

Influence of Thermal Insulation Property of Window for the Korean Apartment House on the Annual Heating and Cooling Load

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ABSTRACT: This study is conducted to find out how the heating and cooling loads change by thermal performance by the dynamic heat load simulation program. The study results are as followings. (1) It is revealed that SC is changeable if a window is Low-E coated and by the colors of windows. U-value of window is highly related to the thickness and the kind of window rather than the colors of window. (2) The thermal insulation property of double window whose U-value is distributed $1 \sim 2 \text{ W/m}^2 \text{ K}$ is twice of the thermal insulation property of single window. The mean U-value of PVC window is about $1.0 \text{ W/m}^2 \text{ K}$ beneficial compared to the mean U-value of aluminum window, which is concluded that it is highly advantageous to take in consideration of the thermal insulation property. (3) As SC decreases by 0.1, it shows that annual heating and cooling loads decrease by approximately 5%. And as U-value of window increases by $0.5 \text{ W/m}^2 \text{ K}$, annual cooling and heating loads increase by approximately 15%. (4) The simulation results show that annual air-conditioning and heating load is different by 134% to the utmost, as it is appeared to be minimums of $213 \text{ MJ/m}^2 \cdot \text{yr}$ in case of U-value 0.6-SC 0.6 and maximum of $499 \text{ MJ/m}^2 \cdot \text{yr}$ in case of U-value 3.0-SC 0.4.

Keywords: U-value, heating and cooling load, simulation program

1. INTRODUCTION

1.1 Background and necessity of research

Since the United Nations Framework Convention and the Kyoto Protocol have become effective, the rational standards of

exhaust for greenhouse gas and reduction of energy consumption have been being reinforced in advanced countries. When it is considered that Korea has a high possibility of being included in the 2nd obligatory countries of Kyoto Protocol from 2013, it

appears obvious that the countermeasures should be considered urgently.

The ratio of the construction part in energy consumptions is up to 25%, which has been highly increased compared to transportation or industrial part. Accordingly, the standards of building insulation and thermal performance of building envelope should be reinforced and improved to decrease the energy consumption.

It is shown that a lot of heat loss is occurred at windows of building envelopes by thermal weakness in winter, and the increase of heat loads due to solar radiation from windows in summer. Especially, 20~40% of heat loss in residential houses and 13~35% in office buildings are occurred at windows [1], and the ratio increases if windows areas are bigger. Windows, however, the essential parts for ventilation and lighting functioning to control indoor environments are regulated to be installed more than 1/10 areas of floors.

These characteristics of windows show that the primary approaching measure can be considered from windows to improve the indoor environments and reduce energy consumption. That is, the research on the thermal performance of window has to be precede and the thermal performance of window according to the specifications and kinds of window has to be estimated quantitatively.

Accordingly, in this study, it is conducted to analyze air-conditioning and heat loads and the efficiency of the energy saving and a basic research is processed to make it possible to choose appropriate windows in planning.

1.2 The process and the scope

This research aims to offer database of window thermal performance for an apartment house to select the optimum window at the design phase, so this research investigated thermal insulation property of Korea windows.

Based on this, firstly the heating and cooling loads were calculated by using a dynamic heat load simulation program to analyze the efficiency of the energy saving. And the cooling and heating loads were converted to the primary energy, the energy consumption by the thermal performance are estimated.

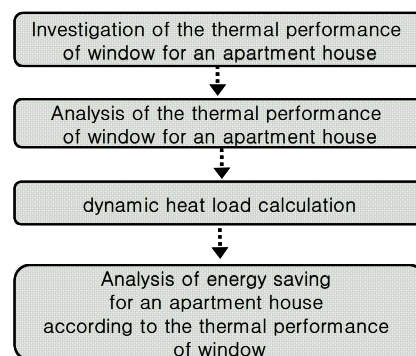


Figure 1: Flow chart of research

2. INVESTIGATION OF THE THERMAL PERFORMANCE OF WINDOW

2.1 Regulations and Standards related to the thermal performance of window

Related to the thermal performance of window, it is stated about U-value of building envelope in Clause 21 of the building law-‘Regulation of building services standard’ and Clause 22 of the same law makes a statement about the average of building envelope and the performance of air tightness in ‘Investigation of Energy Performance Index(EPI) of buildings’ that tender energy saving. Especially the standard of U-value of building envelope is tighter from $3.84\text{W}/\text{m}^2\cdot\text{K}$ to $3.00\text{W}/\text{m}^2\cdot\text{K}$ (central part of Korea), it is expected to increase the energy efficiency of the building.

