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Ecological Dimension in the Development of the Standard for Energy-Efficient Building Material

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Keywords

Shading coefficient, solar absorption, thermal transmittance, visible light transmittance

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ABSTRACT

This study developed minimum requirements for energy-efficient material of campus building in Yogyakarta based on overall thermal transfer value (OTTV) and daylighting criteria. Measures of energy efficiency are 150-200 lux with minimal 80% for the daylighting distribution and 45 W/m^2 for the maximum OTTV. Certain window to wall ratio (WWR) was defined based on the simulation results of the daylighting level and the distribution with considering the feasibility factor. Minimum requirements for the thermal transmittance (U), the shading coefficient (SC), the solar absorption (a) and the visible light transmittance (VT) were generated from the OTTV calculation of the classroom, which meets the OTTV and the daylighting criteria. The material's embodied energy was considered in setting several combinations of SC, VT, a and U for each window orientation and typical WWR. The results show that in warm humid areas lower SC and light color surface are more effective in raising energy-efficient building than lower U glazing. Low-U glazing should be avoided since it contains high embodied energy. Defining specific requirements for each window orientation and typical WWR resulted in higher standard value of U, which then offers more possibilities in the design exploration and selecting low embodied energy materials.

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1. INTRODUCTION

Overall Thermal Transfer Value (OTTV) has been established as Indonesian National Standard for energy conservation on building envelope (SNI 03-6389-2000). OTTV formula is used as a control measure for thermal performance of air conditioned building envelope. It prescribes 45 W/m^2 for the maximum heat transfer through the building envelope [1]. In this standard daylighting aspect having important contribution in energy efficiency, (visual) comfort, health and maintaining positive psychological effect for occupants is excluded. This formula is also not simple for common people and architect, since long calculation must be done to obtain the value.

Several material standards had been established to achieve energy-efficient building envelope. CNMI Tropical Energy Code [2] prescribes maximum thermal transmittance value (U) for the material envelope of air conditioned buildings, and maximum solar heat gain coefficient (SHGC) for the fenestration. Roof constructions should meet the requirements for thermal transmittance and reflectance. It also prescribes air leakage of the fenestration and other openings. CNMI Tropical Energy Code defined some requirements depending on the material type and the building type, such as: non-residential, high-rise residential and low-rise residential. No controls in optical property for daylighting aspect, but only in the opening area.

International Institute for Energy Conservation (2006) has developed Energy Conservation Building Code to provide minimum requirements for the energy design building and construction [3]. Insulation materials, U, SHGC and air leakage of the building envelope should comply the mandatory requirements which are specific for each climate zone. Minimum visible transmittance (VT) is prescribed as a function of the window to wall ratio (WWR). Maximum WWR of vertical fenestration is limited to 40% for all building-types. The scope of Energy Conservation Building Code is more complete than CNMI Tropical Energy Code. It covers 5 climate zones, i.e. composite, hot-dry, warm-humid, moderate and cold. Prescriptive requirements in daylighting are provided in detailed.

Strict requirements, however, limit creativity in building design. For example, 40% of the maximum WWR is sometimes too small or too large for some building types. It should be noticed that window benefits indoor daylight level and also physiological and psychological effect of view area to outside. Energy efficiency is only one of ecological indicators. Natural resource sustainability, human health, comfort and productivity also should be considered in recent developments to avoid the increasing of environmental disaster. Considering the ecological dimension, new material standard for energy efficient building envelope would be developed based on the study of CNMI Tropical Energy Code, Energy Conservation Building Code 2006 and SNI 03-6389-2000. The implementation area of this study is limited for Yogyakarta and campus building type only. Since specific type has different criteria in opening area and building appearance, specific requirements will offer possibility for architects to design more comfortable and human building.

2. ENERGY CONSERVATION BUILDING CODES AND ECOLOGICAL INDICATORS

SNI 03-6389-2000 provides standard for energy-efficient building envelope measured by the Overall Thermal Transfer Value (OTTV). OTTV measures the conductive heat gain through the opaque and the transparent building envelope and the radiative heat gain through the transparent area. A building envelope can be classified as energy efficient if the OTTV does not exceed 45 W/m^2. SNI 03-6389-2000 uses the following formulae to calculate the value of all building types:

$$OTTV = a.[(U_w \times (1-WWR)] \times TD_{EK} + (SC \times WWR \times SF) + (U_f \times WWR \times DT) \qquad (1)$$

