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MEĐUNARODNI
KONGRES I IZLOŽBA
O KLIMATIZACIJI
GREJANJU I HLAĐENJU

Beograd, Sava centar
5–7. XII 2018

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PREDGOVOR

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Predavači su uložili trud, i veliki broj stručnjaka i naučnuka su svoje radove prijavili i poslali, tako da je program upotpunjen prema zadatim temama aktuelne problematike oblasti grejanja, hlađenja i klimatizacije. Obuhvaćena je aktuelna primena obnovljivih izvora, zaštita prirodne okoline, racionalno korišćenje energije, kao i budućih zgrada u okviru koncentracije stanovništva po velikim gradovima, životnih uslova kojima se teži. Deo radova je objavljen u broju 4 casopisa „KGH“
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U Beogradu, *UREDNIK*
novembra 2018.

SADRŽAJ

Nacionalno studentsko takmičenje

ANALIZA POTROŠNJE ENERGIJE U SRPSKOJ KUĆI PROJEKTOVANOJ PREMA NEKIM PRINCIPIMA PASIVNOG SOLARNOG DIZAJNA[1]

ENERGY CONSUMPTION ANLYSIS IN SERBIAN BUILDING BASED ON THE SOME PRINCIPLES OF PASSIVE SOLAR DESIGN

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U modernom svetu danas, zgrade imaju udeo i do 40 % u ukupnoj potrošnji energije. Strategije projektovanja energetski efikasnih zgrada se, izmedju ostalog, odnose na primenu aktivnog i pasivnog korišćenja solarne energije. Pasivne stragtegije obezbedjuju termički i vizuelni komfort korišćenjem prirodnih energetskih resursa. Implementacija solarnih pasivnih principa pri projektovanju zgrada utiče na smanjenje potrošnje energije konvencionalnih sistema kao što su sistemi za klimatizaciju, grejanje, hladjenje (KGH) i rasvetu. Ovaj rad predstavlja analizu mogućnosti za smanjenje potrošnje energije zagrejanje u porodičnoj zgradi korišćenjem nekih principa solarnog pasivnog projektovanja zgrada. Energetska analiza srpske pasivne kuće je sprovedena u okruženju softvera EnergyPlus, dok je Open Studio plug-in u Google SketchUp-u korišćen za dizajniranje pasivne solarne zgrade. Dobijeni rezultati pokazali su značajno manju potrošnju energije u pasivnim solarnim zgradama, u poredjenju sa kućama tradicionalne gradnje.

Ključne reči: *zgrada; pasivni solarni dizajn; potrošnja energije; direktni solarni dobici; simulacija.*

Nowadays, building energy consumption is up to 40 % of total energy consumption in the modern world. Energy efficient building design strategies are related to active and passive use of solar energy, among the other things. Passive strategies provide thermal and visual comfort by using natural energy sources. Implementation of solar passive techniques in a building design provides the load minimization of conventional systems such as heating, cooling, ventilation (HVAC) and light. This paper presents an analysis of the possibilities for reducing heating energy consumption in residential building, using some principle of solar passive building design. Energy analysis of Serbian passive building was carried out in EnergyPlus environment, while Open Studio plug-in in Google SketchUp was used for passive solar building design. The obtained results showed significantly lower energy consumption in passive solar building, compared to the traditional building.

Key words: *building; passive solar design; energy consumption; direct solar gains; simulation.*

1 Introduction

Building sector has a significant share in total energy consumption, so research and development of methods for improving energy efficiency in buildings are very important in the modern world today. Energy consumption in buildings at the global level is 20 - 40% of total energy consumption, while in Serbia it is at the level of even 50 %. This consumption is related to the exploitation conditions of buildings, where the largest consumer is heating system (about 60 % of total energy consumption), than cooling system, installation for the heating of domestic hot water, household appliances etc. At the other side, there are 300-400 000 energy inefficient buildings in Serbia. Those buildings have no thermal insulation and their annual energy consumption is approximately about 220 kWh/m^2, while the European average energy consumption in buildings is 60 kWh/m^2 [1]. So it is very important to design energy efficient buildings or implement the principles for improving energy efficiency of already existing buildings. Buildings all over the world account one-third of global GHG emissions. In order to reduce energy consumption and GHG emission, many efforts have been made by different countries to reduce them, especially in buildings. Solar energy strategies have been used for many years. In architecture, solar design means reducing demand rather than to substitute for fossil fuels and solar energy acts to save energy used.

