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## The Impacts of the Exterior Glazed Structures and Orientation on the Energy Consumption of the Building

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# The Impacts of the Exterior Glazed Structures and Orientation on the Energy Consumption of the Building

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**Abstract.** Buildings use about 40% of the national energy consumption, and approximately 25–30% of this energy is wasted due to inefficient windows. Installation of energy efficient glazing allows significant reduction of cooling load. While increase of heat consumption can be observed in heating period due to significant reduction of solar heat gains. On the basis of computer simulations there were found dependences between overall energy efficiency of the building and such parameters as its orientation, urbanization, and the types of glazing. Building energy modelling (BEM) allows to predict the energy consumption of the building, to find and correct the weak spots in terms of energy consumption and to find the most effective way to use energy saving technologies. The IDA-ICE, chosen as the BEM in the research, is a whole-year detailed and dynamic multi-zone simulation application for study of thermal indoor climate and the entire building energy consumption. The main advantage of the software package is a detailed report for each of the building zones and for the whole building, which includes calculation of heat flows and inflows, maintained temperatures, sources of heat losses and energy costs to maintain a comfort temperature. The variable data are the type of glazing (different window types chosen, with special emphasis on g-value of glass and coefficient of shading) and building's orientation to the world sides. The research demonstrates the effectiveness of using particular glazing types depending on the building conditions. The developed recommendations allow to reduce energy consumption in existing buildings and to reduce construction costs of new office buildings at the design stage.

## 1. Introduction

According to the Report on Resource Efficiency Opportunities in The Building Sector [1], construction and operation of buildings take approximately half of the EU energy consumption, which encourages engineers to develop the methods of reducing the overall energy consumption of buildings and to use the renewable energy sources. Approximately 56% of mentioned energy is used for heating and cooling as well as lighting applications, while 25% to 35% of this energy is wasted due to inefficient windows. Two-thirds of EU buildings were built at a time when no strict requirements were imposed on the energy efficiency level of the building. Most of these buildings are scheduled to be operated till 2050 without major renovations. Significant energy savings can be achieved through simple repairs, including the installation of modern windows with triple glazing.

Successful building envelopes shield the occupants from exterior weather conditions while providing a connection to the outside using natural light and views. The net effect of a window in the energy



balance of a building depends on the characteristics of glazing and orientation of the window as well as the solar and weather data.

Within the framework of this investigation, detailed dynamic energy consumption simulations were carried out to identify optimal characteristics and orientation of glazed surfaces in order to ensure both adequate overall energy efficiency of the building during the year, and the thermal comfort of people.

The most recent and actual studies on overheating in well insulated buildings is shown in figure 1.

**Table 1.** Review of existing studies

Research	Field	Impact on thermal comfort	Energy consumption	Shortcomings
Aleksandrs and Elokhev, 2013	Passive Residential House	were not addressed	Energy consumption for cooling is 5 kWh/m <sup>2</sup> , and 14% of heating consumption	No specified window properties
T. Psomas, P. Heiselberg, T. Lyne, and K. Duer 2017 [2]	Automatic control of windows and blinds in Danish climate	Overheating exceeds 100 hours per year.	were not addressed	Glazing g-value wasn't addressed
T. Psomas, P. Heiselberg, K. Duer, and E. Bjørn, 2016 [3]	Well-insulated single-family residential houses	g-values significantly reduce overheating	were not addressed	U- values wasn't addressed
Pathan, A. Mavrogianni, A. Summerfield, T. Oreszczyn, and M. Davies, 2017 [4]	Residential houses in London	Widespread in both the old apartments and the new building	General data	No sufficient description of the delimiting structure
E. Kähkönen, K. Salmi, R. Holopainen, P. Pasanen, and K. Reijula, 2015 [5]	Residential Houses	In the summer, there are no significant differences in energy efficient and regular buildings	were not addressed	No sufficient description of the delimiting structure
D. Baranova, D. Sovetnikov, D. Semashkina 2017 [6]	Residential homes. The window area 41% of the floor area	An operative temperature above 25 °c is observed 3140 hours	Energy consumption for cooling accounts for 9% of heating consumption	Glazing g-value wasn't addressed