Formulae (1) describes the effect of material properties on the value represented by the thermal transmittance of the wall (U_w) and the fenestration (U_f), the solar transmittance of the window (SC) and the solar absorption of the wall (a). U describes the performance of material in transporting heat from outside to inside in a steady state conditions. In warm humid areas U functions to prevent outdoor warm air flowing quickly to indoor cool air that occurs in mechanically ventilated buildings. Each material has specific U due to its thermal conductivity, the thickness and the density. Conductive heat transfer across fenestration depends on the temperature difference between the indoor and the outdoor (DT). The heat transfer across wall is determined by the equivallent temperature difference (TD_{EK}) and the solar absorption of the wall (a). According to SNI 03-6389-2000 generated value for DT is 5 K and for TD_{EK} is 15 K [1]. By comparison, the Building Control Regulation of Singapore set 12 for the combination value of TD_{EK} and a, and 3.4 for the value of DT [4].

Maximum U prescribed in CNMI Tropical Energy Code is described in Table 1.

Table 1: Maximum U in $W/m^2.K$ [2]

Building construction	Wall	Roof	
		Non & high rise residential	Low rise residential
Mass	none		
Metal building	0.642	0.369	0.369
Steel framed	0.704		
Wood framed and others	0.505		
Insulation directly fastened to deck		0.409	0.409
Attic and others		0.193	0.153

Whereas International Institute for Energy Conservation sets maximum U for warm humid zone such as Table 2.

Table 2: Maximum U ($W/m^2.K$) in warm humid zone [3]

Building element	24-hour use buildings (hospitals, hotels, call centers)	Day time use buildings and other building types
roof	0.261	0.469
wall	0.352	0.352
vertical fenestration	3.177	
Skylights with curb	11.240	
Skylights without curb	7.717	

In SNI 03-6389-2000 SC consists of SC of the glazing (SC_1) and SC of the shading (SC_2). Shading Coefficient (SC_1) is the ratio of the solar heat gain of a particular glazing relative to that of 3 mm thick clear glass at normal incident. Recently solar heat gain coefficient (SHGC) replaces SC as a measure of the fraction of heat gain of solar radiation through the fenestration. The SHGC of a fenestration is approximately equal to the SC multiplied by 0.87.

Prescription of maximum SHGC developed by CNMI Tropical Energy Code depends on the element of the building. SHGC of glass should meet a maximum of 0.4 and the plastic skylight should not exceed 0.35. International Institute for Energy Conservation set the limits of WWR. Vertical fenestration shall comply with a maximum SHGC of 0.25 for a maximum WWR of 40%. Whereas, the maximum SHGC for skylights with maximum Skylight Roof Ratio of 2% is 0.4 and the skylights with maximum Skylight Roof Ratio of 5% is 0.25.

No daylighting aspect is considered in SNI 03-6389-2000. Meanwhile, daylighting contributes up to 15% of the building energy according to the energy consumed by lighting during clear daytime. Building's heat load calculates the energy for lighting as internal heat gain. However, an excessive daylighting produces overheating. CNMI Tropical Energy Code sets only daylit area control [2]. Minimum VT requirements based on the WWR are provided in Energy Conservation Code 2006 [3].

Energy conservation concerns only one part of environmental system. Ecological indicators had been developed in building construction to avoid environmental depletion due to the building construction, occupancy and demolition. Some indicators measure the contribution of building materials in energy conservation and environmental pollutions. Since 40% to 50% of total flows of raw material yearly extracted worldwide are used in manufacturing building products, an environmental conscious in selecting building materials should be assessed based on environmental requirements. Giordano and Torresan [5] developed 11 ecological indicators based on the environmental requirements, i.e. production energy, transportation, thermal transmittance, thermal inertia, expected life span, construction system, recycling scenario, CO_2 equivalent, occurrence of acidification and toxic substance. Embodied energy (in MJ/kg or MJ/m^3 or MJ/m^2 for some materials) measures the energy consumed during the manufacturing process and transportation of building material. Some cases prefer to use carbon footprint (kg CO_2/kg) to describe the amount of CO_2 emissions for the whole product's life cycle.

In developing countries the amount of conventional energy used by manufacturing process and transportation of building material is considerable. Embodied energy of the same material can vary over wide area due to different technology and man power employed in production stage. No study reported the embodied energy as well as the carbon footprint of common building material in Indonesia. Values developed by Indian and other countries for the rests will be adopted as references. Similar conditions in building material production may result in the same amount of the embodied energy [6].

