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THE ANALYSIS OF THE EFFICIENCY OF PASSIVE ENERGY SAVING MEASURES IN OFFICE BUILDING

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Abstract. The European Union is steadily tightening requirements on the energy performance of buildings. This enforces to take new measures to improve the indicators of energy both of existing and newly constructed buildings. Therefore, this article discusses the changes of energy efficiency and annual energy consumption in the office building due to different passive energy saving measures: different heat - optical properties of the glazing, various shading devices. In this article the actual energy efficiency of the object has been established and the best energy-saving measures to achieve the best indicators of energy have been presented.

Keywords:. energy performance, energy saving measures, glazing characteristics, shading.

1. Introduction

Whereas buildings consume more than 40 % of total energy consumed, in order to reduce energy dependency and CO_2 emissions in the European Union (EU) a great attention is paid to promotion of energy efficiency and the use of renewable energy sources.

At 19 May 2010 the recast of the The Directive on energy performance of buildings (EPBD) 2010/31/ES was approved and it changed directive 2002/92/EB. The recast was adopted in order to strengthen the requirements on the energy performance of buildings and to lay down more specific actions that should be taken by member states, to reduce the difference in their achievements and to realize the unused potential for energy savings.

In Lithuania, the current energy efficiency calculation methodology presented at STR 2.01.09:2005 "The energy efficiency in buildings. The energy certification of buildings" does not estimate the energy demand for cooling, so the results do not reflect the real annual energy demand, particularly in new public buildings, which require air cooling.

On the basis of a new EPBD, up to 9 July 2012 the new methodology for calculation of energy performance of buildings should be approved. The energy performance of the building will have to reflect its primary energy (PE) consumption expressed in kWh/m^2. The directive requires that new methodology has to take into account also cooling systems, passive solar systems and shading devices.

The energy efficiency of the building is determined already in its design stage. At that point architectural decisions are particularly important as they can reduce the future energy demand. In the modern commercial or public buildings, high attention should be payed to glazing, which displays significant influence to energy demand. Correctly oriented, high efficiency windows are one of the most important elements of the energy efficient building. Large glazing areas increase the heat losses and accordingly the heating demand in winter, also heat gains in summer increase energy demand for cooling (Motuzienė 2010). The influence of glazing on energy demand has been analyzed by many authors. The influence of optimum fenestration, building shape, orientation and other factors to energy consumptions have been analyzed (Perednis *et al.* 2007; Саснаускайте *et al.* 2009; Šėža 2010, AlAnzi *et al.* 2008). Also factors that have the greatest impact on heating and cooling energy demand of the building, their sensitivity indices (Capozzoli *et al.* 2009), the analysis of heat demand in the building (Stankevičius *et al.* 2002) and options of heat loss reduction through windows were tested (Isevičius *et al*. 2005).

One of the most effective measures used to decrease cooling energy demand – application of shading devices. These were also examined by a number of scientists. Internal and external shading devices have been described by Eicker (2009). Motuzienė (2010) has analysed the combined effects of these measures on the energy demand in Lithuanian climate.

In this paper, passive energy-saving measures, both in the design and existing stage have been analyzed for the office building. Also the class of energy performance of the building was defined and the features of calculation methodology of building performance were analyzed.

2. The analyzed object and calculation methodology

The analyzed object is the fifth floor of the office building located in Vilnius. The total floor area is 2042 m², the largest glazed facade is oriented to the east. The area of glazing is 479 m² and this equals 60 % window-to-wall ratio (WWR). The rest glazing characteristics of the building are presented in Table 1.

