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Beograd, oktobar 2020.
Prof. dr Branislav Todorović

FOREWORD

The Sebian society for heating ventilation and air-conditiong organized the 50th International HVAC&R Congress and Exhibition with endorsement of the most important scientific and professional organizations from all over the world, and with participation of respectable scientist and professionals in the field of HVAC&R, as well as from universities and various industry branches.

The Proceedings contains more than 60 papers writen by more than 150 authors and coauthors from all over the world.

The International scientific committee proposed a number of papers to be published in "Energy and Buildings" noting that they were presented at our Congress. Papers waiting for peer review in that journal are presented in this Proceedings with abstract only.

The Proceedings is another valuable contribution to the rich collection of papers presented during half a century of International HVAC&R Congress.

Belgrade, October 2020.
Prof. Branislav Todorović, Ph. D.

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PARAMETRI LOKACIJE I ENERGETSKA EFIKASNOST U ZGRADARSTVU

LOCATION PARAMETERS AND ENERGY EFFICIENCY IN BUILDINGS

Nebojša LUKIĆ[1], Aleksandar NEŠOVIĆ*[1], Filip GRBOVIĆ[2], Novak NIKOLIĆ[1], Dragan TARANOVIĆ[1]
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Parametri lokacije u nekim slučajevima mogu uticati i na konačan energetski razred zgrada, zbog čega bi se isti trebalo uzeti u ubzir u fazi projektovanja. U ovom radu korišćeni su osnovni (sa jedne strane) i stvoreni (sa druge strane) parametri lokacije kako bi se smanjila godišnja potrošnja finalne energije za grejanje i hlađenje konretne zgrade locirane u Kragujevacu, Centralna Srbija. Istraživanje je spovedeno softverski, kombinacijom programa GoogleSketchUp i EnergyPlus, koji međusobno komuniciraju preko Legacy OpenStudio. Najpre je model zgrade definisan u programu GoogleSketchUp, a potom je programu EnegyPlus, uz korišćenje odgovarajućeg vremeskog fajla, za isti model vršeno simuliranje rada grejnih i rashladnih sistema. Rezultati pokazuju da se primenom navedenih mera tokom godine mogu ostvariti znatne uštede energije, čime se između ostalog čuva životna sredina.

Ključne reči: *parametri lokacije; sitnolisna lipa; zemunica; potrošnja energije; simulacija; energetska efikasnost; zaštita životne sredine*

Location parameters may in some cases also affect the final energy class of buildings, which should therefore be taken into account at the design stage. In this paper, basic (on the one hand) and created (on the other hand) location parameters were used to reduce the annual final energy consumption for heating and cooling of a concrete building located in Kragujevac, Central Serbia. The study was conducted through a combination of GoogleSketchUp and EnergyPlus, which communicate with each other through Legacy OpenStudio. First, the building model was defined in GoogleSketchUp, and then EnegyPlus, using the appropriate time file, simulated the operation of the heating and cooling systems for the same model. The results show that the implementation of these measures can result in significant energy savings throughout the year, thereby preserving the environment, among other things.

Key words: *location parameters; lime tree; earth-sheltered house; energy consumption; simulation; energy efficiency; environmental protection*

1. Introduction

Energy-efficient building (EEB) is defined as a building, which requires a minimum amount of the final energy (thus at the same time preserves and Environment) with the provision of the necessary conditions of comfort [1]. Therefore, the building can become energy efficient by taking the appropriate measures, either in the rehabilitation phase or in the design phase. Taking into account as many parameters as possible in the design phase, predicting the energy behavior of buildings will be closer to reality. Among the influencing factors, location parameters sometimes have a very important place and can play a crucial role in determining the energy class of buildings, and it is often the case that some of them are neglected by designers. Ljiljana Vukajlov [2] sorted all the location parameters into two groups: natural and created. Natural parameters of the site include: Sun, wind, water, greenery (vegetation) and terrain configuration. The created location parameters are: the position, shape and orientation of the building, as well as their distance from each other. The main reason why

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location parameters should be taken into account in the design and construction phase of buildings is that passive measures reduce the final energy consumption in them, which can also generate significant monetary savings. Among the architectural solutions, the earth-sheltered buildings are very interesting because they combine the natural and created local parameters (Fig. 1) of the site, thus achieving many benefits (Tab. 1). Basic text should be tagged as Normal style.