3. METHOD

New material standard will develop minimum requirements for 4 material properties of the building envelope performing the heat load and the daylighting, i.e. U, a, SC and VT. To keep the accuracy, applications of the standard were limited to campus building type in Yogyakarta. Referring SNI 03-6389-2000, standard values of U, SHGC, a and VT should meet the requirement of OTTV ($\leq$45 W/m^2) and the daylighting criteria for classroom and office, i.e. 150 lux to 200 lux for the average daylighting level with $\geq$ 80% for the indoor daylighting distribution [7].

To develop the material-property standard, simulation and analytical methods were conducted to study the energy performance of campus building in Yogyakarta. Simulation models were constructed based on 3 real-campus buildings. The analysis was based on the Ecotect-Radiance simulation results of the daylighting level and the distribution to define typical WWR and proper external SC (SC_2) of campus building. The function of window area in providing view to outside can be measured by its feasibility factor. If obstruction outside is minimal, the feasibility factor is the result of multiplying the WWR and the VT. The value should be more than 0.25 [8]. This window is considered as view window. Window having feasibility factor less than 0.25 was classified into non-view window. This can be applied for classroom without a need of view to outside, such as: computer laboratory, workshop classroom and examination room. Simulation variation in the interior surface reflectance and the glazing VT was done to obtain specific daylighting criteria for each window orientation in energy-efficient campus building. Interior surface reflectances for classroom recommended by IESNA are 70-90% for the ceiling, 40-60% for the wall and 30-50% for the floor [9]. Variations in interior surface reflectance are simulated in two conditions, i.e. high reflectance (the maximum recommended value) and medium reflectance (the minimum recommended value). Each variation might have consequence to change the requirement of the glazing VT.

The OTTV was calculated using the formulae in SNI 03-6389-2000. Ecotect's simulations of the fabric heat gain and the direct solar heat gain were considered as a secondary value of the envelope's heat transfer. The simulations were done under such conditions: the maximum air leakage for glazed swinging entrance doors and revolving doors were 5 l/s.m^2 and for other fenestration and doors were 2 l/s.m^2 [3].

Maximum requirements were obtained by combining value of the U, the *a* and the SC with the OTTV of 45 W/m^2. Since flexible material criteria offer more creativity in design, several combination values of the U, the SC and the *a* for specific orientation were developed. U varies in 3 ranges of value, i.e. high U ($4.2 \geq U_{wall} > 3$ and $7.4 \geq U_{glazing} > 6$), medium U ($3 \geq U_{wall} > 1.5$ and $6 \geq U_{glazing} > 3$), and low U ($1.5 \geq U_{wall} > 0.75$ and $3 \geq U_{glazing} \geq 0.6$). Common wall materials have medium U, whereas low U should be achieved by adding thermal insulation. Low $U_{glazing}$ can be achieved by adding the layers and air space in between, such as: double/triple glazing. It is possible, however, to set higher value of U for maximum requirement of the OTTV.

Maximum requirement of SC was defined in daylighting analysis. The SC can be derived in several combinations of SC_1 ($SC_{glazing}$ or SHGC) and SC_2 (external shading or $SC_{shading}$). Glass block and multilayer glazing are examples of glazing with low U, which has low SC. Glazing with low SC may have high U, such as: tinted single glazing. Usually low $SC_{glazing}$ has low VT. Only special glazing, such as: multilayer glazing with low-e outer coating and some glass blocks, have a combination of low SC and low U with medium VT. Variation in *a* also was set in 2 ranges, i.e. low a ($0.2 \leq a \leq 0.5$) and high a ($0.5 < a \leq 0.8$). Surface with low *a* can be raised by light color painting. The embodied energy was taken into account in defining ecological combination values of material properties.

4. RESULTS AND DISCUSSIONS

4.1 Typical WWR and External SC for Campus Buildings

Campus buildings dominated by classrooms have typical WWR. A quite wide window should be provided to allow airflow and daylight entering the classrooms. Concerning the energy conservation, daylighting and natural ventilation are recommended for mechanically ventilated classrooms as long as the outside conditions are supporting. Although the recent ICT based learning need low lighting to display images transmitted by LCD projector, openings are still required to provide evacuation and positive psychological effects and avoid boredom. Nowadays, projector with new technology can work in medium light level.