However, the strengthened standard as seen in Table I is not that high level yet compared with thermal insulation standard of major industrialized nation-United States, Japan and Germany etc, so coming 2010 the tighter standard that lowers U-value of window to $2.3\text{W}/\text{m}^2\cdot\text{K}$ and requires Low-

E(Low Emission) glass as a must is suggested[2].

Table 1: Standard of U-value for each country

	U-value [W/m^2K]			
	central area	south area	Jeju	
Korea	3.00	3.30	4.20	
Japan	I·II	III	IV·V	VI
	2.33	3.49	4.65	6.51
German	1.5~2.0			
U.S.A.	2.2~2.9			

2.2 Investigation of the thermal performance of window for an apartment house

The thermal performance of window is decided by SC(shading coefficient) of window glass and whole U-value of glass and frame.

To investigate the thermal performance of window this research rearranged SC and U-value of window glass of premier Korean company that has led the glass industry in sales, and investigated U-values of 71 window products for an apartment house of 5 Korean major companies.

SC and U-value of window is changed by the thickness of glass, the composition of glass-single glass, pair glass, triple glass, the color of glass and the kinds of Low-E coating.

U-value is determined by the thickness of glass, the composition of glass and SC is determined by the color of glass and the kinds of Low-E coating rather than the thickness and the kinds of glass.(See Table 2, Figure 1).

Table 2: U-value of window glass according to the kind of glass

		Float glass		Pair glass				Low-E Glass	
Thickness[mm]		6	12	16	18	22	24	22	24
Sample[n]		5	5	4	4	4	4	8	23
U-value [W/m^2K]	Min								
	[color:bronze/silver]	5.8	5.6	3.1	3.1	2.7	2.7	1.8	1.7
	mid								
	[color:blue/green]	5.8	5.6	3.1	3.1	2.7	2.7	1.8	1.8
	Max								
	[colorless]	5.8	5.6	3.1	3.1	2.7	2.7	1.8	1.8

Figure 2 shows that SC of Low-E coated glass is lowered to the maximum of 0.4 point as compared with pair glass and the SC of the low-reflection glass such as silver and bronze colored glass is low, and the SC of blue, green and transparent glass gets high.

Like this, the kinds of window glass are important factors that determine SC and U-value of window.

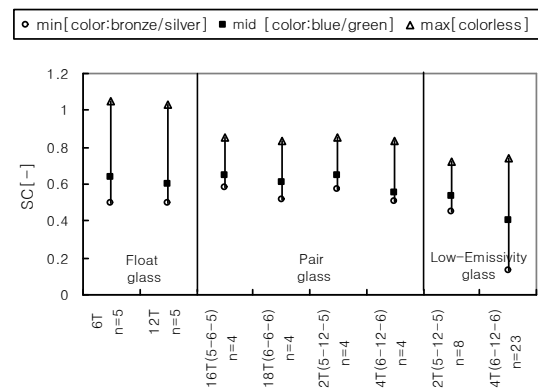


Figure 2: SC of window glass according to the kind of window glass

U-value of the thermal performance is influenced by the kinds of window frames and spacer as well as by the kinds of glass.

The balcony windows, the major object of this investigation, were mostly PVC window using 16mm pair glass(glass 5mm-air 10mm-glass 5mm), and the U-value of double window and system window for extended balcony was lower than $2.00W/m^2K$.

The window frames are classified into PVC and aluminum frame, and to improve the thermal insulation property PVC frame is mostly used or in case of using aluminum frame, Polyamide insulation or A-Zone insulation is universally applicable to decrease thermal flow.

But Figure 3 shows that the mean U-value of PVC window is $2.06W/m^2K$ and the mean U-value of aluminum window is $2.94W/m^2K$, so the thermal insulation property of aluminum window is low in spite of insertion of thermal break.