Table 1. Benefits of using the earth-sheltered houses

Benefits	Source
The need for thermal energy in winter and cooling energy is reduced	[4-13]
The greenhouse gas emissions are reduced	[14]
They have a favorable impact on the construction density in urban areas	
Thermal islands in urban areas are avoided	
Pollution of water and soil is regulated	
The noise level is reduced	[15]

Passive reduction of final energy consumption (especially cooling energy) in buildings (of any purpose) can also be achieved through the application of vegetation (especially trees), which has been demonstrated in a large number of works [16-27]. A modelling method to assess the effect of tree shading was developed and presented in [28].

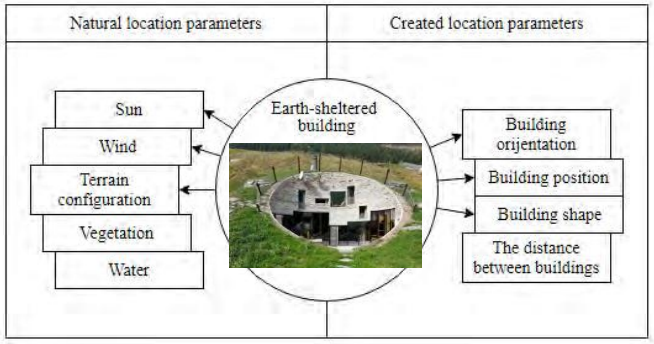

Figure 1. Earth-sheltered building and location parameters *[3]*

A simplified model for efficient tree modeling and simulation (characteristic of a given climate area) has been developed in Amman, a city with a Mediterranean climate, to reduce electricity consumption for building cooling purposes [29]. A method with tabular changes in energy consumption for 178 woody plants, taking into account their geometry and location around the building, was developed in [30]. The frequency of occurrence of trees in the observed locations was taken into account. The survey was conducted in Sacramento, California. The results showed that using this method can predict energy consumption with an error of ±10%. E Simá et al. [31] have taken into account the influence of trees and sur-

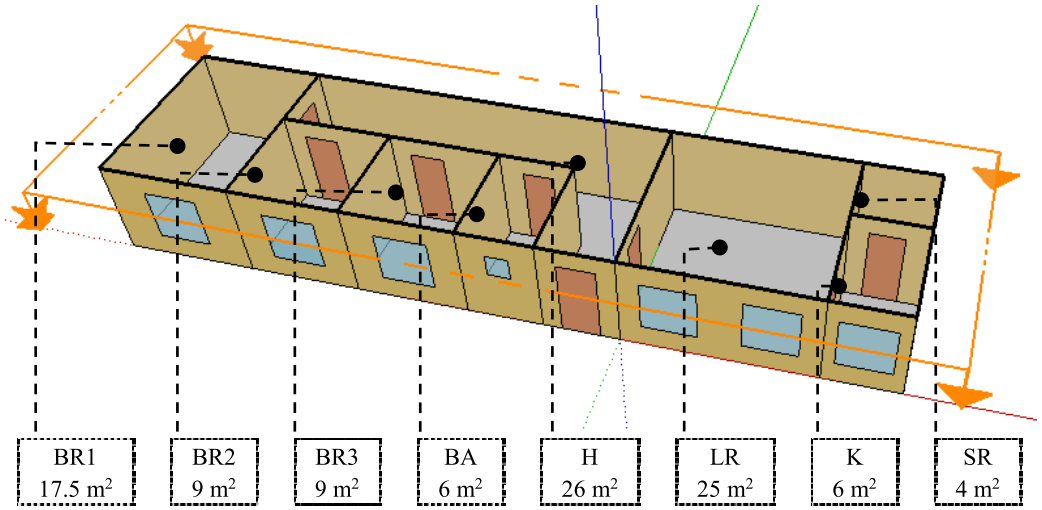

Figure 2. Isometric view and room arrangement BR1 – badroom 1; BR2 – badroom 2; BR3 – badroom 3; BA – bathroom; H – hall; LR – living room; K – kitchen; SR – storage room

rounding buildings on the numerical prediction of the final energy consumption in a building, showing that the shading effect has a large influence on the cooling energy consumption in summer and heat in winter.

