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OPTIMIZATION OF ZERO-NET ENERGY BUILDINGS WITH DIFFERENT LATITUDE AND DIFFERENT THERMAL INSULATION THICKNESS

Abstract: *Reaching zero net energy buildings is one of the leading tracks in scientific research nowadays. One of the factors that can definitely help in reaching of energy saving, is orientation of the building. During the daylight on specific location each side of the inspected building is absorbing different amount of solar energy. It is obvious that this dependence will change with geographic latitude but also with weather conditions at inspected location.*
Some specific angles of the object orientation to the cardinal direction are analyzed in this paper and simulations are done in EnergyPlus software. Characteristic period of the year are simulated, which include heating (winter) and cooling (summer) period. It is also analyzed different thermal insulation thickness at different latitude, with the aim to minimize the energy consumption and to achieve the zero-net energy building (ZNEB) concept.
Analyses are done for the zero-net energy buildings for the geographic latitude of Belgrade, Athens and Berlin.
Keywords: *Zero-Net Energy Building, Geographic latitude, Thermal insulation thickness, EnergyPlus, Energy consumption*

1. INTRODUCTION

The sun has influenced architectural design since primitive times. In the sixth century, the Greek philosopher Xenophanes wrote: "In houses with a south aspect, the sun's rays penetrate into the porticoes in winter, but in the summer the path of the sun is right over our heads and above the roof, so that there is shade. If, then, this is the best arrangement, we should build the south side loftier to get the winter sun, and the north side lower to keep out the cold winds."

Thus it is increasingly important to know and understand the sun's effect on the design and engineering of a building. Paramount in this is knowledge of the sun's apparent position.

The fact the sun is lower in the sky in winter than in summer allows us to plan and construct buildings that capture that free heat in winter and reject it in summer.

The orientation of the whole building plays an important part; the ideal orientation for hot and dry climates should be to keep long axis of the building East-West. This will reduce the heat gain. Conversely, buildings with their long axis running north/south will have higher peak cooling loads and will require larger cooling equipment and obviously high energy costs.

The concept of zero-energy buildings

(ZEB), or net zero-energy buildings (ZNEB) is a general term applied to a building with a net energy consumption of zero over a typical year under normal operation and use. Nowadays, zero net energy buildings (ZNEB) are researched all around the world as they present new generation in building constructions.

Andersson et al. were first to research the impact of building orientation on residential heating and cooling [1]. The study was carried out for 25 climates in the United States. They concluded that in these regions, it is better to have windows oriented towards south or north than to east or west.

Yohanis and Norton investigated useful solar gains in multi-zone non-domestic buildings as a function of building orientation and thermal time constant [2]. Morrissey et al. experimented with building orientation and its influence on affordable passive solar design [3].

Bojic et al. did a research toward positive net buildings in Serbian conditions [4].

Aim of the paper [5] is to summarize results and to suggest optimal orientation of the building from the aspect of the building solar energy absorption through the walls. Analyses are done for the zero-net energy house for the average geographic latitude of Serbia which is 44 north latitude. In paper [6] it can be seen that the south-east orientation has better results than the south-west orientation, and that the east orientation has better results than the west orientation.

2. THERMAL INSULATION

Thermal insulation systems have been used in practice for many years for different applications and purposes, such as to decrease heat transfer to/from surfaces, to control the process and surface temperatures, to avoid the condensation problem, and to provide a comfortable indoor thermal environment. Increasing concerns regarding energy efficiency, climate change and awareness of the limited energy resources, the use of a proper amount of thermal insulation for buildings and industrial applications has gained popularity.

Thermal insulation is primarily used to limit heat loss/gain from/to surfaces under operating conditions at temperatures above or below ambient temperature, i.e., to provide a contribution for energy conservation.

The primary reasons to conserve energy include maximizing the return on investment and minimizing the life cycle cost and the emissions associated with energy consumption.

The economic insulation thickness for building walls depends on various factors, such as building type, function, wall orientation, construction materials, insulation properties and cost, energy type and cost and efficiency of the heating or air-conditioning system [7, 8].

A suitable amount of thermal insulation in the building envelope can result in a considerable reduction in the heating and cooling energy demands of a building and its associated CO2 and SO2 emissions into the atmosphere. In paper [9], for a residential house in Serbia, an optimization of thermal insulation is investigated by using EnergyPlus software and Hooke‑Jeeves direct search method.

3. RESEARCH METHOD

Figure 1 represents the model of investigated residential building. The building is for one family of four members, and it has living room, 2 bedrooms, kitchen, corridor, toilet and WC. Area of conditioned space is 90 m^2. The residential building is analyzed with variable thermal insulation thickness: 0.05m, 0.1 m and 0.15 m.

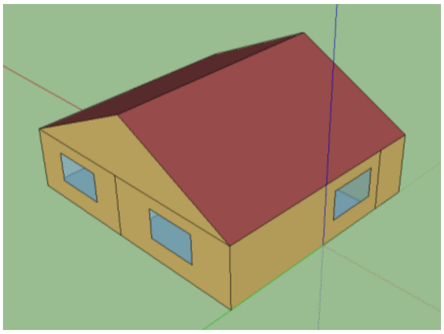

Figure 1 – Modeled residential building

4. RESULTS AND DISCUSION

During the winter house is heated by using electric baseboard radiator, and during the summer house is cooled by air conditioners. Heating and cooling of the building is performed during whole year. House is heated from 6 am to 22 pm. During this time house is heated to 22°C in toilet, and to 20°C in living room, bedrooms, and kitchen. WC and corridor are heated to 18°C. During night setpoint temperature for heating is at 15°C. As for cooling, only conditioned rooms are living room, bedrooms, and kitchen which all have 1 window. There is no need for cooling of the toilet, wc and corridor. Setpoint temperatures for cooling is from 6 am to 24pm is at 24°C.

