

SELECTION OF THE EFFICIENT GLAZING FOR LOW ENERGY OFFICE BUILDING

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Abstract. Building's energy efficiency is already significantly determined at an early design stage of an architectural-constructive part. It is important already at that stage to select in terms of energy and daylighting effective glazing. In this paper, influence of the building's glazing characteristics on its primary energy demand is evaluated in a complex way, performing simulations of the annual energy demand sub hourly. Results show that in cool climate zone, to which Lithuania belongs, it is possible to decrease building's microclimate and lighting systems' energy demand to the level of low energy office building just with the selection of the efficient glazing characteristics. At the same time minimal requirements for daylighting are satisfied.

Keywords: low energy, office building, primary energy demand, daylighting, glazing characteristics, fenestration, simulation, EnergyPlus.

1. Introduction

Transparent parts of the facade are one of the essential constructive elements of the building and at the same time a weak part from the point of view of energy efficiency, because, despite characteristics of the glasses used, their heat transmittance (U -value) is always higher than coefficient of up-to-date wall constructions. Besides, intensive solar radiation may cause thermal or visual discomfort (Menzies and Wherret 2005; Šeduikytė and Paukštys 2008). Therefore energy efficient, properly oriented, sized and shaded windows are one of the key elements both for newly built and retrofitted buildings.

There are quite a few studies related to the energy efficient windows, analyzing different glazing characteristics and their influence on energy demands of energy-using systems. For example Gratia and De Herde (2003) performed a large number of parametric studies and analyzed the influence of various parameters (fenestration, orientation, glazing type and shading devices) on heating and cooling loads of the office building in Belgian climate. The purpose of the study was to give directions for architects to design energy efficient buildings with a good thermal indoor climate.

Many researchers have tried to define the most efficient fenestration. Ghisi and Tinker (2005) defined that in terms of lighting energy demand ideal window-to-wall ratio (WWR), depending on orientation and geometry of the room varies between 10 and 37 %. Su and Zhang (2010) evaluated heating and cooling energy demand of

the office building. They recommended WWR value from 40 to 50 % for the office building with clear glazing. Tzempelikos and Athienitis (2007) showed the influence of WWR on heating, cooling and lighting energy demand, as well as on daylighting (DL). They defined that sufficient WWR for a south-facing typical perimeter office in Montreal is 30 %.

Bodart and De Herde (2002) analyzed, how width of the office room, WWR, window location, orientation and light transmittance influence lighting energy demand and global (heating, cooling and lighting) primary energy (PE) demand of the office building. Meanwhile Franzetti *et al.* (2004) concluded that choice of the relative aperture rate ($\tau_1(A_{windows}/A_{floor})$, where τ_1 – glass light transmittance) is one of the most sensitive parameters influencing global energy needs of an office building.

Glazing influences building's heating, cooling, ventilation, HVAC auxiliary equipment and lighting energy demand (Fig 1) and as a consequence comfort parameters are affected as well. Till now only some of the mentioned studies emphasized the importance of taking into account the interaction between lighting and HVAC systems. Such a full complex assessment was made by Poirazis *et al.* (2008). Authors have analyzed 7 different glazing alternatives for the office building in Swedish climate and showed influence of different parameters (type and size of windows, type and position of shading devices, etc) on total energy demand.