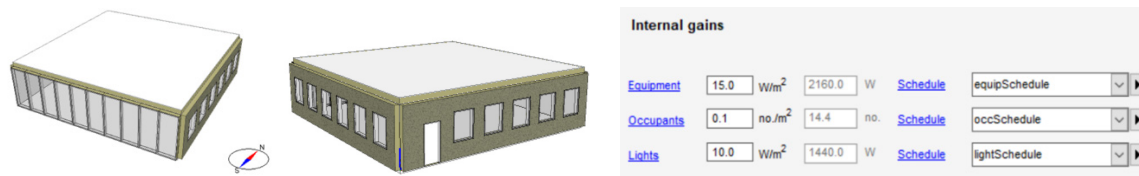
## 2. Method

Building energy modelling (BEM) allows to predict the energy consumption of the building, to find and correct the weak spots in terms of energy consumption and to find the most effective way to use energy saving technologies. The IDA Indoor Climate and Energy (IDA-ICE) 4.8, chosen as the BEM in the research, is a whole-year detailed and dynamic multi-zone simulation application for study of thermal indoor climate as well as the entire building energy consumption. The main advantage of the software package is a detailed report for each of the building zones and for the whole building, which includes calculation of heat flows and inflows, maintained temperatures, sources of heat losses and energy costs to maintain a comfort temperature.

IDA-ICE was validated according to ISO 13791: 2012 "Thermal performance of buildings – Calculation of internal temperatures of a room in summer without mechanical cooling – General criteria and validation procedures" guidelines [7] and [8]. Climate data is taken from ASHRAE 2013 and the wind profile from ASHRAE 1993. The accuracy of IDA-ICE climate data was multiply tested [9] [10].

The heat transmission ratios of building envelope were adopted according to the requirements of LBN 001-15 “Thermal performance of building envelope”.

A model created for the study is an office building and specifics of heat gains, located in Riga, Latvia (figure 1).



**Figure 1.** The 3D model of office building and profile of internal heat gains.

The building parameters are as follows:

- Floor area – 144,0 m<sup>2</sup>
- Volume – 432,0 m<sup>3</sup>
- Wall area – 144,0 m<sup>2</sup>
- Windows/Walls – 38,7 %
- Walls/Volume – 0,3333 m<sup>2</sup>/m<sup>3</sup>
- Area of other windows – 19,8 m<sup>2</sup>
- Adjusted indoor temperature in summer/winter – 25 °C/20 °C
- Ventilation – constant air flow 2 l/sm<sup>2</sup>

The area of main glazed window façade is 35,7 m<sup>2</sup>. Area of other glazing is 19,8 m<sup>2</sup>. In scope of this study properties and orientation of main glazes faced were changed while properties of other windows remained constant ( $U=1.21 \text{ W/(m}^2\cdot\text{K)}$ ,  $g=0.34$ ). To evaluate the impact of window properties on the annual energy consumption of the office building, 16 scenarios were developed. The value of overheating (25 °C) was chosen to evaluate overheating and cooling loads based on the recommendations of the standards ASHRAE 62.1-2007. 25 °C thresholds also is assumed in other studies focused on thermal comfort [11] [12] [13]. In addition CIBSE Guide J [14] estimates an overheating on the basis of a temperature of 25 °C [15] [16]. Building occupied from 9.00 till 17.00 from Monday till Friday and from 11.00 till 15.00 on Saturday. The occupancy is assumed 0.5 on Saturday. External wall assumed as light weight concrete with thermal insulations.

The main parameters describing the heat properties of the windows are the heat transference coefficient, air permeability, water tightness, and solar permeability ( $g$ ). In modern dynamic calculations, the important role belongs to  $g$ -value of glazing, which varies between 0,22 and 0,89.

The orientation of windows and the impact of  $g$ -value on energy consumption during the year were analyzed, taking into account the climate data, heating and cooling consumption (separately), and the influence of blinds. The working algorithms of blinds are as follows:

1. (Sun) – blinds are closed if the sun radiation on window surface exceeds 100 W/m<sup>2</sup>.
2. (Sun + Get heat) – blinds are closed if the sun radiation on window surface exceeds 100 W/m<sup>2</sup>, and people stay in the room. When people do not stay in the room, the blinds activate if the sun radiation does not exceed 100 W/m<sup>2</sup> and the room does not need to be heated.
3. (Sun + Get heat + Preserve heat) – blinds are closed like in the "Sun" and "Get Heat" scenarios, but also during the night when there is no need for heating and people do not stay in the room.