Passive Solar Design is known as one of the most effective strategies for decreasing the energy consumption in building. Generally, Passive Solar Design is described as the use of form and materials of the buildings to admit, store and distribute energies from renewable sources (solar, wind etc.) appropriate for buildings; primarily solar energy and fresh air by means of without mechanical or electronical devices for space heating, cooling and lighting [2]. A passive building is defined as ‘’a building which is constructed to achieve a comfortable interior climate without a separate active heating device`` [3]. Passive buildings are capable of achieving the lowest energy requirements through striking a balance between the heat losses and the heat gains with respect to the particular climatic condition of building’s location. When a building is considered with the concept of utilization of solar energy to be a low-energy one, it should be designed to be as ‘self-sufficient’ as possible in terms of providing thermal comfort needs. This state comes from characteristics of passive solar design.

Passive solar homes range from those heated almost entirely by the sun to those with south-facing windows that provide some fraction of the heating load. The difference between a passive solar home and a conventional home is

[1] This paper was presented at the National Students Competition 2018 organized by the Serbian HVAC&R Society.
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design. And the key is designing a passive solar home to best take advantage of the local climate. Elements of passive solar design include building location, building shape, window location and glazing type, insulation, air sealing, thermal mass, shading, sunroom for passive solar heating, and sometimes auxiliary heat (depends from location) [4].

There are three basic types of passive solar design - direct gain, indirect gain and isolated gain, that differ in how elements of passive solar design can be incorporated.

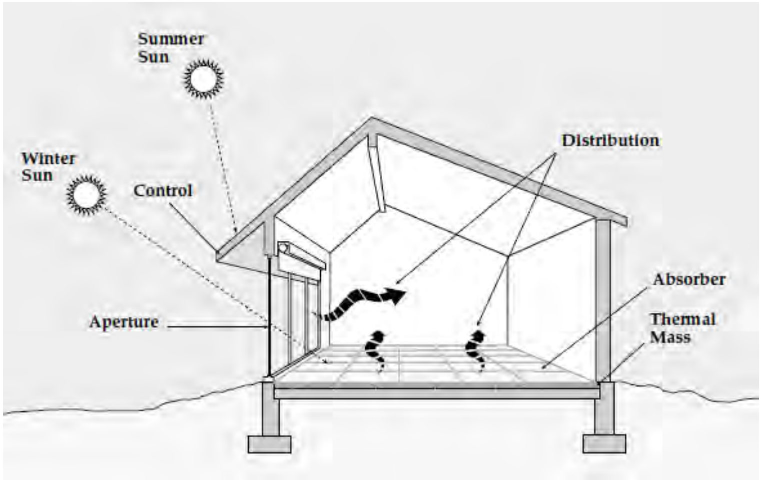

Fig. 1 Elements of passive solar design and direct solar gains

Direct gain is the simplest passive design technique - heat is collected and stored directly in the living space (Fig. 1). Sunlight enters the house through the aperture - usually south-facing windows with a glazing material made of transparent or translucent glass. The sunlight then strikes masonry floors and/or walls, which absorb and store the solar heat. At night, as the room cools, the heat stored in the thermal mass radiates into the room. The amount of passive solar energy depends on the area of glazing and the amount of thermal mass. The ideal ratio of thermal mass to glazing varies by climate. Another important thing is that the thermal mass must be insulated at the outside.

Indirect gain – heat is collected and stored adjacent to the primary living spaces and thermally linked (not visually) to them. The most common indirect gain approach is using a Trombe wall – thermal storage between the south facing windows and the living spaces.

Isolated gain – sunspace – heat is collected adjacent to or apart from the weather-skin and stored either apart from or in the living spaces. This is also known as a solar room or solarium, is a versatile approach to passive solar heating. A sunspace can be built as part of a new home or as an addition to an existing one. The simplest and most reliable sunspace design is to install vertical windows with no overhead glazing.