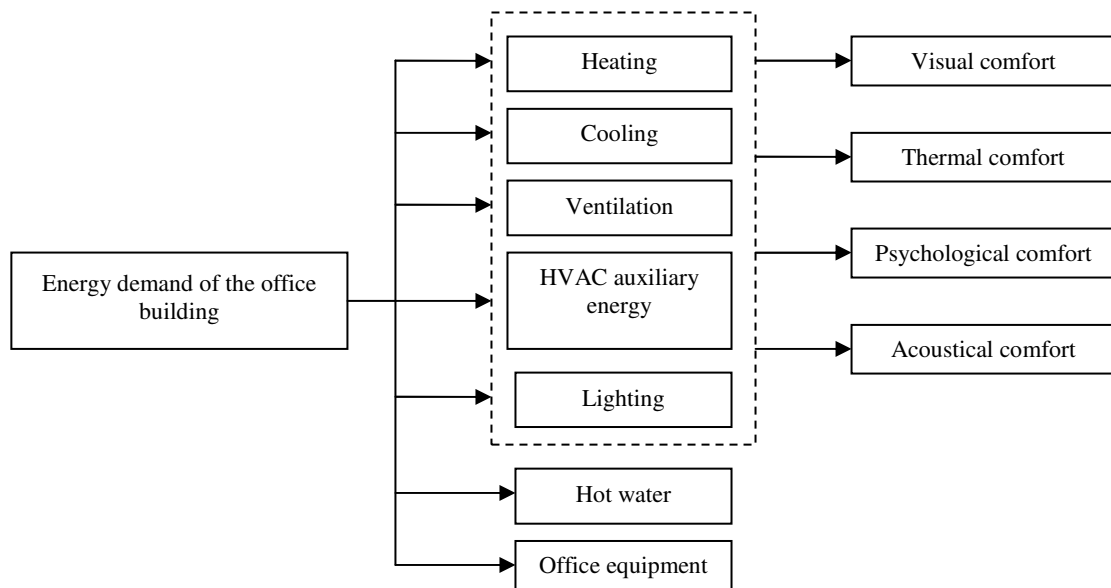


Fig 1. Energy demand of the office building influenced by glazing

Studies performed still give no answer what fenestration is optimal in terms of energy efficiency (when all related demands are evaluated) and DL in the cool climate countries, like Baltic States. Such an answer would help architects and HVAC engineers to create low energy office building and thus implement the requirements of the new directive 2010/31/EU on the energy performance of buildings.

This paper shows how to create a low energy office building just with the use of passive measures. Since in Lithuania official definition for the low energy office building still does not exist, according to the requirements set in the United Kingdom and Netherlands, a presumption was made that maximum PE consumption for low energy offices in Lithuania could also be approximately 160 kWh/m² (Jensen *et al.* 2009).

2. Methodology

Building is a complicated system with many interacting processes (see Fig 2).

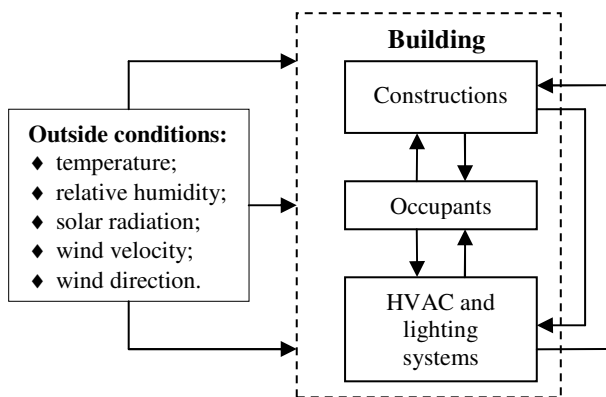


Fig 2. Building as a system

Constructions, HVAC systems and occupants are affected by outside conditions. Meantime heat (cool) accu-

mulated by constructions of the building depends on internal heat gains as well. These gains appear from occupants and HVAC systems. Building constructions influence operation of the HVAC systems and also comfort of occupants. They usually have possibility to adjust operation of the HVAC systems.

Simplified methods, used in the engineering practice, are not always appropriate to evaluate these complicated interactions. Integrated building simulation methods are in this case more suitable.

In this study integrated modelling is performed using EnergyPlus dynamic building energy simulation tool. Simulation of the energy demand for heating, cooling, HVAC auxiliary energy and lighting energy demand is performed sub hourly for the period of one year.

Often, in similar analysis, the fact, that energy in form of heat and in form of electricity is of different quality and it is in principle incorrect to sum up them directly, is not evaluated. Therefore, in this analysis energy demands of different systems are converted to the PE. The assumed PE factor for electricity is 3 and for heat – 1.12.

Each building is different and it is impossible to perform analysis of one particular building and apply its results universally to other buildings. Therefore, for further calculations, the rectangular shape building, which is characteristic in many cases, was created (Fig 3).