Three campus buildings have different average WWR. Campus Building I has highest WWR (0.45), whereas Campus Building III has lowest WWR (0.19). Thirty to forty percent of window area provides enough view to outside without bothering the students' concentration. At least 0.85 of VT for 30% to 40% of WWR will be required to achieve more than 0.25 for the feasibility factor. Less than 30% of window area is recommended only for classrooms which no need view to outside, such as: audiovisual room or computer laboratory. Simulations under existing reflectances (higher than the maximum value) without environment created sufficient daylit rooms in three classrooms in Campus Building II (Figure 1).

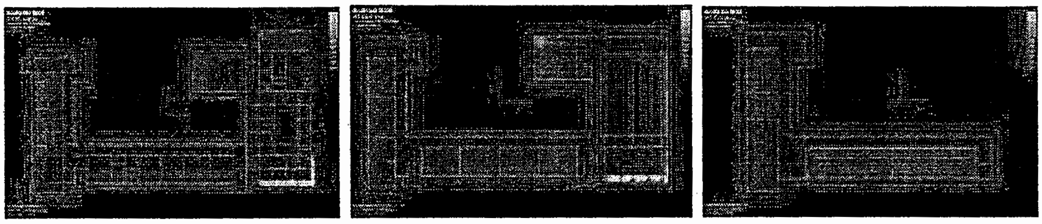

Figure 1: Daylighting simulation results of the 3rd floor (left), the 3rd floor (middle) and the 4th floor (right) of Campus II

When the reflectances reduce to maximum value, i.e. 60% for the wall, 90% for the ceiling and 50% for the floor, only Room 2402 meets the criteria. Table 3 presents the daylighting performances of the rooms. Most of window areas are shaded against the sun ($SC_{shading} \approx 0$). Although the $SC_{glazing}$ is relative high, the wide external shading devices creates low average SC. Sufficient daylighting levels were achieved by reflected sunlight. These low SC helped the building envelope to raise low thermal transfer value or OTTV. Larger room needs higher SC to achieve sufficient daylighting level and distribution. Sufficient daylighting levels with even distributions cannot be achieved when the interior reflectance was decreased into minimum recommended values. The SC must be increased to meet daylighting criteria under such condition. However, increasing of the SC can lead into more than 45 W/m^2 of the OTTV. To meet the daylighting criteria, high interior surface reflectance, therefore, is more effective than increasing the VT.

Table 3: Daylighting performance of existing rooms

Classrooms and areas (m^2)	Orientation	WWR	$SC_{shading}$	Average SC	$SC_{glazing}$	VT	Average daylighting levels (lux)	Daylight distribution
Reading Room 269.8	North	0.37	0.013	0.015	0.94	0.87	150	73.1%
	South	0.37	0.003		0.94			
	West	0.37	0.031		0.94			
Architecture Studio 401.2	North	0.37	0.030	0.028	0.94	0.87	150	78.9%
	South	0.37	0.006		0.94			
	West	0.37	0.048		0.94			
Room2402 156.8	North	0.30	0.001	0.011	0.94	0.87	150	98.3%
	South	0.39	0.022		0.94			

Simulations with lower VT changed the daylighting performances (Table 4). It will be better to keep the VT as low as possible to maintain the daylight distribution and to avoid overheating. Glazing with high VT usually has high SC. Reduction of the WWR will achieve moderate daylighting level, but it potentially reduces the daylight distribution.

Table 4: Daylight distributions of Room 2402 in maximum and minimum of VT

Corridor orientation	VT	Reflectances				Daylight distribution
		wall	ceiling	floor	average	
North	0.87	0.50	0.90	0.50	0.63	97.1%
	0.65	0.60	0.90	0.50	0.67	82.3%
South	0.87	0.60	0.90	0.50	0.67	99.7%
	0.60	0.50	0.90	0.50	0.63	80.3%
West	0.87	0.60	0.90	0.50	0.67	81.9%
	0.75	0.60	0.90	0.50	0.67	82.3%
East	0.87	0.63	0.90	0.53	0.69	80.7%

4.2 Combinations of U, a, SC and VT

Calculations of room 2402 with variation in corridor orientation show that the average OTTVs and the total envelopes' heat gain are less than 45 W/m^2 (Table 5). Simulations with variation in orientation show that the same dimension of external shading may have different value of SC if the orientation changes. Since the OTTVs are higher than the heat gain through the envelope, implementation of the standard based on OTTV formulae will produce lower envelope's heat gain than that based on total envelope heat gain.