Considering the foregoing, the aim of this paper is to consider, through the software GoogleSketchUp and EnergyPlus, the possibility of planting deciduous trees in front of the southern façade of the earth-sheltered building located in the territory of the city of Kragujevac in order to reduce final energy consumption for heating and cooling during the year.

2. Research subject

2.1. Building model

Building model shown in Fig. 2. The net area of the building is 102.5 m2. The net conditioned building area is 98.5 m2 (storage room is unconditioned room). The total surface of the thermal shell is 337.6 m2, window-wall ratio is 9.92% and the shape factor of the building is 1.27. The building is intended for the permanent stay of a four-member family and it is modeled according to the Serbian regulation on energy efficiency in the residential sector (Tab. 2).

Table 2. Serbian building energy performance regulation [1]

Parameter	Description	Building model	New buildings
Heat transfer coefficient [W/m^{2}K]	Exterior wall	0.269	0.3
	Flat roof (above heated room)	0.148	0.15
	Flat roof (above unheated room)	0.148	0.3
	Floor	0.249	
	Window	1.5	
	Exterior door	1.012	1.6
Heating set-point [°C]	Bathroom	22	
	Other rooms	20	
Outdoor air flow rate [h^{-1}]	Kitchen	1.5	
	Bathroom		
	Other rooms	0.5	

2.2. Building location

To simulate weather conditions for the city of Kragujevac (latitude of 44.02°N, longitude of 20.92°E, the average altitude of 209 m) the EnergyPlus weather file was used [15]. Kragujevac (with the time zone of GMT+1h) is characterized by moderate continental climate with pronounced seasons. Some meteorological data for Kragujevac are shown in the Figs. 3-8.

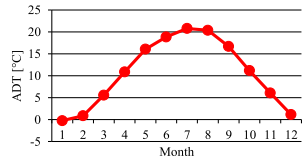

Figure 3. Air drybulb temperature

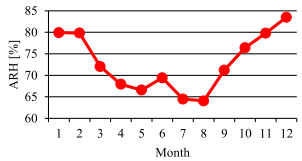

Figure 4. Air relative humidity

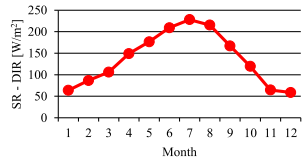

Figure 5. Direct solar radiation

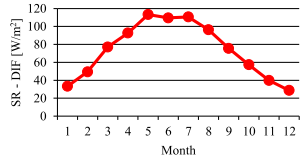

Figure 6. Diffuse solar radiation

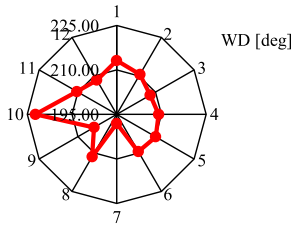

Figure 7. Wind direction

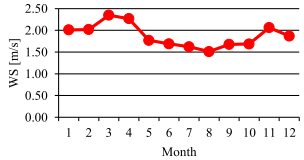

Figure 8. Wind speed

2.3. Description of thermotechnical systems

2.3.1. Ground source heat pump

In order to provide thermal comfort during the heating season, a REHAU GEO 7 heat pump was used, coupled to one side with vertical probes (primary heating circuit) and on the other with underfloor heating (secondary heating circuit). A simplified scheme of the heating system is shown in Fig. 9. The technical parameters of the REHAU GEO 7 heat pump and vertical geothermal probes (VGP) are given in Tab. 3.