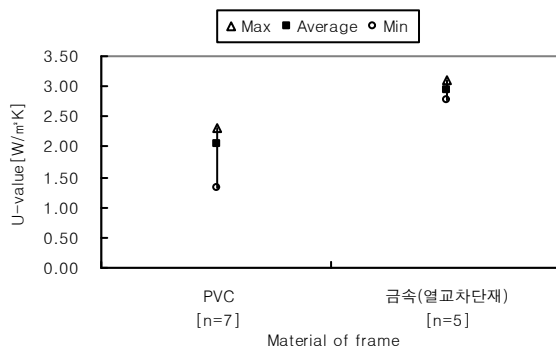


Figure 3: U-value of window according to the material of frame

As a result of the comparison of thermal insulation property according to the composition of window and kind of window glass, in case of the same thickness of glass, U-value of Low-E coated glass is lower about by $0.5 \text{ W/m}^2 \text{ K}$ and the thermal insulation property of double window whose U-value is distributed in $1 \sim 2 \text{ W/m}^2 \text{ K}$, which is twice of the thermal insulation property of single window(see Figure 4).

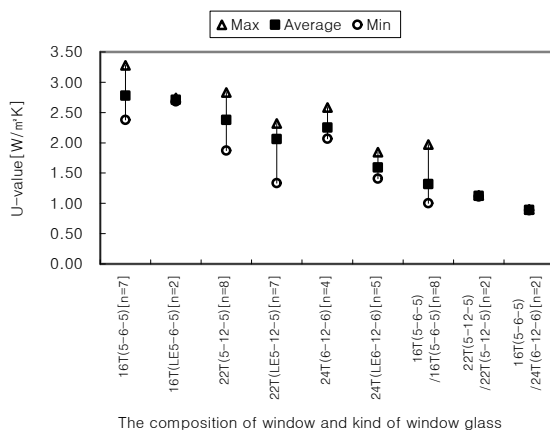


Figure 4: U-value of window according to the composition of window and kind of window glass

3. HEATING AND COOLING LOAD ACCORDING TO THE THERMAL PERFORMANCE OF WINDOW

3.1 The scheme of dynamic heat load simulation

This research used AE-CAD(CAD System for Architectural Environment) which supports simulation program related to architectural environment and Sim-Heat(Simulation Program for Heat Load) which is to calculate heat load and air flow. While other heat load simulation programs calculate heat loads by convection-radiation-combined heat transfer at the surface without consideration of the mutual radiation of wall, Sim-Heat calculates radiation heat transfer respectively, and is designed to verify the influence of radiation component in indoor heat transfer process [3].

The standard housing model-area of 85 m^2 , height of 2.8m, core and 3-bay type-was chosen for simulation(see Figure 5). And the windows-PSD1($3900 \text{ mm} \times 2400 \text{ mm}$) 1EA PSD2($2400 \text{ mm} \times 2400 \text{ mm}$) 2EA-were located at the south side and the other windows- PSD3($2300 \text{ mm} \times 2400 \text{ mm}$) 1EA, PSD4($1600 \text{ mm} \times 2400 \text{ mm}$) 1EA, PW1($900 \text{ mm} \times 500 \text{ mm}$) 1EA-were located at the north side.

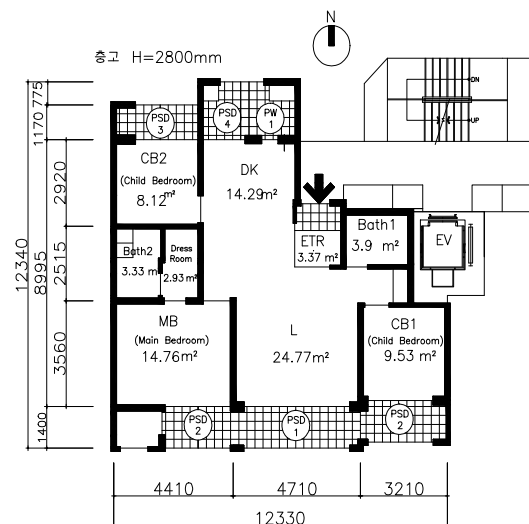


Figure 5: Standard house model

This simulation of this research was done to a sidewall house located at the top floor, therefore, was weak thermally because it was exposed to the air widely. Condition of thermal insulation property of building envelope was set according to 'Design

Standard for Energy Conservation' 2001(see Table 3).