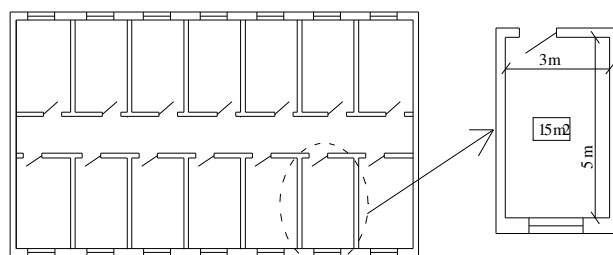


Fig 3. Plan of the typical floor and typical office of the analyzed building

The assumptions were made that amount of the solar heat, gaining through the roof, is insignificant compared to the heat, gaining through the windows, and the building is wide insomuch that glazing of separate facades has just one orientation. This enables to discern one office room as a typical one related to the heat regime in a particular orientation of the facade.

3. Model description

Creation of the room's model (geometry, constructions, occupation, comfort conditions, HVAC and lighting systems, their characteristics and operation schedules) in DesignBuilder program enables to perform further simulations with EnergyPlus.

Constructions. Analysed building is made of light-weight constructions. Heat transmittance (U-value) of the external wall equals $0,243 \text{ W/m}^2\text{K}$ (STR 2.05.01:2005), assumed outside air infiltration is 0.2 h^{-1} . Since the analysed element is a typical office room, it is assumed that other rooms have the same heat regime and there is no heat exchange between them, i.e. internal partitions are adiabatic.

HVAC. During the working hours, microclimate (HVAC) systems maintain: for warm season – $+24 \text{ }^\circ\text{C}$; for cold season – $+21 \text{ }^\circ\text{C}$. For unoccupied hours: during the heating season, heating system maintains 3 K lower (18°C) temperature (LST EN 12831:2003) and cooling system is always off. Preheating time (time required to rise temperature to $21 \text{ }^\circ\text{C}$) is 1 hour. Minimal supply of the fresh air is 10 l/s per person. Ventilation system is equipped with 70% efficiency heat recovery unit. Heating system – with local heating devices, heat generator – gas fired boiler with 94% efficiency, the coefficient of performance (COP) of the air cooled chiller – 2.5 .

Occupation. Occupants, computer equipment and lighting systems have the same activity schedules as offices – weekdays from 8:00 to 17:00. Despite that realistic occupation of the office building is not constant and fluctuates individually in each office room, it is assumed, that in the analyzed case type of work requires constant occupation during the working hours. There are two occupants in the room.

Lighting. The assumed lighting level – 500 lx (HN 98:2000). Efficient lighting system with linear control according to the lighting level was selected. The specific lamp power equals $3 \text{ W/m}^2/100 \text{ lx}$ (LST EN 13779:2007).

Office equipment. Internal heat gain from the office equipment is 4 W/m^2 .

Glazing. From the point of view of energy, the main characteristics of the glazing, next to fenestration and orientation are: heat transmittance U , solar heat gain coefficient g and light transmittance τ_l . In general they depend on the window construction and type of glass used.

4. Simulated glazing alternatives

To analyse glazing influence on building's energy demand, 5 glazing types with different characteristics were selected (Fig 4).

Efficiency of the glazing both in terms of energy and DL is characterized by ratio τ_l/g . When this ratio is less than 1, glazing does not ensure sufficient DL and if ratio is more than 1.55, such glazing is considered as very efficient.

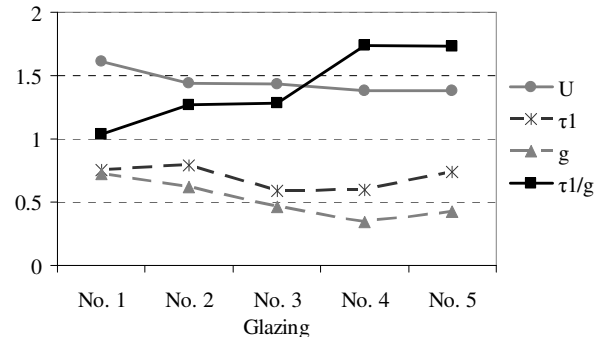


Fig 4. Characteristics of the selected glazing alternatives

Note: further glazing type will be defined by number (No. 1, No. 2, etc.).