Passive House standards must be adapted to the climate and geographic situation. The local building traditions and the specific climatic conditions of each region must be analyzed in order to achieve the best passive solution. Integrating passive design solutions at the very early design stage add little or nothing to the cost of the building construction. The Passive House Institute in Darmstadt has developed several Passive House building techniques to suit the Central European climate. However, it would be wrong to directly apply all the passive techniques, especially those regarding insulation, windows and ventilation from the Central European example to other parts of the world [5]. The Passivhaus standard for central Europe requires that the building fulfills the following requirements [6]:

- The building must not use more than 15 kWh/m² per year in heating and cooling energy.
- Total energy consumption (energy for heating, hot water and electricity) must not be more than 42 kWh/m² per year
- Total primary energy (source energy for electricity and etc.) consumption (primary energy for heating, hot water and electricity) must not be more than 120 kWh/m² per year

Some countries have their own standards that define passive house in more strict way. In Germany the term passive house refers to the rigorous, voluntary, Passivhaus standard for energy efficiency in buildings. In Switzerland is in use similar standard – MINERGIE-P. It is estimated that the number of passive houses around the world range from 15 000 to 20 000 and the vast majority have been built in German-speaking countries or Scandinavia. Experience, mainly within Germany and Austria, has shown that it is possible and economic to build these particular kinds of construction and that they can maintain good air quality and thermal comfort along the year.

In order to achieve these standards it is necessary to follow the basic passive solar design principles that help in reducing the energy demand till almost 80% compared to the conventional buildings.

This paper presents an analysis of the possibilities for reducing energy consumption in Serbian residential building, using the principle of solar passive design. The investigated building was located in Kragujevac, Serbia. The EnergyPlus software uses weather data from its own database file. That file contains data for a lot of parameters (pressure, air temperature, relative air humidity, solar radiation, wind speed, percipitations …) [7]. For these investigations, data about direct and diffuse solar radiation are very important, because passive solar building design depends of them. Building energy analysis was carried out in EnergyPlus environment, while Open Studio plug-in in Google SketchUp was used for passive solar building design [8]. Simulated building has auxiliary heating system – electric space heating, which operates from October 15th to April 15th next year. Air temperatures in the heated rooms are set to 20^{0}C from 07:00-09:00 and from 16:00-21:00, and to 15^{0}C from 09:00-16:00.

2 Model of passive building in EnergyPlus software

Building orientation is the basic principle in a passive house design, so it has been most frequently studied. It is generally agreed that a southern orientation is optimal for gaining heat in the winter and for controlling solar radiation in the summer. This means that southern façade of the building must be oriented towards the equator in the northern hemisphere (and the northern façade towards the north in the southern hemisphere). As a general rule, the longest wall sections should be oriented toward the south [5, 9]. By facing the longer axis of the building in the east/west direction, the longer dimension of the home faces will be more likely to gain the maximum solar radiation. For that reason, areas which are most frequently used, such as kitchen, living room and rooms for children, must be located into this part of the building. This orientation is also advantageous for summer cooling conditions because it minimizes the east-west façades to morning and afternoon sunlight.

Building geometry is considered as a significant factor influencing the building energy consumption. When a building is designed, the ratio between its outer surface and the total constructed volume should be as small as possible, tending towards the ideal case of a hemisphere (*Compactness index*). Also, *Shape factor*, which represent the proportion of a building's length to its width (in order to maximize solar gains), is very important [10].

Based on these basic passive solar design principles, a residential family building is designed in the Open Studio plug-in for Energyplus software (Fg 2). The green axis is oriented to the north and the red axis is oriented to the east.

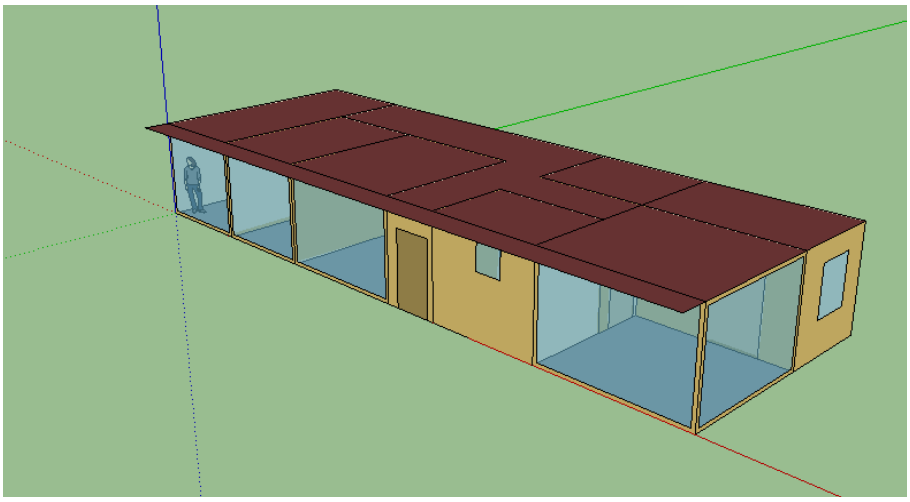

Fig. 2 Modeled building in EnergyPlus software (with passive solar design principles)