Table 5: The OTTV and the heat gain through envelope per area

Corridor orientation	Wall areas (m^2)	Wall orientation	WWR	SC	OTTV (W/m^2)	Fabric heat gain (W/m^2)	Direct solar gain (W/m^2)	Total envelope heat gain (W/m^2)
North	56.4	North	0.30	0.001	28.77	14.14	8.81	22.95
	56.4	South	0.39	0.022	29.94			
South	56.4	South	0.30	0.000	28.72	13.95	9.54	23.50
	56.4	North	0.39	0.026	30.47			
East	56.4	East	0.30	0.016	29.59	15.86	13.53	29.40
	56.4	West	0.39	0.072	32.31			
West	56.4	West	0.30	0.013	29.33	15.46	15.42	30.89
	56.4	East	0.39	0.075	34.23			

Total heat gain through the envelope of each orientation is lower than the average OTTV. It means that an envelope having less 45 W/m^2 for the OTTV will transfer heat gain lower than the OTTV. Probably the DT and the TD_{EK} are higher than the real values.

4.3 The ecological dimension in setting the material standard

Several combinations of SC, U, VT and a as minimum requirements for energy-efficient building material with 0.35 to 0.42 of the WWR are presented in Table 6. These combinations are valid for 0.35 to 0.42 of the WWR. Values put on the Table 6 were based on these considerations:

- Material with lowest (combination) value should be available in the market or possible to produce.

- Window with high VT usually has high $SC_{glazing}$.
- Low-U_{wall} is ecollogically preferable than low-$U_{glazing}$.

Low solar absorption (light color paint) is an effective and simple method to reduce the OTTV. Lower SC reduces the OTTV faster than lower U. An envelope oriented to south without shading (external shading = 0.55) is possible to have high $SC_{glazing}$ and $U_{glazing}$, such as 5 mm clear glass, but the opaque envelope should be insulated. An envelope with narrow shading should be light color painted, whereas an envelope without shading, except an envelope oriented to South, must use medium $SC_{glazing}$. Glazing types having $SC_{glazing}$ medium and medium $U_{glazing}$ are optilight or solarplus.

Table 6: Recommended combinations of VT, SC, U and a

Orientation	Min. VT	Minimum interior reflectance (wall; ceiling; floor)	Maximum total SC		Max. U_{wall} ($W/m^2.K$)	Max. $U_{glazing}$ ($W/m^2.K$)	Max. a
			$SC_{shading}$	$SC_{glazing}$			
North	0.65	0.60; 0.90; 0.50	0.011	0.94	4.13	7.40	0.80
			0.400	0.94	1.75	7.40	0.30
			0.55*	0.60	4.00	6.00	0.30
South	0.60	0.50; 0.90; 0.50	0.011	0.94	4.15	7.40	0.80
			0.400	0.94	3.85	7.40	0.30
			0.55*	0.94	1.00	7.40	0.30
West	0.75	0.60; 0.90; 0.50	0.011	0.94	4.13	7.40	0.80
			0.400	0.94	1.71	7.40	0.30
			0.55*	0.60	4.00	6.00	0.30
East	0.87	0.63; 0.90; 0.53	0.011	0.94	4.11	7.40	0.80
			0.400	0.94	1.28	6.00	0.30
			0.55*	0.60	2.64	6.00	0.30

Note: *) Fifty five percent is the yearly $SC_{shading}$ value of envelope without external shading.

Each combination above has its own consequences. Reduction of U of the same material needs to increase the thickness. It means that material with lower U has higher embodied energy. Cavity with proper thickness and number can decrease the material's U without adding the material in large volume. However, it must be considered that thicker material consumes larger space. It is unpracticable to raise very low U by adding the thickness. Adding thermal insulation is a practical method to achieve low U below 1 $W/m^2.K$. Cellulose is a kind of insulation with relative low embodied energy [10].

Low-U glazing can be achieved by two methods. The first is by adding the thickness. As glass (40060 MJ/m^3) has relative-high embodied energy [11], adding the thickness should be avoided. The second is by adding air space between the layers. Suggested fill gases having low-embodied energy are air and argon (11.85 KJ), although they produce higher U compared to krypton (508.2 MJ) and xenon (4.5 GJ) [11]. Several advanced (double) glazing can achieve 0.6 $W/m^2.K$ of the U, such as: vacuum windows with two glass layers, a narrow spacing, and a low-E coating; aerogel windows filled with highly insulating silica aerogel and transparent honeycombs, inserted between glass panes. The last two types are ecologically recommended than triple glazing. Low-U wall usually has lower embodied energy than low-U glazing.

