spaces of a dwelling. The SHGC is expressed as a number ranged between 0 and 1; *the lower SHGC is, the lower amount of solar heat inside is; the higher the SHGC is, the greater the amount of passive solar gain inside is.*

Window6 Software constructs complete window from glazing system (standard or with complex layers), standard frames and dividers. Energetic efficient window technologies based on low-*E* and/or solar control coating, gas fill, double and/or triple panes, fixed and/or mobile sash and frame, weather-stripping are available to produce windows with the U-factor, SHGC, and properties needed for any application.

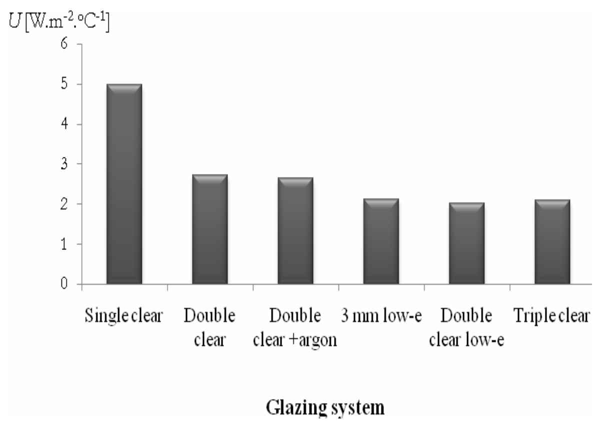

Fig. 3. – Influence of the glazing system

Several kinds of windows [4], [5] are introduced and compared by the same parameter of *the thermal transmittance U-factor* function of the glazing system (Fig. 3), the frame material (Fig. 4) and the squared window area (Fig. 5). The effect of various conditions will be shown hence, the calibration graph must be plotted with the same thermal transmittance on ordinate.

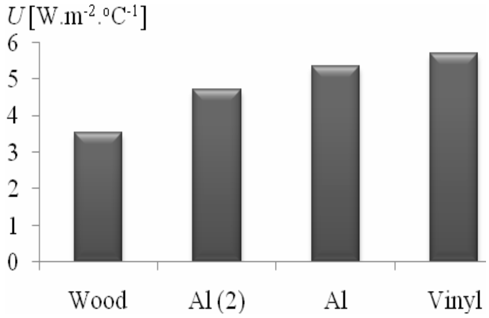

Fig. 4. – Influence of the frame material

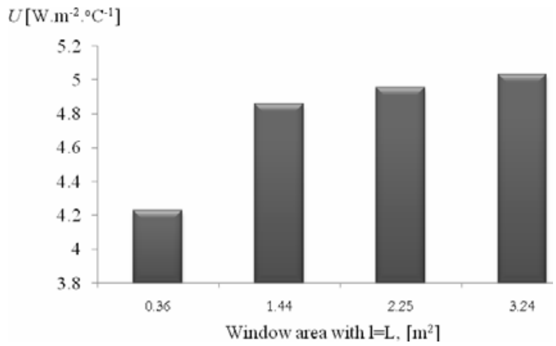

Fig. 5. – Influence of the squared window area

Four kinds of windows are introduced and compared using *the Window6 and ISOVER Software* and the effect of various factors will be shown (s. Tables 1...3):

a) Case 1 - simple glazing, aluminum frame,
b) Case 2 - double glazing, wood frame,
c) Case 3 - double glazing, wood frame, argon gas fill,
d) Case 4 - two glass layers plus two film layers with low-e.

Window6 computes the solar heat gain coefficient (SHGC) and the visible transmittance (VT) of the glazing system (s. Table.1).

Table 1 – Representative Window Solar Heat-Gain Coefficients and Visible Transmittances Calculated with Window6

Case	Solar Heat Gain Coefficient	Visible Transmittance (-)1
1	0.732	0.712
2	0.551	0.588
3	0.596	0.609
4	0.376	0.521

Window6 constructs complete window from standard or with complex layers glazing system, standard frames and dividers, and compute the *U*-values for frame and glazing (s. Table 2).

Table 2 – U-Values for Frame and Glazing

Case	U-frame W. m-2. 0C-1	U-glazing W. m-2. 0C-1
1	5.68	5.710
2	2.27	2.664
3	2.27	2.539
4	2.27	1.642

The graph from Fig. 6 indicates typical whole-window *U*-values for the following types of windows:

a) POOR - single glazing, aluminum frame,

b) GOOD - double glazing, wood frame,

c) BETTER - double glazing, wood frame, argon gas fill,

d) THE BEST - two glass layers plus two film layers with low-e, argon gas-filled.