The building has 8 conditioned zones – living room (DNS), bedroom (SS), two rooms for kids (DS1, DS2), kitchen (KUH), bathroom (KUP), toilet (T) and hall (H). All zones are oriented to the south, except kitchen, toilet and one part of the hall (Fig 2). The total floor area of the building is A=108.28 m^2. The bedroom and rooms for children have one triple glazed glass wall which is south oriented. Also, two walls in the living room are modeled as glass walls (like triple glazed window too). One of them is south oriented and the second is east oriented. This design can significantly reduce heating energy consumption, because of great amount of solar gains through windows.

Thermal insulation. Passive building means also the good thermal insulated building. A well insulated building helps in reducing heat loss during the winter and keeping the house cool during the summer. Building envelope must be greatly insulated, especially external structural walls, because of thermal bridges are eliminated (there are no longer interruptions caused by floor slabs), heat gained from the sun is dissipated in the cavity and ventilated throughout openings, and temperature swings are drastically reduced. Since insulation is important in warm climate as well as in cold climate, less energy is required to heat houses in cold conditions or cool houses in warm condition which results in a good interior thermal comfort along the whole year [10]. In the modeled building, the exterior walls, roof, and the floor were thermally insulated by polystyrene. In this investigation, the polystyrene thickness was 0.25 m, while U value was 0.112 W/m^2 for exterior walls and roof-ceiling and 0.409 W/m^2 for floor.

Overhangs and shadings are important devices in a passive house because they help in reducing overheating during the summer season. The southern façade through which the sun mostly comes inside must be correctly shaded, or equipped by sized overhangs, in order to prevent overheating and to keep the house cool during summer months. Because shading devices can have a huge impact on the building appearance as well as reducing the cooling demand, they must be considered and evaluated at the early stage of the design process, in order to be effective for both technical and visual aspect for being well-integrated in the whole architecture [9]. Modeled building has concrete overhang at the whole length of southern façade, with thickness of 110 mm.