This building is located in Belgrade (Serbia), but it is also simulated for different geographical location in Europe – Athens and Berlin. These locations have different weather condition during the whole year. Latitude, longitude and elevation of used cities are given in Table 1.

Table 1 – Geographic position of cities

	Latitude North	Longitude East	Elevation, m
Athens	37°58’	23°43’	15
Belgrade	44°49’	20°28’	99
Berlin	52°30’	13°23’	49

Figure 2 shows used building orientation and how the building was oriented from true north.

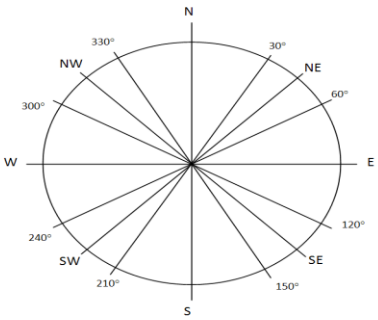

Figure 2 – Building orientation in degrees from north

Figure 3 represents the total annual building energy consumption (in kWh) for different orientation and different location, and for thermal insulation thickness of 0.05 m, and this is unfavorable case. It can be concluded that the best solution is to have the living room and bedroom 1 oriented towards the south, for all locations. Energy gained from solar are biggest when house is oriented toward south. This can lead to conclusion that energy gained during day through window is very important. Energy saving is about 10 % for Belgrade, 6 % for Athens and 5 % for Berlin. It can be also seen that if the house is oriented to east or south-east it has lower energy consumption than to the house oriented towards west or the south-west.

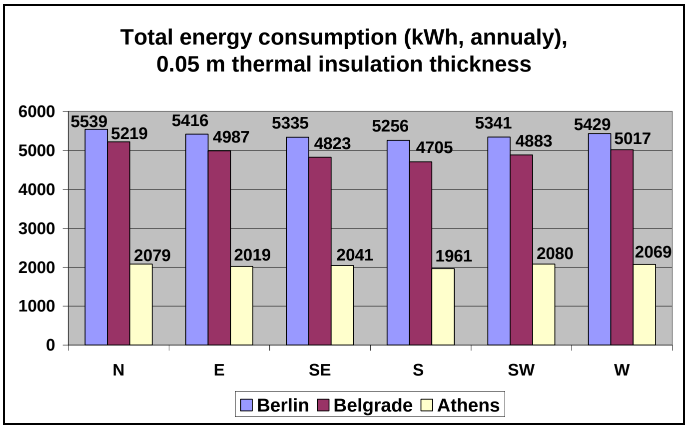

Figure 3 – Total building energy consumption for different location, different orientation and for thermal insulation thickness of 0.05 m

Results of window heat addition for different orientation and Belgrade location are given in Table 2 for detailed view. This simulation was also for 0.05 m thermal insulation thockness.

Table 2 - Window heat adition by room and house orientation, GJ

	N	E	SE	S	SW	W
Living room	1.424	3.724	4.942	5.124	4.802	3.585
Bedroom1	1.434	3.728	4.94	5.118	4.793	3.576
Bedroom2	3.726	5.097	4.775	3.574	2.085	1.457
Kitchen	3.548	1.433	2.112	3.659	4.846	5.03
Total	10.132	13.982	16.769	17.475	16.526	13.648

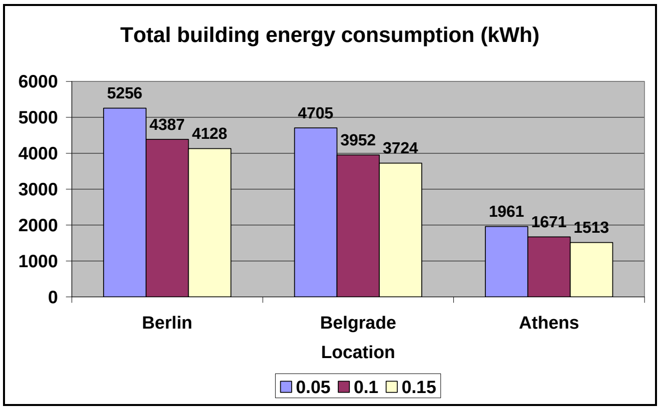

Figure 4 – Total building energy consumption for south oriented building at different location and for different thermal insulation thickness

Figure 4 represent the total building energy consumption depending on different thermal insulation thickness and different location, for the most favorable case when the living room and bedroom 1 were oriented to the south. The first case is the building with 0.05 m of thermal insulation thickness, the second case is the building with 0.10 m and the third case is the building with 0.15 m of thermal insulation thickness, respectively. Energy saving is about 20 – 22 % for the buildings with thermal insulation thickness of 0.15m at all locations.

5. CONCLUSION

Results show that the smallest total energy consumption is when the house is oriented towards south. Also, energy consumption for heating is the smallest in same direction.

Energy savings are about 5 % for Berlin, about 6 % for Athens and about 10 % for Belgrade when the north and the south direction are compared. It also can be seen that south east orientation has better results than the southwest orientation. All these analyses were for 0.05 m thermal insulation thickness.

In case of variable thermal insulation thickness (0.1 m and 0.15 m), it can be concluded that the energy saving is about 20 – 22 % for the building with the biggest thermal insulation thickness of 0.15 m.

If we have thermal insulation thickness of 0.15 m at the building and the building is south east oriented, than the total energy savings compared to north oriented building with 0.05 m thermal insulation thickness are: 25 % for Berlin, 27 % for Athens and 28 % for Belgrade.

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