Table 3: The thermal insulation property of each part

Part	U-value [W/m ² K]	Criterion [W/m ² K]
Sidewall and Outer wall exposed to the air directly	0.406	OK(≤0.47)
Sidewall and Outer wall exposed to the air indirectly	0.553	OK(≤0.64)
Roof(top floor) exposed to the air directly	0.267	OK(≤0.29)
Slab (heating from slab)	0.780	OK(≤0.81)

The calculation case for simulation was divided into Group-1 that only changed SC, with the U-value fixed in 2.50 W/m² K to estimate the annual heating and cooling load according to SC and Group-2 that only changed U-value, with the SC fixed to 0.6 to estimate the annual heating and cooling load according to U-value. And the simulation cases were re-sorted into Group-1-1, Group-1-2, Group-2-1, Group-2-2 by exhaust ventilation, because the heating load can be decreased over 30% with exhaust ventilation (see Figure 6).

Table 4: Simulation cases

Group-1		Group-2	
Group-1-1 : Exhaust ventilation*on Group-1-2 : Exhaust ventilation off		Group-2-1 : Exhaust ventilation on Group-2-2 : Exhaust ventilation off	
U-value [W/m ² K]	SC[-]	U-value [W/m ² K]	SC[-]
2.5	0.1	0.6	0.6
	0.2	0.9	
	0.3	1.2	
	0.4	1.5	
	0.5	1.8	
	0.6	2.1	
	0.7	2.4	
	0.8	2.7	
	0.9	3.0	
	1.0	3.3	

* Exhaust ventilation: If indoor temperature rises over 26°C, windows are opened to exhaust warm air of the room.

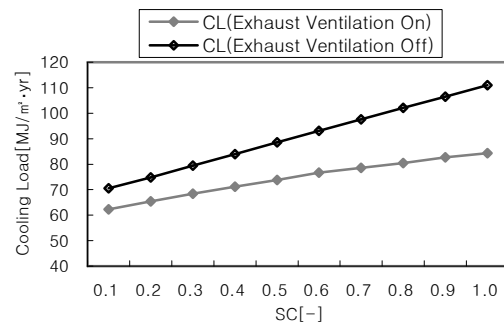


Figure 6: The cooling loads according to SC of window

3.2 Cooling and heating load according to SC and U-value of window

Shading Coefficient (SC) indicates the ratio of the solar heat gain which passed through a glazing system from outside to inside of the building. If SC is low, that means that the amount of solar heat gain is decreased as well as that of solar radiation.

Figure 7 presents the result of annual heating and cooling load according to the change of SC, with U-value fixed at 2.50W/m² K. There is a sharp decrease in heating load and little increase in cooling load when the SC of window rises. In case of exhaust ventilation, when SC increases from 0.1 to 1.0, annual thermal load decreases by 42%, that is, annual thermal load is decreased by 5% with increase of SC by 0.1.

Solar heat gain with increase of SC is of great advantage to the reduction of heating load in winter.

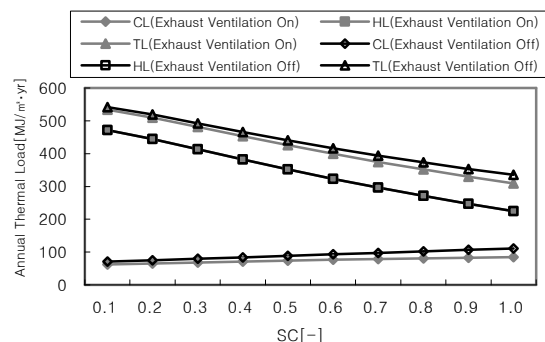


Figure 7: Cooling and heating loads according to SC of window

U-Value is an important measure to estimate the rate of heat loss according to the kinds of materials. The window with low U-value means that the thermal insulation property of window is high. As see Figure 8, there is a sharp increase in heating load and little decrease in cooling load when the SC of window rises. In case of exhaust ventilation, when U-value of window increases from $0.6\text{W/m}^2\text{K}$ to $3.3\text{W/m}^2\text{K}$, annual thermal load increase by 121%, that is, annual thermal load is decreased by 15% with decrease of U-value by $0.5\text{W/m}^2\text{K}$.

The reason why the cooling load is almost same is that solar heat radiation from window can be let out easily as the form of heat transmission.

In case of this standard house model that heating load is much more than cooling load, total annual thermal load is increased as U-value of window increase.