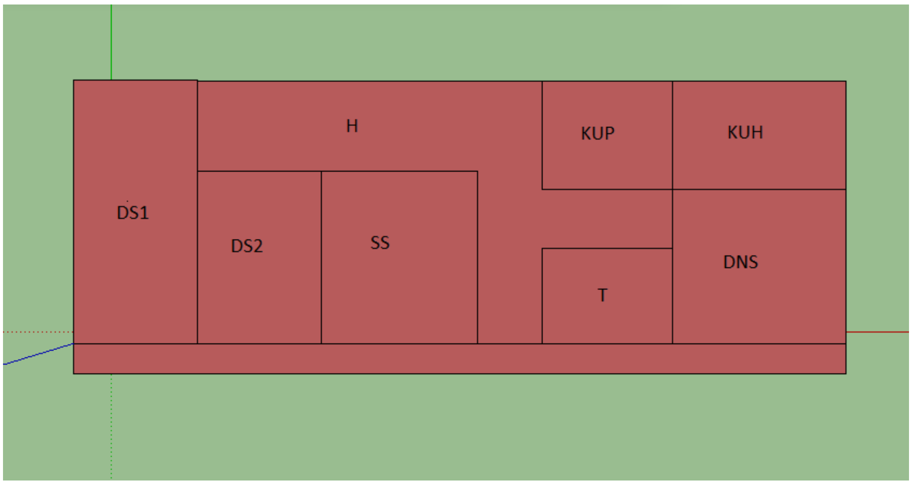

Fig. 3 Cross section of the analyzed building – room schedule

Windows are responsible for wasting a notable percentage of total building energy loss approximately by 20-40% [9]. Designing window should be practiced based on the particular climatic condition of buildings to reduce the energy demand. Glazed surfaces play an important role in a passive house because they serve as solar collectors bringing in light and heat while also providing natural ventilation. The basic role regarding windows in a passive house is the southern position because it allows them to collect warm solar energy when heat is needed, or vice versa to let fresh air in when is needed. Locating the majority of glazed surfaces on the southern façade helps in achieving the maximum solar gain and reduces the ones in the northern façade helps for the insulation of the building against winter cold. Passive House standards recommend using double or triple glazing which helps in reducing heat losses through the windows. Passive House Institute refers to the U-value speaking about the whole window, which means the glazing parts included the frame that does not have to exceed 0.70 - 0.85 W/m^{2}K [5]. Following all these recommendations, triple-glazed windows are designed at modeled building, with argon gas filled between glazings. They have a very low U factor – 0.685 W/m^{2}K.

In these calculations, the intensity of infiltration and ventilation in the living room was 0.7 air changes per hour, and at the other rooms it was 0.5 air changes per hour.

3 Building energy consumption

Total energy consumption E_p in building is related to the electricity. Electricity in building is consumed for heating (eh), lighting (el), domestic hot water (DHW) and appliances (eq).

$$E_p = E_{ac} + E_{eh} + E_{eq} + E_{el} \quad (1)$$

where:
E_{eh} - electricity consumption of the electric heating,
E_{el} - electricity consumption for lighting,
E_{el} - electricity consumption for DHW system and
E_{eq} - electricity consumption for the appliances - electric equipment.

Building heating energy consumption per unit of area is

$$E_{pA} = E_p/A \quad (2)$$

Primary energy consumption E_{prim} of the building is

$$E_{prim} = p_{EL}E_p \quad (3)$$

where p_{EL}=3.04 stands for the primary conversion multiplier for electricity [11].

4 Results and analysis

The aim of this investigation was to show energy saving in Serbian residential building, based on the some principles of passive solar design. The analyzed building is not passive building, it is only the building in which some principles of passive solar design are incorporated. The residential building is analyzed in order to minimize heating energy consumption. On that way, the green gases emission will be minimized too.

Table 1 represents the total building energy consumption (E_p), total building energy consumption per unit of area, primary energy consumption (E_{prim}) and building heating energy consumption per unit of area (E_{pA}).

The obtained values for energy consumption in analyzed buildings do not correspond to the Passive house standards for Central Europe, but they represents the possibilities for great energy saving in Serbian buildings by implementation passive solar strategies in building design. It is known that buildings in Serbia have average total energy consumption of the 220 kWh/m^2, and 60 % of this amount is related to the heating energy consumption. Compared to buildings in Serbia, analyzed building has three times lower total annual energy consumption, and also more than four times lower annual heating energy consumption. The following figure (Fig 4) represents total annual energy consumption in the analyzed building.

Table 1- Annual building energy consumption

	Energy consumption (GJ)	Energy consumption (kWh)
Heating	10,66	2961,11
Lighting	0,54	150
Electric equipment	3,83	1063,89
Water heating	15,62	4338,89
Total building energy consumption	**30,65**	**8513,89**
Total building energy consumption per unit of area	0,283	**78,62**
Primary energy consumption	93,18	25882,23
Primary energy consumption per unit of area	0,86	**239,03**
Building heating energy consumption per unit of area	**0,098**	**27,35**