Table 1. Glazing characteristics of the building

Characteristics	N	S	W	E
Glazing area, m²	53	59	43	324
Heat transfer coefficient of the glazing *U*, W/m² K	1.2			
Solar heat gain coefficient SHGC, %	0.31			
Heat transfer coefficient of aluminium profile *U*, W/m² K	1.9			
Proportion between glazing areas and aluminium profile, %	90/10			

The building is occupied by 180 occupants. Occupation time is 8:00 – 17:00 h, six days a week. Here a manifold heating system is designed and separate heat meters for each office are mounted. In summer ventilation system, as well as the cooling system, operate during the occupation hours. The maintained temperature is 24 ˚C in summer and 20˚C in winter season.

The calculation of heating demand of the building was based on the currently valid in Lithuania standard STR 2.09.04:2008. The calculation of cooling power and demand was based on STR 2.09.02:2005, also setting up the heat balance and using calculation of a computerized program of Lithuanian Construction and Design Institute (LSPI).

Heating and cooling energy demand have been converted to the primary energy (PE) pursuing to assess their impact on the total energy demand. Final energy demand conversion to PE demand was based on the prEN 15315:2005 using PE indicators: conversion factor for natural gas – 1.1 and for electricity – 2.8.

The certification of energy performance of buildings currently is based on provisions of the directive on the energy performance of buildings 2002/91/EB. During the process of certification, theoretical power consumption of the building is determined and based on it the building is assigned to the class of the energy performance. Then the certificate is issued. Energy consumption in kWh/m^2 is expressed in final energy, not PE. In addition, this methodology of energy performance does not include the cooling demand, which, if is converted into PE, can show the actual energy performance and the components of building's energy demand.

The energy certification of the analyzed building was made using the official national certification program "NRG – sert". It was defined that building meets the requirements of energy efficiency class B. The annual total energy consumption, evaluating the effectiveness of heating system is 98 kWh/m². If effectiveness is not evaluated, demand would be 93 kWh/m² (Fig 1). Real energy efficiency can be reflected just in terms of PE, that is why, these results have been converted to PE (see Fig 1).

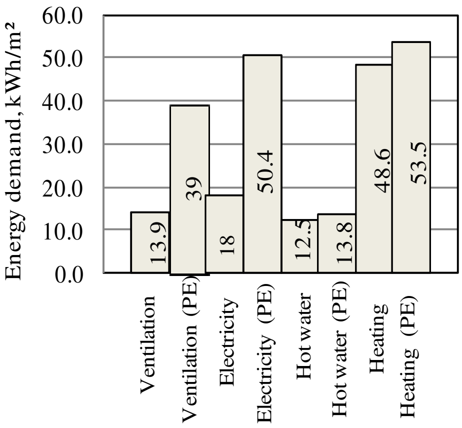

Fig 1. Energy demand in analyzed object by "NRG – sert"

Using the certification program "NRG – sert", we can meet some restrictions on the choice of input data, comparing to analytical calculation methodology. The comparison of used methodologies is shown in Fig 2.

According to STR 2.09.04:2008, the solar heat gains, entering through the glazing, are calculated taking into account the solar heat gain coefficient *g* of glazing and the correction factor for obstruction *a*. This indicator assesses the obstructions, caused by buildings and trees F_H, and shading effects F_C. In the F_C values are determined: 1) when exterior louvers are fitted outside 2) when canopies, balcony, awning are used; and 3) other measures within or between the glasses are used.

According to the calculation methodology of the cooling demand, solar heat gains, entering through the glazing, are evaluated by coefficient *K*. It assesses the obstacles in the way of solar radiation and includes solar heat gain coefficient *g* and effect of shading devices.

Meanwhile, determining the energy performance in accordance with STR 2.01.09:2005 or "NRG-sert" program, some difficulties were found. Here coefficient *g* values are given in that regulation and they can be chosen just according to the window frame type.