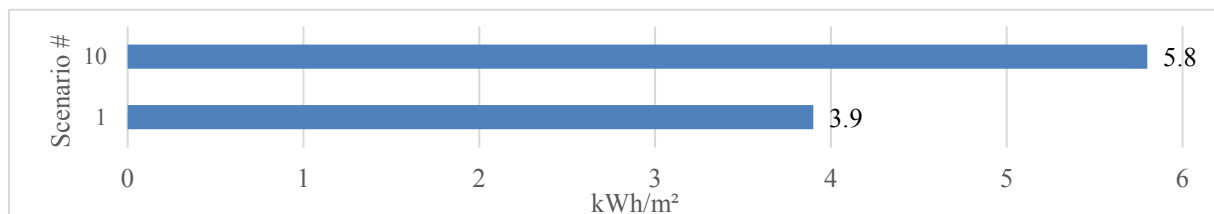
Simulations in IDA-ICE software were performed according to the Table 2. The second column shows the orientation of the glazed wall, which has the biggest impact on the internal climate of the office space. The changing parameter of glazing is  $g$ -value, while  $U$ -value of the stainless glass is same for all simulations. The fifth column shows the presence of the blinds, their type and working principle.

**Table 2.** List and transcript of scenarios.

Scenario #	Orientation of the glazed wall	<i>U-value</i>	<i>g-value</i>	Blinds: working algorithm #
1	North	1.24	0.34	No
2	South	1.24	0.34	No
3	South	1.24	0.34	Outdoor marquise blinds: 1.
4	South	1.24	0.34	Outdoor marquise blinds: 2.
5	South	1.24	0.34	Outdoor marquise blinds: 3.
6	South	1.24	0.34	Indoor blinds: 1.
7	South	1.24	0.34	Indoor blinds: 2.
8	South	1.24	0.34	Indoor blinds: 3.
9	South	1.24	0.59	No
10	North	1.24	0.59	No
11	South	1.24	0.59	Outdoor marquise blinds: 1.
12	South	1.24	0.59	Outdoor marquise blinds: 2.
13	South	1.24	0.59	Outdoor marquise blinds: 3.
14	South	1.24	0.59	Indoor blinds: 1.
15	South	1.24	0.59	Indoor blinds: 2.
16	South	1.24	0.59	Indoor blinds: 3.

### 3. Data analysis of energy consumption dynamic simulations

The simulation reflected on Figure 2 shows that the energy consumption is approximately 30% bigger for scenario # 10, which means that glazing with lower *g-value* (0.34) more effectively protects the room from overheating during summer.

**Figure 2.** Energy for cooling (kWh/m²) for the building with north-oriented glazed wall.

In the case of simulation # 10, the heat in the room is saved more efficiently, because energy consumption for heating is about 10% less than for simulation # 1. Figure 3 reflects the annual cost of heating and cooling for the building with the north-oriented glazed wall. It can be concluded that scenario # 10 is more beneficial than scenario # 1, despite the fact that in the last case the cost of cooling is smaller. This can be explained by the climatic properties of Latvia – the cooling season is shorter than the heating one.