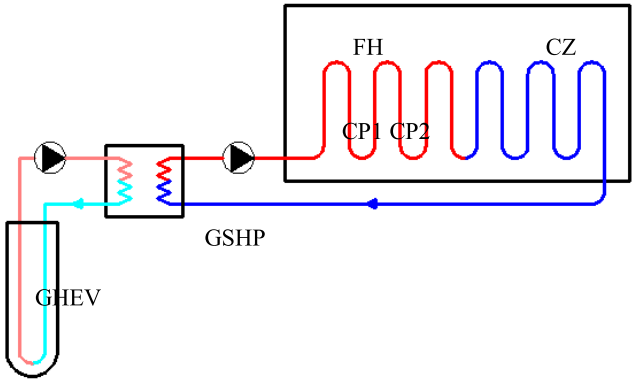

Figure 9. Scheme of the heating system CP1 – circulation pump 1; CP2 – circulation pump 2; GSHP – ground source heat pump; GHEV – vertical ground heat exchanger; CZ – conditioned zones; FH – floor heating

Table 3. Technical parameters REHAU GEO 7 heat pumps and vertical geothermal probes [32, 33]

REHAO GEO 7		GVP	
Parameter	Value	Parameter	Value
$Q_{GSHP\text{-}COND}$ [W]	7300	n_B [-]	2
COP [-]	4.1	H_B [m]	73.2
$Q_{GSHP\text{-}COMP}$ [W]	1600	R_B [m]	0.0889
t_{MAX} [°C]	55	λ_G [W/mK]	2.08
p_{MAX} [bar]	3	c_G [J/m^{3}K]	2347000

$Q_{GSHP\text{-}COND}$ – condenser power GSHP; COP – coefficient of performance GSHP;
$Q_{GSHP\text{-}COMP}$ – compressor power GSHP; t_{MAX} – maximum water temperature at the entrance to the floor panel; p_{MAX} – maximum operating pressure on the secondary side; n_B – number of bore holes; H_B – bore hole lenght;
R_B – bore hole radius; λ_G – thermal conductivity of the soil;
c_G – specific volume thermal capacity of the soil

2.3.2. Window air conditioner

Each room (except the pantry) is equipped with a Venting window air conditioner model WFM1 12RNH1. The technical characteristics of the selected windov air conditioner are shown in Tab. 4.

Table 4. Technical parameters Window air conditioner Venting WFM1 12RNH1 [34]

Parameter	Value
$Q_{WAC\text{-}COND}$ [W]	3500
COP [-]	2.61
$Q_{WAC\text{-}COMP}$ [W]	1430
V_{WAC} [m^3/h]	460

$Q_{WAC\text{-}COND}$ – condenser power WAC; COP – coefficient of performance WAC;
$Q_{WAC\text{-}COMP}$ – compressor power WAC; V_{WAC} – volume flow fan

3. Small leaved lime

The Small leaved lime tree (Fig. 10, Tab. 5) is one of the more commonly grown trees in urban areas because it is highly tolerant of urban air pollutants and easily adaptable to different soil types. It tolerates pruning very well, so its height can be easily controlled. Its development is matched by as much sun exposure as possible, but occasionally shady, especially in the hottest part of the day. The leaves (Fig. 11, Tab. 5) are bright green, heart-shaped, while the flowers are pale yellow, with a very pleasant aroma. Due to its dense canopy, Small leaved lime is well suited for use in tree gardens and parks. In addition, the sanitary and hygienic importance of this species is great because it thickens the dust cover, produces excellent shade and significantly lowers the temperature below the canopy [35, 36].

Figure 10. Small leaved lime [37]

Figure 11. The leaves of Small leaved lime [38]

4. Scenario simulation

The complete survey was conducted through 4 simulation scenarios (Fig. 12). In the first scenario (S1), the consumption of thermal and cooling energy during the year in a

Table 5. Small leaved lime profile [36]

Parameter	Description
Name botanical	Tilia cordata
Family	Mallow family (Malvaceae)
Species	Deciduous tree
Height (maximum)	10-30 m
Height at 20 (maximum)	About 14 m
The height of the trunk	Tree height / 1.4
Tree diameter (trunks)	About 1 m
Leaf	The leaves of Small leaved lime are heart-shaped, dark green, firm and the margin is finely serrated
Leaf shape	Cordate
Leaf margin	Serrated
Leaf position	Alternate
Fall foliage	Yellow
Appearance of leaves	The second half of April
Flowering	June - July
Changing leaf color in autumn	The second half of September
Blossom color	Yellow
Blossom description	The yellow flowers form 7-11 cm long cymes
Declining leaves	The second half of October
Gender distribution	Monoecious / hermaphrodite
Branches	The branches are olive green to reddish provided with lenticels
Bark	The bark is brown, smooth first and later fissured lengthwise
Location	Sun to half-shade
Soil	Sandy-loamy to loamy
pH value	Slightly acidic to alkaline
Usage	Single tree or planting in groups, parks