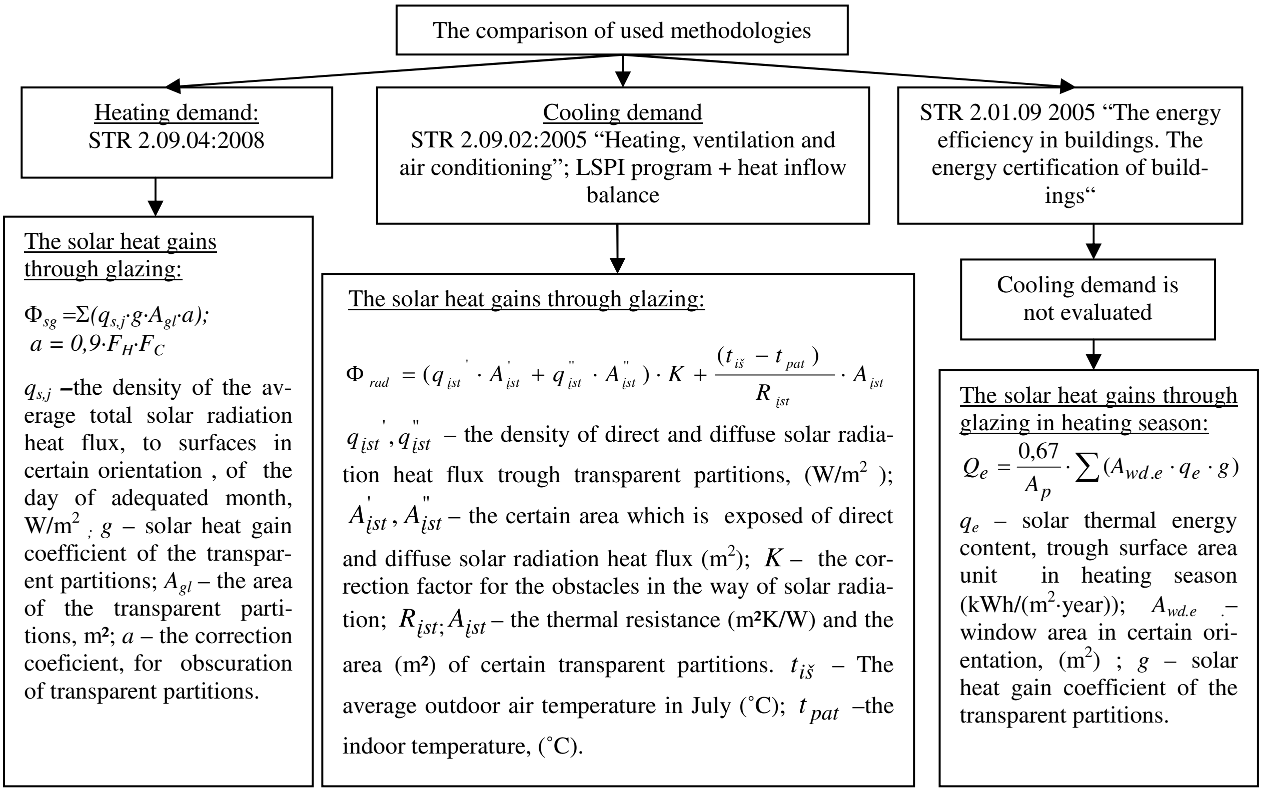

Fig 2. The comparison of used methodologies

Using “NRG-sert” program, you can only select the type of window frames, and the program automatically selects coefficient *g* according to the data. This energy performance methodology was developed more than five years ago and since the properties of modern windows are developing fast, there should be a possibility to assess the coefficient *g* more accurately or there should be possibility to enter the actual characteristics of the window.

3. Energy-saving measures for existing building

Using analytical calculation methodologies the estimated annual energy demand (PE) composes 78 kWh/m² for heating and 168 kWh/m² for cooling.