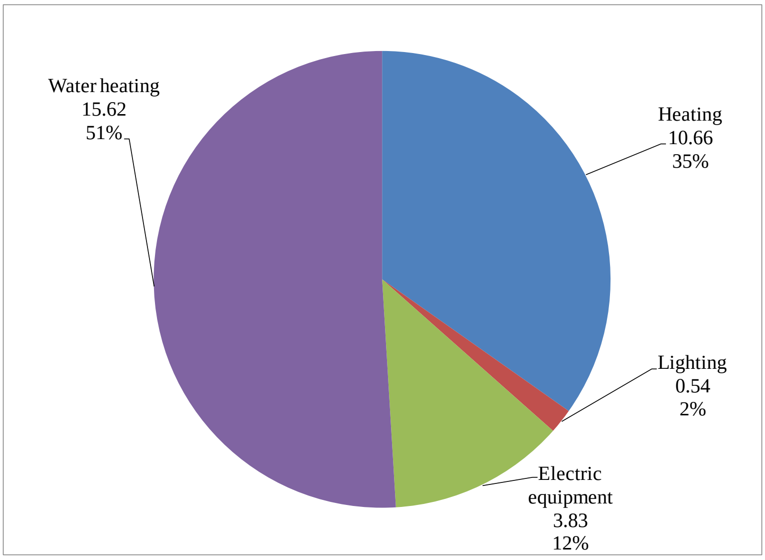

Fig. 4 Total annual energy consumption in the analyzed building

Modeled building is simulated in EnergyPlus software, and the next image (Fig. 5) represents the obtained results for solar gains through windows in building (annually), per zone. Solar heat gain through windows has the highest value for the living room, because there are two windows - glass walls. Solar heat gains have also significantly values for bedroom and rooms for children. All of them are south oriented and they receive a large amount of solar energy.

Fig. 6 represents the obtained results for heat loss energy through windows in building (annually), per zone. It can be concluded that heat loss energy through windows has very small values, because of the good thermal properties of the windows (low U factor). Heat loss energy through windows has the uniform values, except for the Toilet and kitchen. The reason is very small dimension of the windows in these building zones.

Results for annual ventilation total heat gain, per zones, are shown in Figure 7. The highest value of ventilation heat gain is for the bathroom, a little bit less for the hall, and negligible for all other zones. EnergyPlus calculates ventilation total heat gains according to the principle that this gain occurs when the sum of Zone Ventilation Sensible Heat Gain and Zone Ventilation Latent Heat Gain is bigger or equal then the sum of Zone Ventilation Sensible Heat Loss and Zone Ventilation Latent Heat Loss.

These gains occur in the period when the outdoor temperature is higher than indoor temperature. In the analyzed building, ventilation heat gains were appeared from April to October. Next figure (Fig. 8) shows the distribution of annual ventilation total heat gain (per zones), from April to October next year. The highest value of ventilation total heat gain is for hall and a little bit less for bathroom.