In offices with continuous work, adequate visual comfort must be provided. One of important factors, influencing visual comfort, is daylight. The calculation methodology of the minimal fenestration, which satisfies hygiene norms requirements for DL, is established in Lithuanian standard STR 2.05.20:2006. Minimal required WWR calculated according to the standard for analyzed room, depending on orientation and coefficient τ_l , varies between 59% and 86% . These WWR values are used for further calculations as fenestration alternatives.

Constructed model is simulated with different glazing alternatives, changing the following glazing characteristics: WWR, orientation and glazing type. In total 100 alternatives are simulated. The model is programmed to calculate energy demand for heating, cooling, ventilation and auxiliary energy used to power HVAC systems pumps and fans. The energy used to heat or cool air supplied by ventilation system, is assigned accordingly to heating or cooling energy demand.

5. Results

Energy demands for heating, cooling, lighting, fans and pumps were analyzed separately as well as required heating and cooling loads. However, pursuing to identify efficient characteristics of the glazing, shading devices the analysis of the overall PE demand has to be performed (see Fig 5).

5.1. Glazing

Calculations showed that for each orientation and glazing type, dependency of the total annual PE energy demand on fenestration is analogous: with the rise of the fenestration, energy demand and influence of the glazing characteristics rises as well. Fenestration increase from 20% to 100% for southern, eastern and northern facade may increase energy demand approximately 3–3.5 times for the

clear glazing (No. 1) and 2.2–2.5 times for glazing with multifunctional coatings (No. 4). Meanwhile, for the northern facade, with fenestration increase from 20 % to 40 %, the energy demand for some glazing types decreases, because of the lower energy demand for lighting. Increase of the fenestration to the maximum, for northern orientation for clear glazing can raise energy demand 1.8 times and accordingly 1.2 times for glazing with multifunctional coatings. It is noticed for all orientations – the higher the relation τ_i/g , the lower the energy demands.

The most energy efficient fenestration for the conditioned office building is 20 % for southern, eastern and western facades and 20–40 % for the northern facade (see Fig 5). Such fenestration values are defined for the conditioned office building. Meanwhile it is stated in the regulation STR 2.05.20:2006 that public building must have glazing which limits solar heat gains, if fenestration (WWR) is more than 30 % for orientations from NE to SW and more than 20 % for other orientations. So stan-

dard does not consider if building is conditioned or not. Tendencies show increase of the conditioned spaces of public buildings; therefore above mentioned fenestration limits should be reviewed and differentiated taking into account if building is conditioned or not.

Energy efficient fenestration does not satisfy minimal requirements set by national standards for daylight. Therefore the most efficient fenestration in terms of energy and daylight is the one equal to the minimal required by standards (it varies between 59 % and 86 %).

For all of the calculated alternatives, even when fenestration equals minimal required value, energy demand is much higher (see Fig 3) than the one set for the low energy office building in UK or Netherlands. An exception is the north orientated facade with an efficient glazing (No. 4, No. 5) with energy demand 157–164 kWh/m². Such energy demand is close to the low energy building's demand. For all other alternatives it is necessary to apply extra energy efficiency measures, such as shading.