Light color interior surface can help the interior to achieve sufficient daylight level with even distribution, whereas, light color exterior surface is effective to reduce the envelope thermal transfer value. Choosing light colored paint is also an ecologically recommended. Light color reduces the OTTV effectively without adding the material volume. Same material with different color has the same embodied energy. Although solvent based paint (128 MJ/l) has higher embodied energy than water based paint (115 MJ/l) at the same volume, the embodied energy per area is lower. Painting with solvent based (6.1 MJ/m^2) for the same wall area expends more energy per square area than that with water based (7.4 MJ/m^2). Painting the interior surface with light color is less expensive than replacing the glazing with higher VT or increasing the SC. Light color painted exterior surface is less expensive and easily applied than replacing the wall with lower U. Therefore, high exterior/interior surface reflectance is highly recommended for energy efficient buildings. It must be noted that an external surface with too light color potentially creates glare. Planting high tree with proper dense foliages can reduce the glare produced by the light color surfaces.

Low SC can be achieved by two methods. The first is by choosing glazing with low SC or SHGC. Heat absorbing glass, reflective glass, and Low-E glass are kinds of glazing with low SC. They are produced by adding metallic coating to prevent significantly reduction of the VT. Low-e coating adds 8.42 MJ/IG unit to the embodied energy [11]. Installing large shading above the window is the other method to reduce the SC. Higher SC of the glazing can be applied as long as the cumulative SC remains the same. The increasing of the embodied energy due to the lower value of the SC, however, is too complicated to estimate. Shading can be made of any material with large variations in design. It should be noted that enlarging the shading should be followed by increasing the VT of the glazing in order to maintain the daylight level. However, glazing with high VT usually has higher glazing SC. An envelope without shading is difficult to raise energy efficiency, since it requires low glazing SC and U, but high VT. Planting high tree with proper dense foliages can behave as external shading with low SC and embodied energy. Vegetative shading with lower SC is ecologically recommended in creating low SC than glazing with lower SC. However, the energy (embodied energy and energy for building operation) saving should be compared to the benefits of psychological effects, visual and thermal comfort produced by the envelope design.

Heat gain simulations of the recommended combinations with large external shading and those with medium external shading were done to examine whether a classroom with such combinations has a maximum of 45 W/m^2 for the envelope heat gain. Simulation results present on Table 7. The maximum envelope heat gain is 45 W/m^2 reached by model oriented to South with wide external shading. Variation in annual solar intensity falling on the model envelope resulted in lower envelope heat gain of other models with different window orientation and external shading width. Overall results describe that recommended combinations can be applied to achieve energy-efficient building.

Table 7: Simulation results of the envelope heat gain of the recommended combinations

Orientation	VT	Interior reflectance	Total SC		U_{wall} (W/m^2.K)	$U_{glazing}$ (W/m^2.K)	a	Fabric heat gain (W)	Direct solar gain (W)	Envelope heat gain (W/m^2)
			$SC_{shading}$	$SC_{glazing}$						
South	0.60	0.50; 0.90; 0.50	0.011	0.94	4.15	7.40	0.80	3166	1885	45
			0.400	0.94	3.85	7.40	0.30	1162	1319	22
West	0.75	0.60; 0.90; 0.50	0.011	0.94	4.13	7.40	0.80	3224	1772	44
			0.400	0.94	1.71	7.40	0.30	1455	1195	23
East	0.87	0.63; 0.90; 0.53	0.011	0.94	4.11	7.40	0.80	2885	1027	35
			0.400	0.94	1.28	6.00	0.30	2117	798	26

7. CONCLUSION

Thirty five percent to fourty two percent of window area on 2 room-sides is the typical WWR for campus buildings in order to provide sufficient daylight level with even distribution and low heat gain. It is recommended to have low SC for the envelope than low U glazing. Low U glazing should be avoided in order to keep the embodied energy down. Low SC can be achieved by planting vegetation with proper leaf index area to create high shading effect with low embodied energy. Choosing material with light color is effective to reduce the OTTV and ecologically recommended. Minimum requirements for energy efficient building material respecting the WWR and the window orientation offer more possibilities to select eco friendly material and more opportunities for designers to develop their creativity and innovation in their design process.

It is suggested for the next study that more detailed requirements for the envelope material properties present in a matrix with standard for external SC presented in vertical and horizontal shadow angle or a list of vegetation. A simple and complete standard can help architects, building material industries and stake holders to achieve energy-efficient buildings.

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