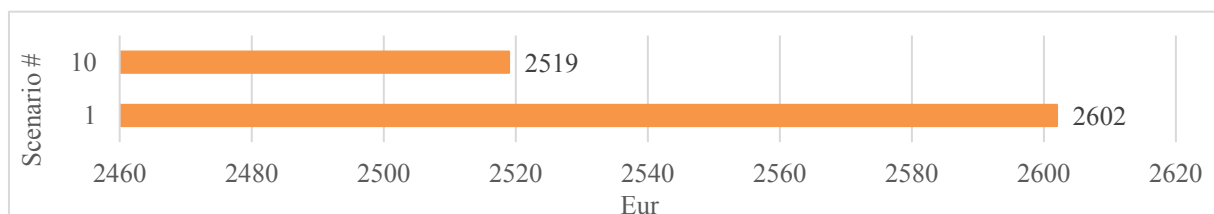
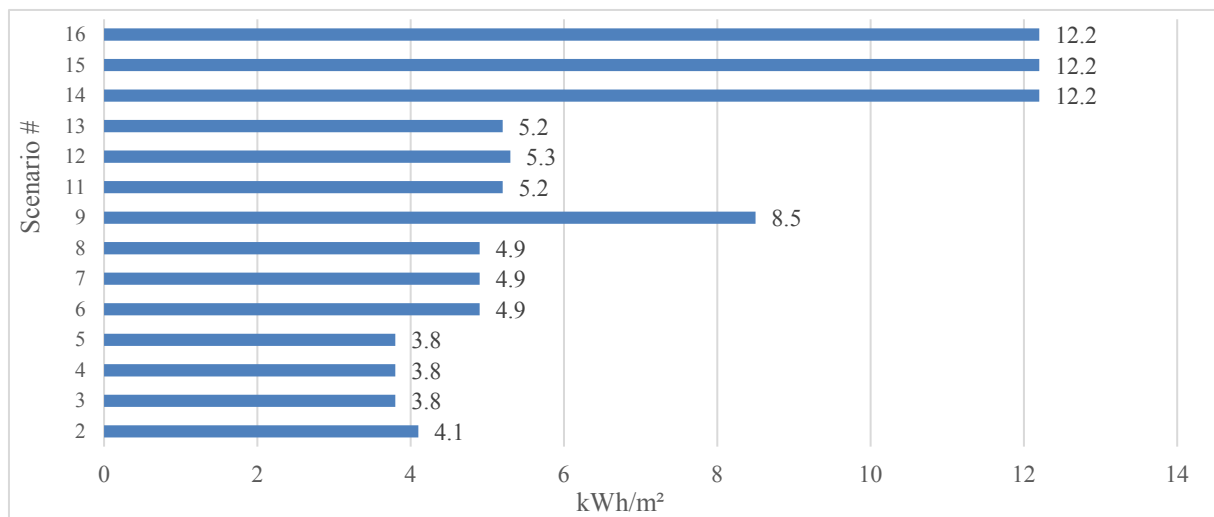
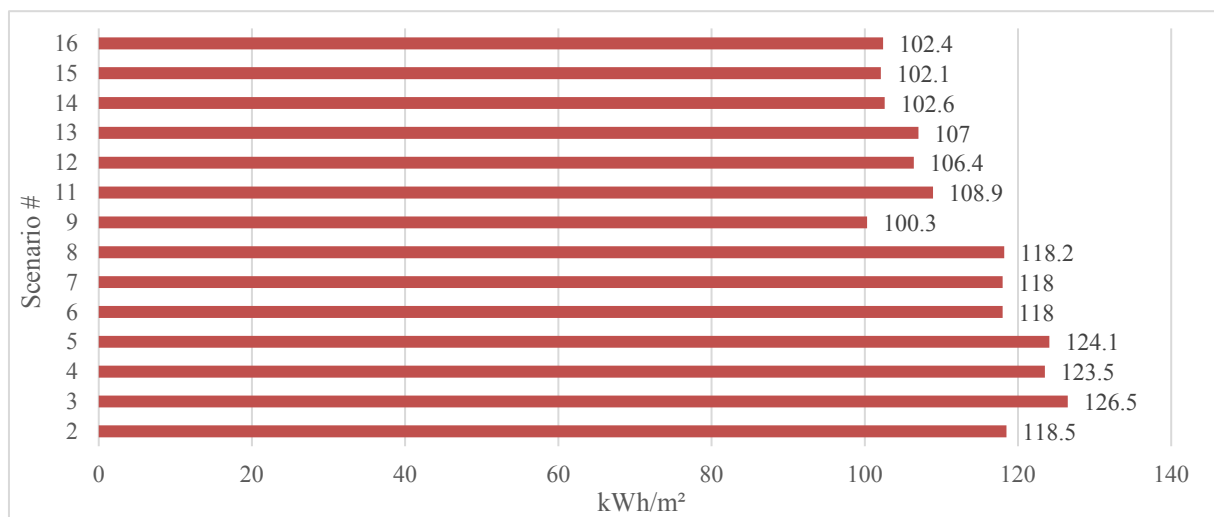
**Figure 3.** Costs Eur/year for heating and cooling for a building with north-oriented glazed wall (heat 0.06 €/kWh; electricity 0.16 €/kWh).