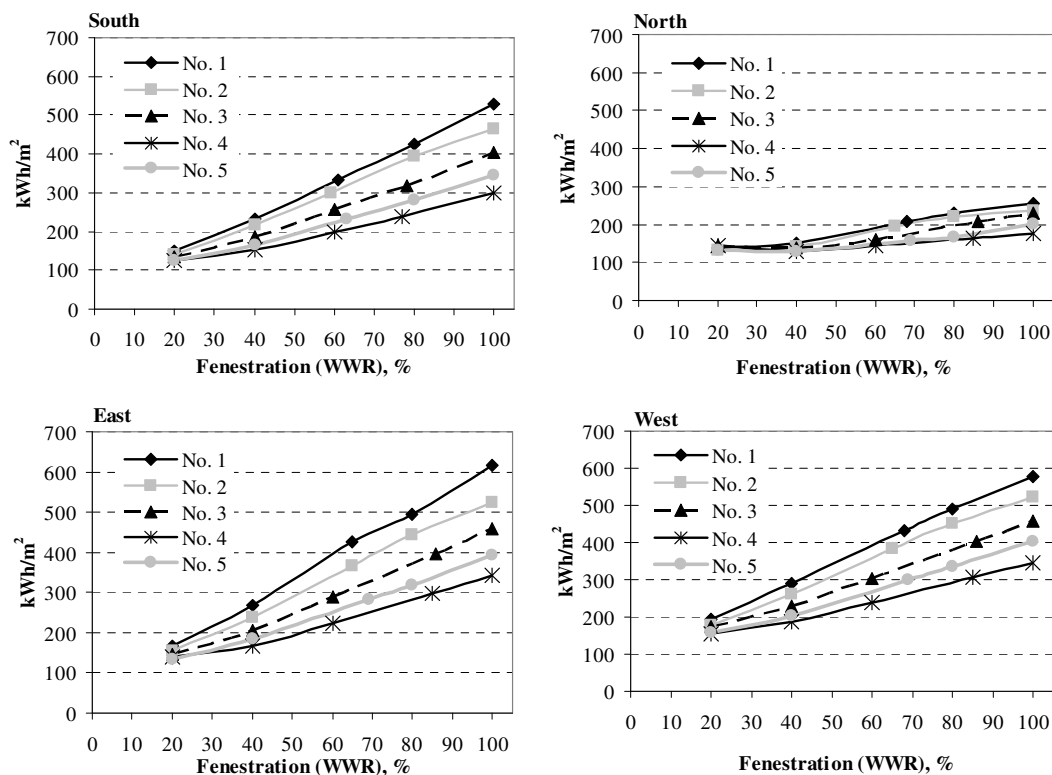


Fig 5. Dependence of building's annual PE energy demand on glazing characteristics

5.2. Shading

Seeking to improve energy efficiency of the analysed building, two types of shading devices were applied for alternatives with the WWR equal to the minimal required:

- 1) internal horizontal blinds with control according to the set lighting level;
- 2) external blinds with control according to 120 W/m² radiation intensity.

After the application of the internal blinds, total annual PE demand for south, west and east orientations decreased up to 48 % and after application of the external blinds – up to 59 %. Meantime for north orientation the decrease of PE demand when internal blinds are applied is just 1–7 % and when external blinds are applied – 5–20 %.

Both for external and internal blinds PE savings depend on the efficiency of the glazing and this can be seen from Fig 6 and Fig 7.