In order to reduce the energy demand of the existing building, one of the possibilities can be the installation of effective shading devices. But shading devices are more relevant and useful in summer, when air cooling is necessary to maintain optimum indoor air temperature. Lithuanian architects often underestimate the impact of shading on energy demand, while in other countries they are successfully applied in building design. Shading should be designed in a stage of planning, because it can later be very expensive. External and internal louvers, various canopies, parapets, as well as special glass membranes can be used as the solar protection measures. Nevertheless, internal louvers, which are often used in office buildings are less effective, than external - they can hold up to 30 % of solar heat. Using the interior blinds, sunlight passes through the window, heat concentrates between a window and interior blinds, therefore this hot cavity heats the room. If, however, interior blinds are chosen, aluminium louvers, which reflect the heat, would be most relevant.

The most effective protection from sun is application of external louvers. They can hold up to 80 % of solar heat. Handled external louvers help to avoid the decrease of solar heat access to lodgings in winter.

In Lithuania there are no official recommendations for using sunscreen measures. Indirect obligation to use them may be discovered only in regulation of STR 2.05.20:2006 because it regulates the maximum solar heat gain coefficient. If SHGC is not appropriate, the requirements can be met by applying shading devices (Motuzienė 2010).

In the analyzed building, as protection from solar heat gains, internal horizontal louvers are used. In this paper, to estimate impact of the different shading devices on energy demand, different shading options were analyzed:

1) external louvers;
2) canopies, balconies, awnings;
3) shading within or between the glasses;
4) no shading;

The calculation results are shown in Fig 3.

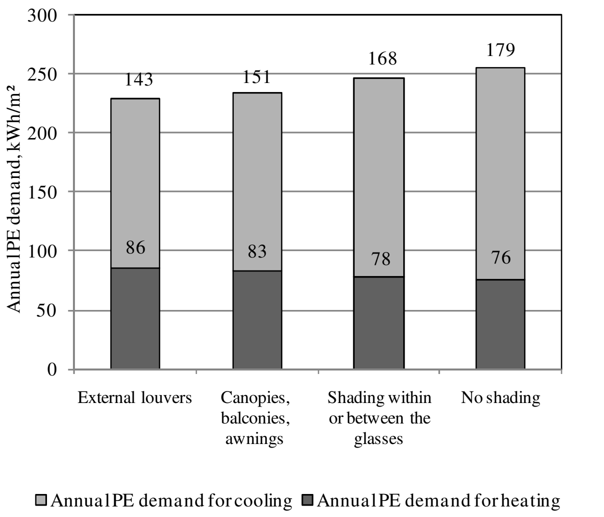

Fig 3. The impact of the different shading devices on energy demand

Analytical calculations have shown that for the analyzed building, which has eastern orientation, possible PE savings for cooling are up to 20 % (Fig 3), but at the same time heating PE demand may be increased up to 12 %, when external louvers are applied. Internal blinds, which are commonly used in office buildings, save up to 16 % of cooling demand. Estimating the total annual PE demand, the energy savings compose 20 %. All these results show the energy savings due to shading, comparing to the case when shading is not used.

Whereas external louvers are used, in the analyzed building the potential of energy saving composes 15 %. Of course, the calculation results can be different due to: methodology of calculation, internal gains, type of the building, area and thermal-optical properties of the glazing.

In any case, the energy savings, using sunscreen measures are significant; therefore they should be taken into account in determining the class of energy performance. Considering that shading devices can increase the efficiency, this should be used both in new and existing modern buildings with large glazing areas of the facade.

4. Energy-saving measures for building in design stage

4.1. The impact of building's facade orientation and shading on its energy demand

If the building is still in the design stage of architectural part, then the orientation of glazed facades may be changed. The orientation can be regarded as a passive solar energy use or passive energy saving measure. The effect of using shading also depends on the orientation of the facade.

In this calculation procedure with reference to STR 2.09.04:2008 we take into account, that shading reduces heat solar heat gains into lodgings and increases heating demand, but shading can also save the energy demand for heating. Some computer programs, can simulate external louvers controlled by different set points, and assess their real impact on energy demand in summer and winter.

There was made an analysis of influence of different orientations and shading devices on annual PE demand of the analyzed building.