Figure 4 demonstrates the comparison of energy consumption for cooling of office space with a south-oriented glazed wall with different blinds types with different working algorithms. It is seen that the least amount of energy for cooling is spent in scenarios where low g-value (0.34) glazing and blinds with different operating principles are implemented. Scenarios #14, #15, and #16, show less effective results. In these simulations glass with a g-value 0,59 and indoor blinds with all operating principles were implemented.



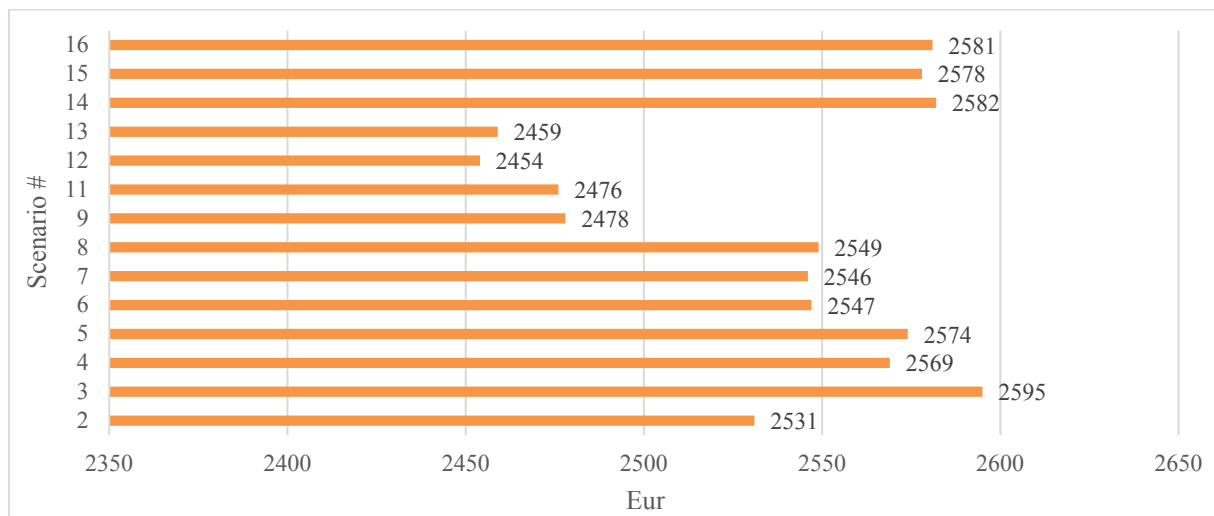
**Figure 4.** Energy for cooling (kWh/m²) for building with south-oriented glazed wall.

Figure 5 shows the comparison of energy consumption for heating of office space with a south-oriented glazed wall with different blinds and different working algorithms. In scenario #9 the heat is saved most effectively (a g-value of used glazing – 0,59; no blinds). The worst results were shown by scenarios # 3, # 4 and # 5 that used glazing with a g-value of 0.34 and marquis blinds with different working algorithms.



**Figure 5.** Energy for heating (kWh/m²) for buildings with South-oriented glazed wall.

From the graphic on Figure 5, it can be concluded that scenarios # 12, 13, 11 and 9 are more beneficial than all other simulations. One of them is a scenario that uses glazing with a g-value 0,59, no blinds, which allows to state that in Latvian climate, technologically complex shading systems do not give a great energy-saving effect.