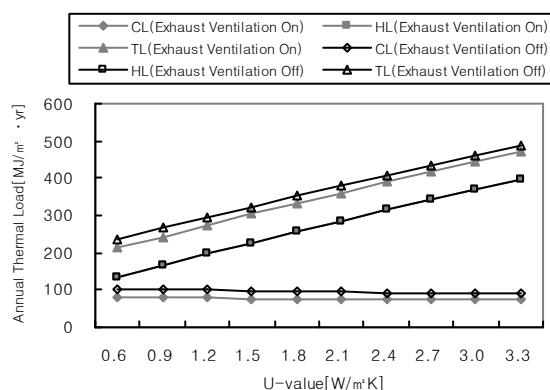


Figure 8: Cooling and heating loads according to U-value of window

As a result of simulation, annual thermal load and SC of window are in inverse proportion to each other and annual thermal load is directly proportional to U-value of window. Therefore the window with low U-value and high SC can be helpful to save the heating and cooling load of a house.

But U-Value and SC of window interact with each other, therefore the choice of appropriate window considering U-Value and SC of window is important to calculate exact annual thermal load.

4. THE CHOICE OF APPROPRIATE WINDOW TO SAVE COOLING AND HEATING ENERGY OF AN APARTMENT HOUSE

4.1 The conversion of cooling and heating loads into the primary energy

Heating and cooling load of a building has a direct effect on the energy consumption, which determines energy performance of buildings. Therefore in this study, heating and cooling load of house are converted to the primary energy consumption by which the reduction of energy consumption according to the thermal performance of windows can be estimated.

The process of converting heating and cooling load into the primary energy is as follows. First, it was supposed that a house is cooled by air conditioning system (COP 4) and heated by city gas boiler (COP 0.87). Figure 9 shows the process of conversion.

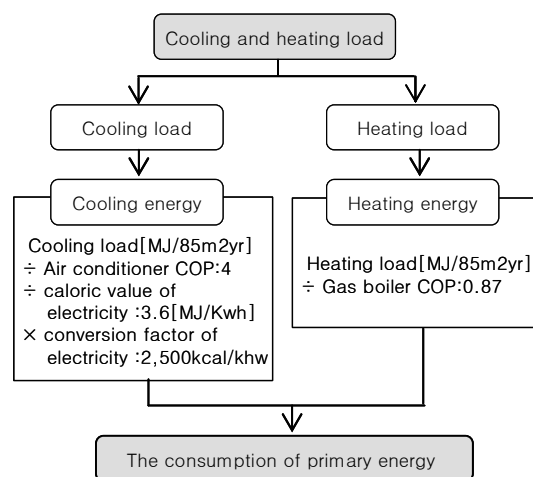


Figure 9: The process of converting cooling and heating loads into the primary energy

4.2 The choice of appropriate window to save cooling and heating energy of an apartment house

As previously stated, the heating and cooling load of house can be more than doubled by the thermal performance of

window, which means the choice of window is very important for improving the energy performance of house.

Figure 10, 11 are the graphs that present the relation between U-value, SC of window and the primary energy consumption of a house. As the same with the change pattern of annual thermal load in chapter 3, the lower U-value and the higher SC, the more the energy consumption of house is saved.

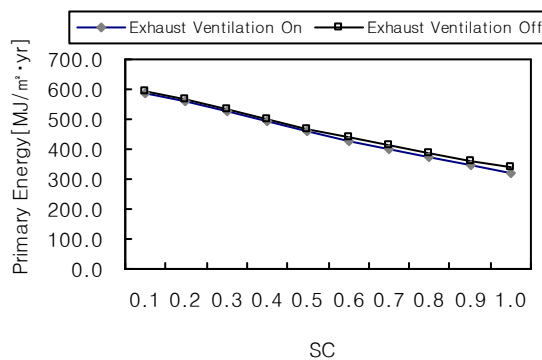


Figure 10: The consumption of primary energy according to SC of window

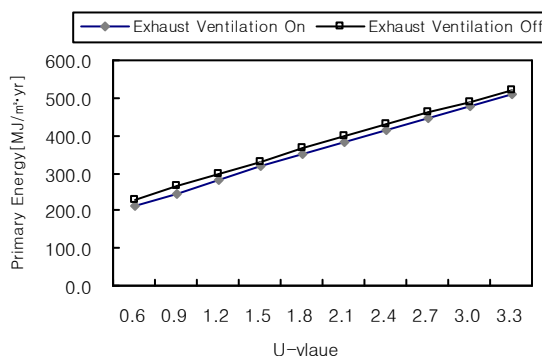


Figure 11: The consumption of primary energy according to U-value of window

That is, the house using the window of low U-value and high SC can reduce the cooling and heating energy. Accordingly, this study calculated the heating and cooling loads of 18 cases with different U-value and SC, analyzed the result of calculation to estimate the effect of energy saving according to the thermal performance of window (see Table 5).