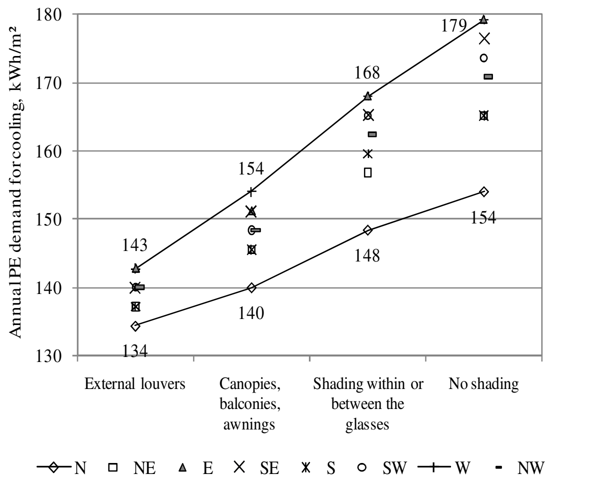

Fig 4. The influence of different orientations and shading devices on annual PE demand

The calculating results shows (Fig 4), that choosing the best orientation of the main façade, we can save up to 14 % of annual PE demand for cooling. Also, choosing the best shading devices – external louvers for different orientations we can save up to 21 % of cooling demands.

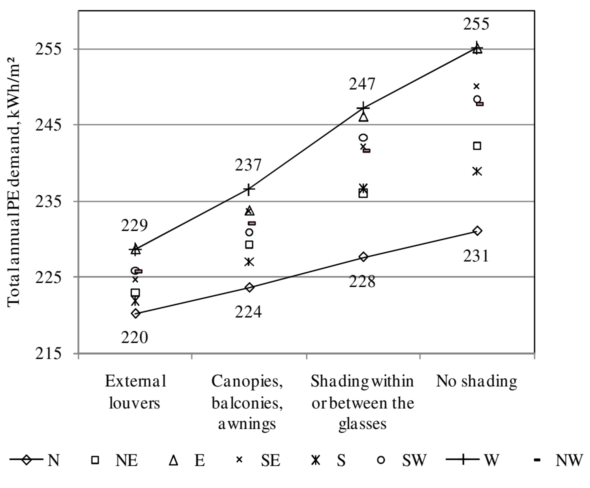

Fig 5. The impact of building's facade orientation and shading on its total PE demand

When external louvers are used, the cooling demand and the impact of orientation of main gazing façade on energy demand is minimum (Fig 5).

The impact of building's facade orientation and shading on its total PE demand is up to 10 %.

4.2. The impact of thermal and optical properties of glazing on energy demand

As it was mentioned above, almost all of modern office buildings have large glazing areas, which determine their high energy consumption. This can be compensated choosing more efficient glazing. Nowadays their range is particularly wide. However, their thermal-optical properties are very important. The main indicators of thermal performance of glazing are heat transfer coefficient *U*, W/m² K and solar heat gain coefficient *g*, %.

Therefore, the calculation of PE demand in the analyzed object was made for 4 different variants of shading and 5 glazing (Table 2) types. Their heat transfer coefficient ranges from 0.7 to 1.4 W/m²K, and solar heat gain coefficient *g* from the 28 % to 61 %.

Table 2. Properties of analyzed glazing

	Glazing's type	U, W/m²K	g, %
1	IPLUS NEUTRAL A+Ar+Clear+Ar+IPLUS NEUTRALS S	0.7	52
2	IPASOL Blau 40/23+Ar+ Clear	1.1	52
3	ANTELIO Green+Ar+IPLUS NEUTRAL S	1.1	28
4	Sun Guard HP Silver 43	1.2	31
5	Clear+PLUS NEUTRAL S	1.4	61

The calculation results (Fig 6) show that comparing the first and second glazing (Table 1), with the same SHGC factor 52 % but different heat transfer coefficients U=0.7 W/m² K and U=1.1 W m²K, annual PE demand for heating differs 15 – 20 %, while annual PE demand for cooling differs by only 2 %, depending on shading applied.