building that was modeled according to the Serbian Rulebook on the Energy Efficiency of Buildings in the Residential Sector was analyzed (Fig 2, Tab 2). The building in this scenario uses only the created location parameters (the distance between buildings is not taken into account), so the results obtained in the other scenarios will be compared with the results from S1. In Scenario 2, the natural location parameters according to Fig. 1, were used for the same model of the house, which is actually characteristic of the earth-sheltered houses, so in this scenario the consumption of heat and cooling energy in them was considered. In S3, a building from S1 was used, but a row of Small leaved lime trees (building from natural site parameters uses vegetation only) was planted in front of the southern facade according to Tab. 6. Finally, in scenario 4, the house model from S1 uses all natural site parameters except water.

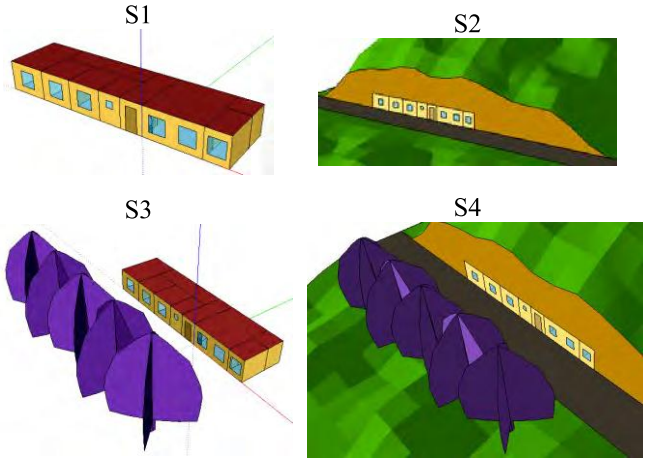

Figure 12. Scenario simulation

Table 6. Small leaved lime profile [36]

Parameter	Distance from the south facade	Number of seedlings	Tree height	Trunk height	Crown diameter	Pillowing time	Leaf fall time
Description	10 m	5	10 m	7.1 m	7.46 m	15.04.-01.05.	15.10.-01.11.

5. Results and discussion

Fig. 13 shows the results of monthly heat and cooling consumption for building S1. The building consumes 4697.39 kWh/a (47.69 kWh/m^2/a) of thermal energy and 3848.61 kWh/a (39.07 kWh/m^2/a) of cooling energy. In the transitional periods (April and October) major changes in the outside temperature occur (Fig. 3). Therefore, the final energy is then used for the ambient needs of the building, both for heating and cooling. The heat consumption in April (end of the heating season) is 58.77 kWh/month, while in October (the beginning of the heating season) it is 88.17 kWh/month. On the other hand, the cooling energy consumption for the same months is 137.63 kWh/month and 253.18 kWh/month.

Building S2 (earth-sheltered house) consumes much less energy for heating and cooling because it uses natural location parameters (Fig 14). If the building on all sides (except the south façade) is covered with ground, then the thermal energy consumption is reduced by 1563.05 kWh/a to 3134 kWh/a, or 31.82 kWh/m^2/a. The same goes for the cooling energy consumption, which is now 3164.5 kWh/a (32.13 kWh/m^2/a). In other words, the savings in thermal energy are 33.27% and cooling energy 17.78%.

When a Small leaved lime trees was planted in front of building S1 according to Tab. 6, annual thermal energy consumption would increase by 3.22% compared to S1, or by 54.69% compared to S2 (Fig. 15). The main reason for this is the second half of October (the beginning of the heating season), when the analyzed building is still in the shade due to the beginning of the fall of leaves, which lasts until the beginning of November. On the other hand, the cooling energy consumption decreased by 15.94% compared to the S1 building, while it increased by 2.24% compared to the S2 building.