Table 5: Simulation cases

	U-value [W/m²K]	SC [-]
Low-E Glass	0.6	0.2
		0.4
		0.6
	1.0	0.2
		0.4
		0.6
	1.5	0.2
		0.4
		0.6
Pair Glass	2.0	0.4
		0.6
		0.8
	2.5	0.4
		0.6
		0.8
	3.0	0.4
		0.6
		0.8

As the results of simulation, the annual thermal load of case U0.6-SC0.6 is the lowest 213 MJ/m²·yr and the annual thermal load of case U3.0-SC0.4 is the highest 499 MJ/m²·yr, which means the energy consumption of house can be different by 134% (see Figure 12).

Also the cases including U1.0-SC0.4, U1.5-SC0.6, U3.0-SC0.8 showed the results ranging from 303 to 306 MJ/m²·yr, which mean there are no meaningful differences each other. The cases including U1.5~SC0.2, U2.0-SC0.4, U2.5-SC0.6, U3.0-SC0.8 showed 400~414 MJ/m²·yr, The cases of U1.5-SC0.4, U2.0-SC0.6, U2.5-SC0.8 resulted in 352~355 MJ/m²·yr, which also mean that there do not exist remarkable differences. With these results, it can be said that there can be no major changes in annual cooling and heating load even though the U-value increases by 0.5 W/m² K, if the SC goes up by 0.2 at the same time (see Figure 12).

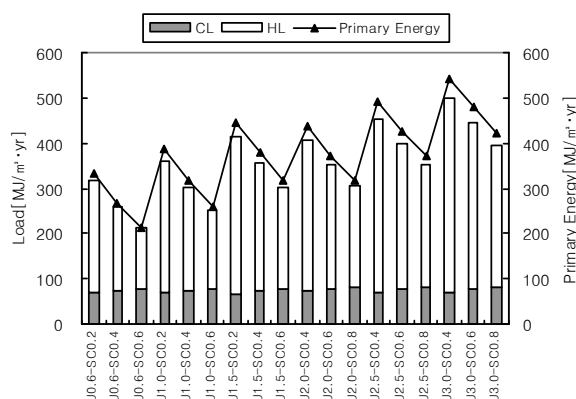


Figure 12: Cooling & Heating load and the consumption of primary energy by each case

Consequently, to improve energy performance of house through window, there are two ways. First, U-value of window can be decreased by using Low-E glass, pair glass or using the frame with low conductance. Second, SC can increase by using the glass with low SC like green, blue color or colorless glass. And the latter can save installation expense of window, that is, more economical than the former.

5. CONCLUSION

This study is conducted to find out how the air-conditioning and heating loads change by thermal performance by the dynamic heat load simulation program.

The study results are as followings.

(1) It is revealed that SC is changeable if a window is Low-E coated and by the colors of windows. U-value of window is highly related to the thickness and the kind of window rather than the colors of window.

(2) The thermal insulation property of double window whose U-value is distributed 1 ~ 2W/m² K is twice of the thermal insulation property of double window. The mean U-value of PVC window is about 1.0W/m² K beneficial compared to the mean U-value of aluminum window, which is concluded that it is highly advantageous to take in consideration of the thermal insulation property.

(3) As SC decreases by 0.1, it shows that annual air-conditioning and heating loads decrease by approximately 5%. And as U-value of window increases by 0.5W/m² K, annual air-conditioning and heating loads increase by approximately 15%. Consequently, it is shown that it is advantageous to take a window whose U-value is low, but whose SC is low as well.

(4) The simulation results show that annual air-conditioning and heating load is different by 134% to the utmost, as it is appeared to be minimums of 213 MJ/m²·yr in case of U-value0.6-SC0.6 and maximum of 499MJ/m²·yr in case of U-value3.0-SC0.4.

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