When heat transfer coefficient decreases, the energy demand for heating also decreases energy demand for cooling changes a little. Perednis (2007) also examined dependency of the cooling energy demand on heat transfer coefficient of the window. The cooling demand trend, is the same as in the mentioned paper, but more intense. This depends on the calculation methodology and the characteristics of the building.

Comparing the second and the third glazing (Table 2), which heat transfer coefficient is 1.1 W/m² K, but different SHGC factors - SHGC = 52 % and SHGC = 28 %, the cooling demand varies from 7 to 19 %, and the annual energy demand for heating varies by 15 %, depending on different shading. Decreasing SHGC increases the energy demand for heating and reduces the energy demand for cooling.

Maximum difference of energy demand for heating between the first and fifth glazing is up to 37 %, when the heat transfer coefficient is varying from 0.7 W/m K to 1.4 W/m K. Maximum difference of energy demand for cooling is between the third and fifth glazing - up to 25 %, when SHGC factor changes from 31 to 61%.

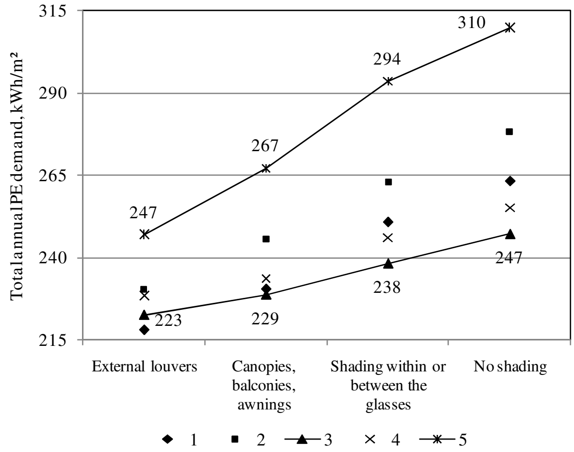

Fig 6. The impact of thermal and optical properties of glazing on energy demand

Therefore, it can be concluded that the optimal demand for heating and cooling (Fig 6) in the analyzed building, where internal louvers are used, the best combination would be with ANTELIO Green + Ar + IPLUS NEUTRAL S glazing.

5. The analysis of calculations results of cooling demand, carried out by computerized program Proclim

The cooling capacity and demand for the analyzed object were determined using analytical methodologies. In order to check the accuracy of the results, there was made a comparison between the results of two methodologies – analytical and computerized program Proclim. The analyzed object in Proclim has been modelled due to its characteristics and shading devices, which were discussed earlier.

The calculated cooling capacity by Proclim was converted to PE cooling demand in kWh/m² and compared with the calculation results of cooling demand by chosen analytical methodology. The results are shown in Fig 7.

Proclim is a calculation program for cooling capacity, created by a Swedish company Swegon. While designing the analyzed object and it's characteristics, the location was chosen Vilnius city. This programme has data library, where you can choose additional data. According to the selected location of the object, Proclim picks the outdoor air temperatures. You can also compose the orientations of building facade design, the areas of glazing, their types, heat transfer and SHGC factors. You can enter the data required for internal heat gains calculation.

Fig 7 shows that the annual PE demand for cooling differs from 21 % to 28 %, depending on orientation of the main facade. This discrepancy occurs because of ProClim ability to evaluate heat or cool capacity, accumulated in the inner partitions. To evaluate this by analytical methodologies it is quite complicated.

However, comparing cooling demand, calculated using different methodologies, same trends can be noticed: maximum energy demand in the western and minimum at the northern orientation.