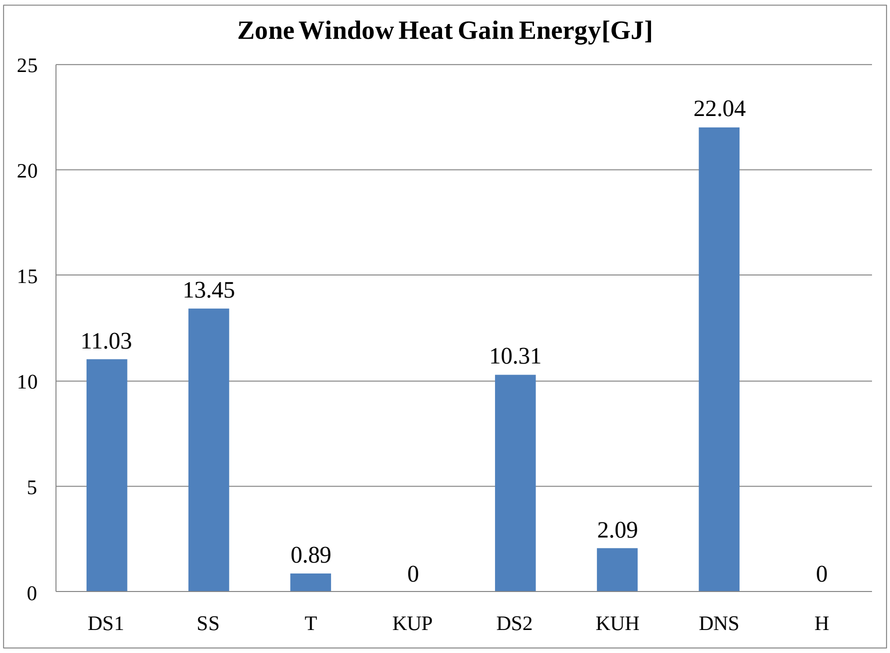

Fig. 5 Annual zone window heat gain in the analyzed building – solar gains

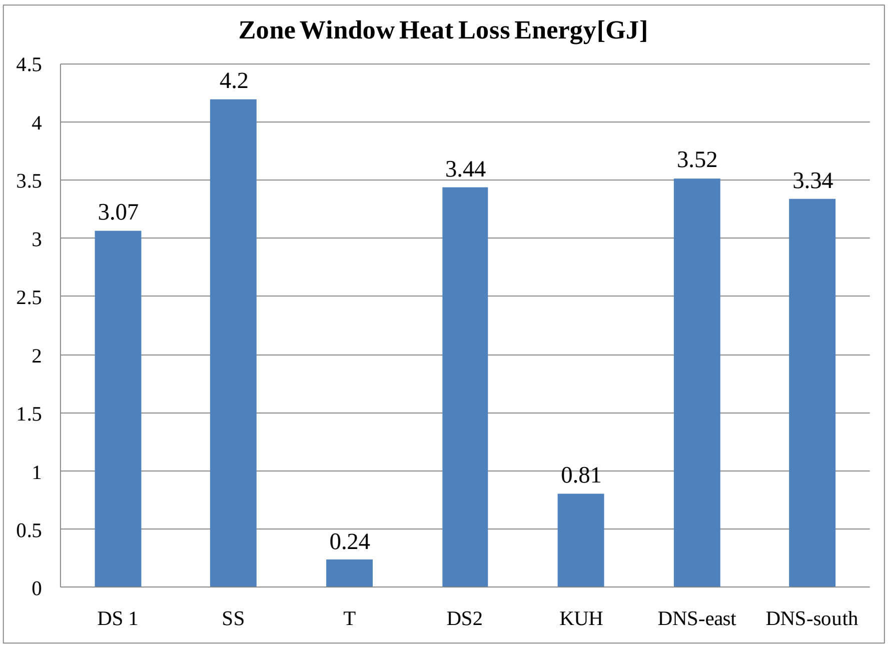

Fig. 6 Annual zone heat loss energy in the analyzed building through windows

At the Figure 9 it can be seen the annual ventilation total heat loss, per zones. Due to leakages in the building construction, opening and closing of windows, etc. the air in the building shifts. In this paper, the intensity of infiltration and ventilation was 0.5 air changes per hour, except in the living room (0.7 air changes per hour). The real value of intensity of infiltration and ventilation is hard to predict and depend of several variables - wind speed, difference between outside and inside temperatures, the quality of the building construction etc. The total ventilation heat loss occurs when the sum of Zone Ventilation Sensible Heat Gain and Zone Ventilation Latent Heat Gain is less than the sum of Zone Ventilation Sensible Heat Loss and Zone Ventilation Latent Heat Loss.

This results show that ventilation heat losses are the greatest for living room and room for children, which are at the sideways of the building, oriented to east and west, respectively.