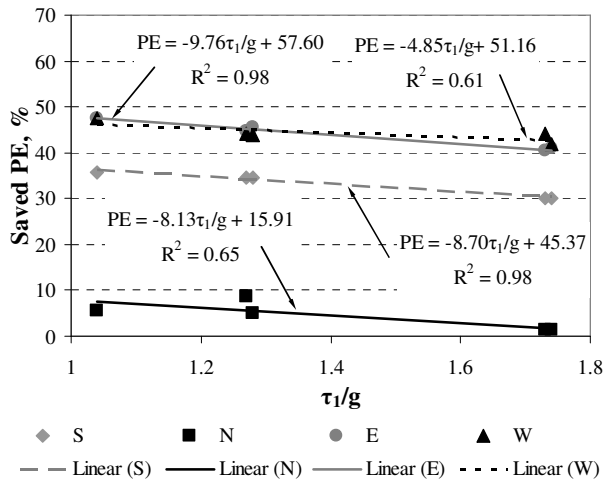


Fig 6. PE savings when internal blinds are applied

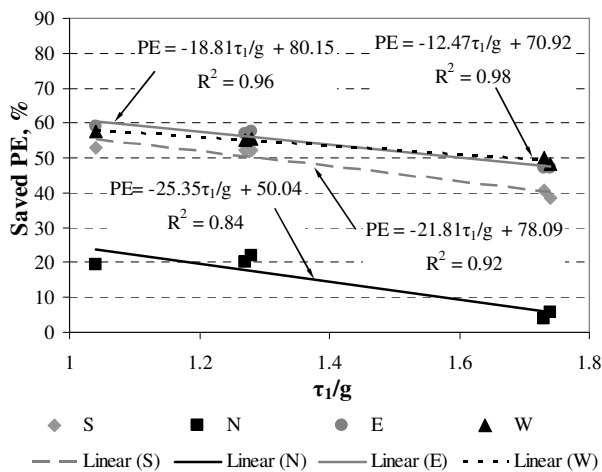


Fig 7. PE savings when external blinds are applied

Despite that application of internal blinds decreases PE energy demand for all cases, it still does not decrease it to the level of the low energy office building (LOEB) (Fig 8). North orientation with efficient glazing (No. 4 and No. 5) still stays the most efficient with PE energy demand 155–162 kWh/m².

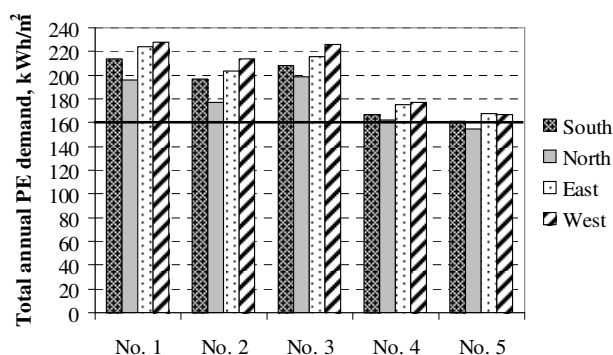


Fig 8. PE demand after application of internal blinds

After application of automatically controlled external blinds (Fig 9), energy demand decreases to the demand of LOEB for efficient glazing (No. 4 and No. 5) for all orientations. Minimal total PE demand is for south orientation and it can decrease up to 137 kWh/m² (glazing No. 5). For the glazing, which is less efficient (No. 1, No. 2 and No. 3), demand of LOEB is reached not for all orientations and is never reached for west orientation.

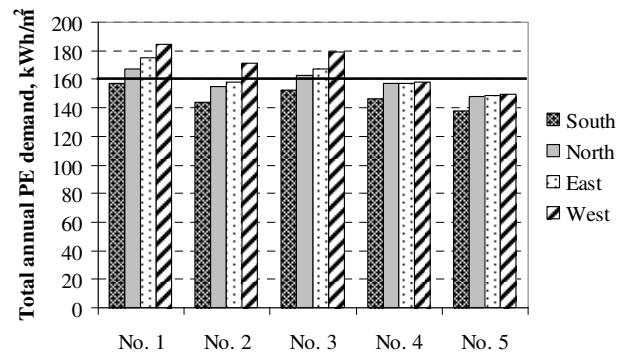


Fig 9. PE demand after application of external blinds

Results have shown that efficient shading in combination with efficient fenestration and glazing can reduce annual total PE demand to the demand of the LOEB also for south, east and west orientations.

6. Conclusions

1. Due to the results of analysis it is suggested to set that in the zone of Lithuanian climate overall annual lighting and microclimate systems' PE energy demand of the low energy office building shouldn't exceed 160 kWh/m². Also it is recommended to revise national regulations, setting requirements determining minimal fenestration for public buildings.
2. The complex analysis of the energy demand has shown that in cool climate zones like Baltic States the most energy efficient fenestration for the conditioned office building is 20 % for southern, eastern and western facades and 20–40 % for the northern facade. At the same time the most energy efficient fenestration does not satisfy hygiene norms requirements for daylight (DL). Therefore, the most efficient in terms of energy and DL is the fenestration, equal to the minimal required by hygiene norms.
3. In the climate of Lithuania and neighbouring countries the most energy efficient orientation of the facade of the conditioned building, when shading is not applied, is the north. For this orientation, when fenestration is the most efficient, the lowest calculated overall annual PE energy demand may reach 157 kWh/m². For the efficient glazing of the northern facade in Lithuanian climate it is not advised to apply internal shading. Meanwhile, for other orientations, internal and external shading may reduce PE demand respectively up to 48 and 59 %. Application of external blinds may diminish the energy demand for southern facade up to 137 kWh/m².

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