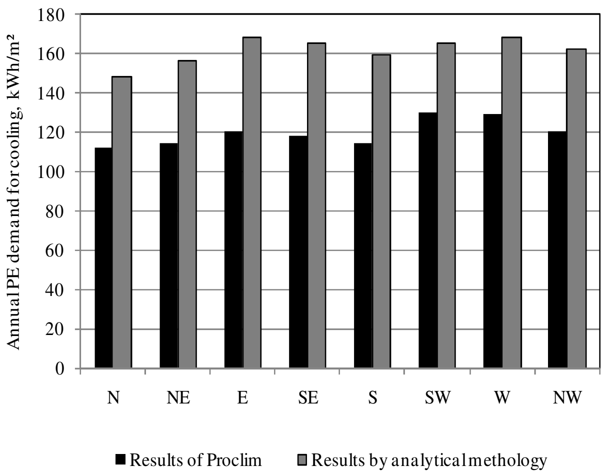

Fig 7. The comparison of calculation results of cooling demand using different methodologies

It can be concluded that, using the most popular analytical methodology for the calculation of cooling capacity or demand, and adopting discussed assumptions, the results are enlarged in about 20 %. This is because the cooling power is calculated on the basis of the maximum possible heat gains and the methodology does not include late flows more accurate assess of the energy demand for cooling, in the new regulation of building energy performance it is recommended to use a dynamic calculation methodology.

6. Discussion

In Lithuania the certification of energy performance of buildings is determined in accordance with the energy demand for heating (together with the heat which is needed for ventilation) and electricity consumption which is determined according to the type of the building. Therefore, the current national certification of energy performance of buildings is not suitable for office buildings, where the ventilation and cooling systems consume the major part of energy. Motuzienė (2010) in her Doctoral Thesis offers to assess not only the energy demand for heating and cooling but also to assess the lighting, fans and pumps energy consumptions, because the glazing of office buildings affects all these components of energy demand.

Figure 3 in article shows that the component of cooling demand is very significant comparing with heating demand, because they are converted to PE. Cooling demand can be significantly reduced by using shading devices, especially in modern office buildings with big glazing areas.

In accordance with regulation STR 2.01.09:2005, when evaluating glazing, only heat transmission coefficient and window frame type are taken into account. However, not frames, but glazing and its thermal - optical properties make the greatest impact on energy demand.

In order to make more accurate evaluation of energy power and demand for cooling, dynamic calculation method should be chosen. Otherwise, using the popular analytical calculation methodology for cooling power and demand, the results can be raised by at least 20 % (Fig 7). In Norway the use of dynamic calculation methods for certain buildings - offices, supermarkets, hospitals, universities are necessary, in order to reduce excess energy (Rode 2008).

The accuracy of calculating methodology of STR 2.01.09:2005 was analyzed also by Kaušylaitė (2007). This author found out that, in accordance with the Lithuanian methodology for energy performance, the energy demand for heating is 78 % lower than actual consumption and more than double than the design energy demand for heating. Whereas the coefficient of energy performance depends only on heat transfer coefficient of external elements and control type of heating system.

Therefore, updating the calculation methodology of energy performance of buildings, the analyzed comments on STR 2.01.09:2005 may be useful.

7. Conclusions

1. Energy demand for cooling makes a great impact on total energy demand, especially in terms of PE. In the analyzed building PE energy demand for cooling composes from 62 % to 70 % of total annual PE demand. That is why it is suggested to assess cooling energy demand in the new procedure of certification.
2. The use of shading devices also makes a significant influence on energy demand. In the analyzed building it is possible to save up to 20 % of PE annually. Therefore, it is suggested to pay more attention at shading devices and more accurately assess solar heat gain coefficient of the transparent partitions, when updating the calculation methodology of energy performance of buildings.
3. In this article, the calculation results of the most popular analytical methodology for the calculation of cooling power and demand, and discussed assumptions, enlarged the results by about 20 %, compared to dynamic calculation results. Therefore in the new regulation of buildings certification it is recommended to use dynamic calculation methodology.

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