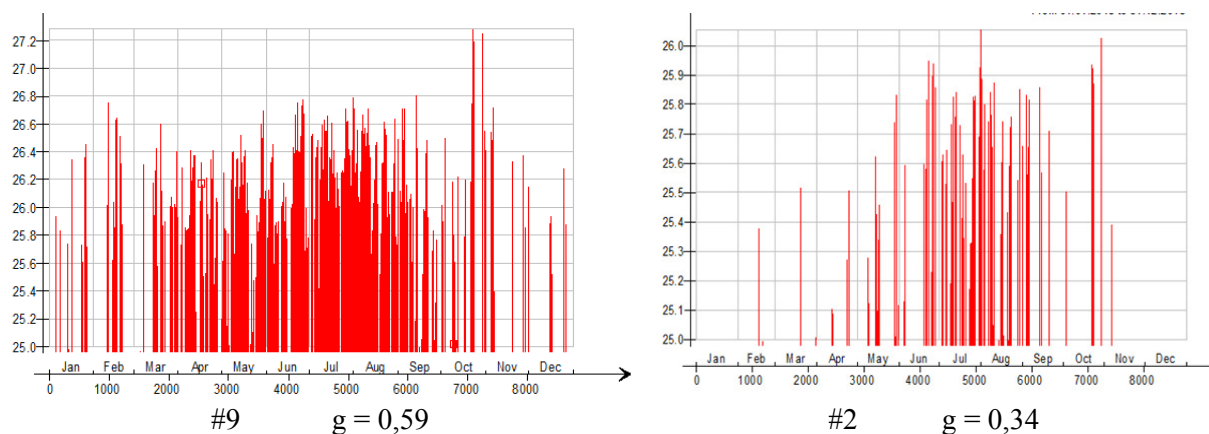
**Figure 6.** Costs (EUR/year) for heating and cooling for building with South-oriented glazed wall par (heat 0.06 €/kWh; electricity 0.16 €/kWh).

Figure 6 combines all data, allowing to explore the energy consumption for every scenario. After exploring all the results, we can conclude that the leadership belongs to scenario # 9 (the glazed wall of the building is South-oriented and the parameters of glass are  $U = 1,24$  and  $g = 0,59$ ). This is also reflected in the amount of consumed energy in the year cut, as well as relatively low price for this type of glazing (no expensive complex shading systems used).

#### 4. Room operational temperature analysis

The optimal air parameters in the room are determined using the operating temperature of the room [17]. Despite the fact that glazing with simple coating ( $g = 0,59$ ) provides the highest energy savings and is cost-effective, it is necessary to explore the operating temperature of the scenario # 9 and to compare it with that of scenario # 2 which analyses a similarly oriented building with other glazing parameters ( $g = 0,34$ ).

Figure 7 shows the comparison of operational temperatures, that exceeds a human comfort temperature of 25 °C all year long, for two scenarios. It is apparent that in the scenario # 9, indoor surfaces get overheated over 25 °C more frequently than in the scenario # 2. Also, the maximum surface temperature exceeds 27 °C in scenario # 9, and in the scenario # 2 it is 1 °C less.



**Figure 7.** Room operative temperature.

## 5. Conclusions

In modern office buildings the glazing surface area reaches up to 90% of the wall area. The increased proportion of facade area glazing not only results in additional cooling loads but also significantly aggravates the thermal comfort. Several studies showed the notable overheating of essential spaces during the summer while not applying passive or active cooling methods.

During simulations, it was found that for north-oriented buildings, glazing with low g-value (0.34), 30% more effectively protects the room from overheating in the summer period. In winter, however, the same glazing worse keeps the heat in the room. Therefore, the results of the year energy balance for north-oriented building, allows to conclude that the glazing with a g-value of 0,59 is more beneficial, both from comfort and financial point of view.

By the results of simulations, for southeast oriented buildings, glazing with low g-value (0.34) twice more effectively protects the premise from overheating during summer. The detailed analysis of thermal comfort leads to conclusion that glazing with a lower g-value can drastically reduce the congestion risk in the premises, as well as the operational temperature of the premises.

While usage of external blinds can improve protection from indoor overheating, however, within the framework of this investigation, installing complex blinds did not help to achieve a significant reduction of energy consumption for both heating and cooling needs. The main reason for that is relatively low number of sunny days in Latvia (approximately 78 days per year). Also, the necessity of define daylight intensity in the office was assumed in the simulation algorithm, thus the blinds were opened and the shade coefficient of them was not sufficient to completely eliminate the heat inflow. Of two types of blinds widely used in Latvia, marquis type blinds appeared to be more efficient than indoor blinds – the installation of the marquis blinds helps to reduce the energy consumption for cooling by 19% compared with indoor blinds.’

## Acknowledgement

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