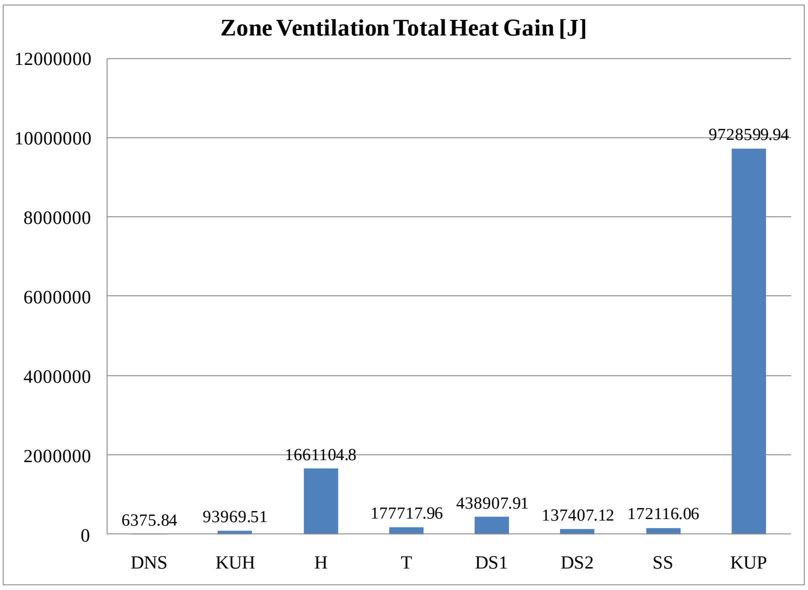

Fig. 7 Annual ventilation total heat gains, per zones

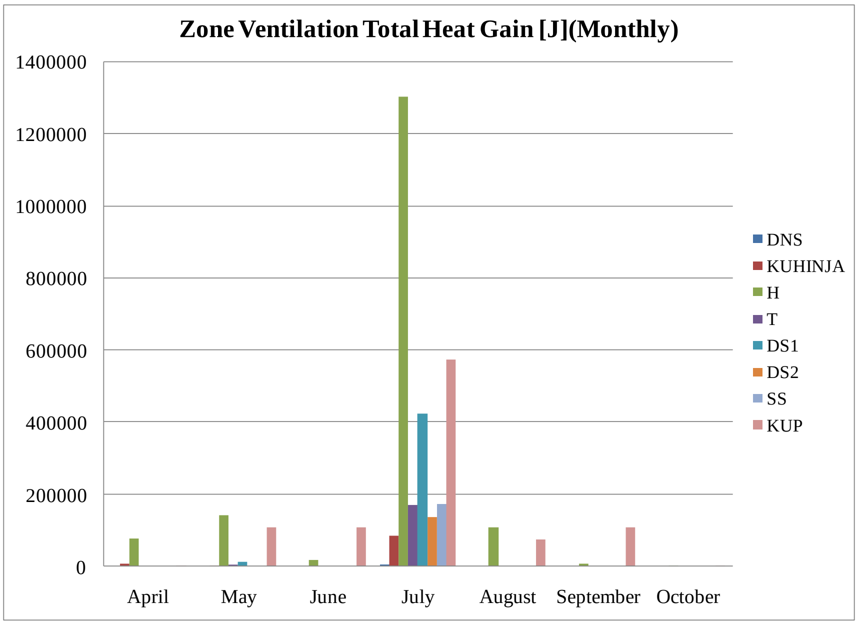

Fig. 8 Annual zone heat loss energy in the analyzed building through windows (monthly)

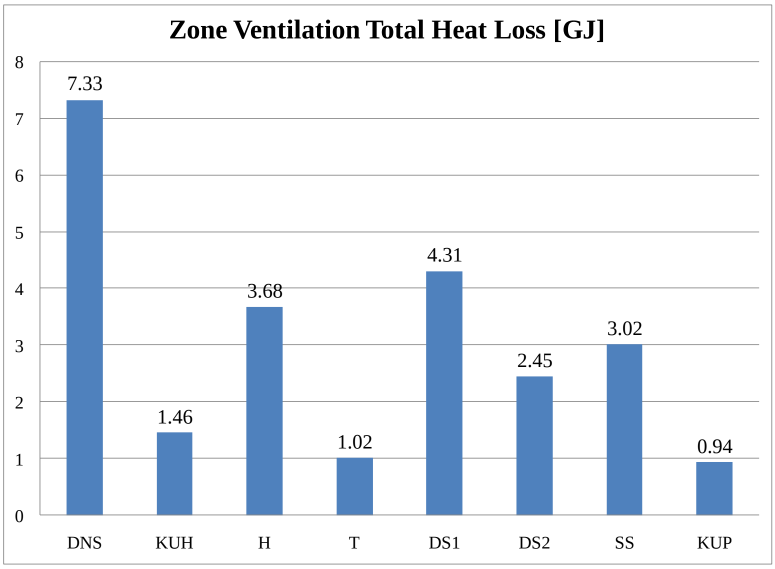

Fig. 9 Annual ventilation heat loss (per zones) in the analyzed building

5 Conclusion

This paper presents an analysis of the possibilities for reducing heating energy consumption in residential building, using some principle of solar passive building design. As mentioned earlier, the obtained values for energy consumption in analyzed buildings do not correspond to the Passive house standards for Central Europe, but they represent the possibilities for significant energy saving by implementation passive solar strategies in building design.

In order to achieve the passive house concept, it is necessary to use additional principles of passive design, for example, Trombe wall. Installing the Trombe wall can significantly reduce the energy consumption for heating. As the water heating energy has the biggest part in total building energy consumption (51 %), it is recommended to install solar collectors on the roof, for domestic water heating. On that way, a significant amount of energy for water heating would be saved. It's also possible to integrate solar systems into the building, such as PVs and solar collectors. This represents a good practice that has many advantageous aspects: the renewable systems works as both building envelope material and energy generator and it saves in materials and energy costs.

Implementation of all these systems can contribute to reducing of total energy consumption, and also, to achieving Passive House.

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