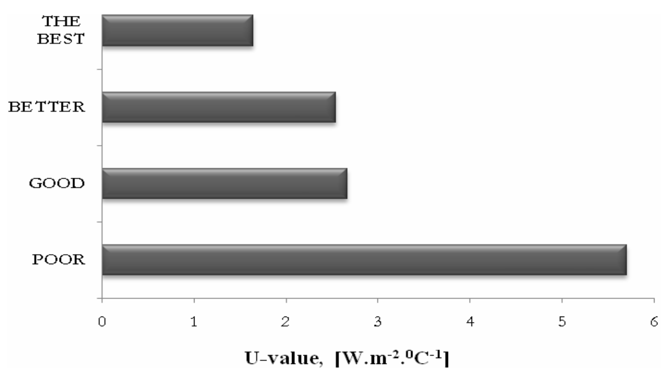

Fig. 6. – *U*-values for windows case-study

3. Case-Study for a Dwelling

We have analysed a 2-storey residential dwelling with outer garret [6]. Both layouts of the ground floor and vertical section are given. Outer walls are made using prokoncept system [7].

During the winter time, the outer walls keep cold air out, and the inner walls keep warm air inside, and *vice- versa* for the summer time. ISOVER Software [8] computes the thermal transmittance (*U*-value) of the opaque building elements (s. Table 3).

Table 3 – U-Value for the Opaque Elements Calculated by ISOVER

Element	*U*-value $W. m^{-2}.^{0}C^{-1}$
Wall	0.81
Floor	0.63
Roof	0.63

The type of the doors and windows must be considered. The modern, high quality doors and windows can significantly reduce the heating costs. Four kinds of windows are introduced and compared using mentioned method.

CASAnova Software [9] gives absolute and specific values for one year/month per m^2 of heated floor area of the heating and/or cooling energy demand, the transmission and ventilation losses, and the useable solar and internal gains (s. Table 4).

Absolute heat energy demand [11] at the level of the dwelling in order to maintain a free temperature inside will be computed by the relation:

$$\text{EH} = E_T + E_V - \eta(E_S + E_I), \tag{3}$$

Where: *EH* is the absolute heat energy demand, $[kWh.a^{-1}]$; E_T - transmission heat loss energy; E_V - ventilation heat loss energy; η - use factor; E_S - solar heat gain energy; E_I - internal (casual) heat gain energy.

Table 4 – Yearly Specific Heat Balance of Dwelling Computed by CASAnova Software

Case	Transmission and Ventilation Losses $kWh. m^{-2}a^{-1}$	Useable Internal and Solar Gains $kWh. m^{-2}a^{-1}$	Heat Energy Demand $kWh. m^{-2}a^{-1}$
1	222.7	60.3	221.0
2	170.2	49.7	182.0
3	168.4	46.3	180.6
4	155.5	33.4	178.0

5. Conclusions

1. High-performance windows have reduce the heat loss, in the cold season and the heat gain, in the hot season.
2. Low U-factor minimizes heat loss and low solar heat gain minimizes cooling load.
3. Window performance is important for the thermal comfort. Depending on your size and quality, the windows have affected heating and cooling load.
4. Ideal window properties depend on the climate and location because of the solar heat gain can be wanted or unwanted.
5. State-of-the art technologies, *e.g.* highly-insulated dynamic glazing can turn windows into net-energy gainers through flexible solar heat control and controlled day lighting.
6. The proposed method is useful to follow the simulation of energy balance in a dwelling in order to establish the potential energetic efficiency of each envelope element.

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PERFORMANŢA ENERGETICĂ A FERESTRELOR

(Rezumat)

Se efectuează analiza influenței ferestrelor în zona climatică Bucureşti din România prin simularea balanței energetice într-o clădire de locuit. Această simulare oferă un criteriu de comparație pentru proiectarea conservării energiei în clădirile noi şi câteva sugestii pentru arhitecți privind alegerea tipului optim de fereastră funcție de condițiile locale.

Se oferă o prezentare succintă a modelării ferestrelor în programul de simulare *Window6.*

Câteva tipuri de ferestre sunt luate în considerare şi comparate utilizând programele de calcul *Window6* şi *ISOVER.* Eficiența energetică a patru tipuri de ferestre folosite în oraşul Bucureşti, România este analizată folosind programul *CASAnova*. Rezultatele simulării sunt prezentate.