Lastly, building S4 shows the best results (Tab. 7). Although heat consumption is higher by 4.18% over the S2 building (the same reasons as when comparing the S3 building with the S1), it is still much lower compared to the S1 (30.48%) and S3 (32.65%). During the cooling season, a combination of natural and created site parameters (Fig. 12) can save up to 33.69% over S1. Overall, the annual saving compared to S1 is 31.93%, or 59.06 kWh/m^2/a (heating 33.15 kWh/m^2/a, cooling 25.91 kWh/m^2/a).

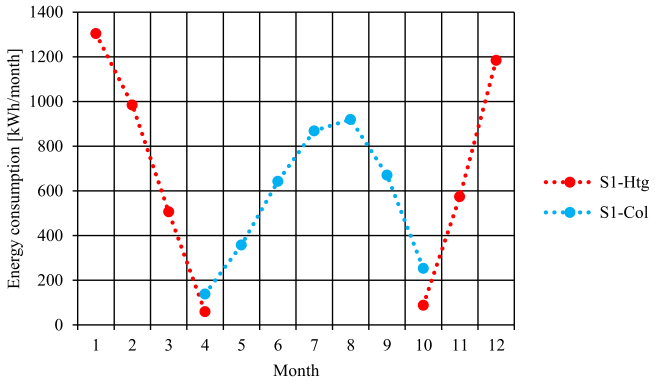

Figure 13. Final energy consumption for heating and cooling for building S1

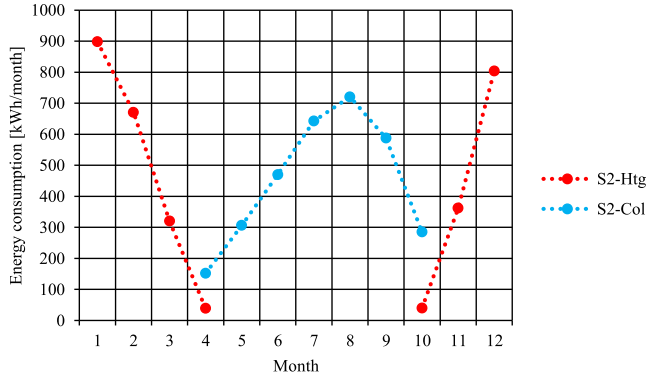

Figure 14. Final energy consumption for heating and cooling for building S2

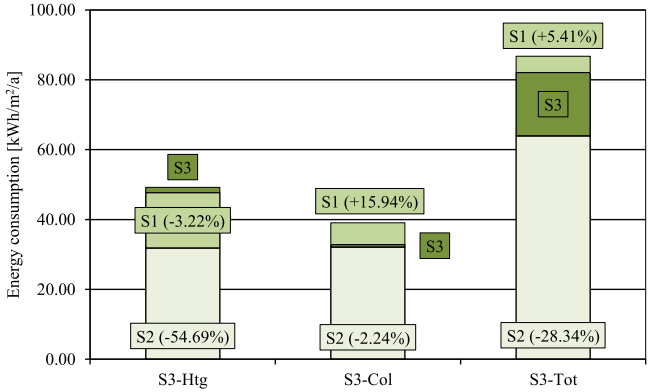

Figure 15. Final energy consumption for heating and cooling for building S3

Table 7. Final energy consumption for heating and cooling for building S4

Energy savings	Heating	Cooling	Total
S1	+30.48%	+33.69%	+31.93%
S2	-4.18%	+19.36%	+7.64%
S3	+32.6%	+21.12%	+28.04%
S4	33.15 kWh/m^2/a	25.91 kWh/m^2/a	59.06 kWh/m^2/a

6. Conclusion

Location parameters may in some cases also affect the final energy class of buildings, which should therefore be

taken into account at the design stage. In this paper, basic (on the one hand) and created (on the other hand) location parameters were used to reduce the annual final energy consumption for heating and cooling of a concrete building located in Kragujevac, Central Serbia. The study was conducted through a combination of GoogleSketchUp and EnergyPlus, which communicate with each other through Legacy OpenStudio. The results showed that the heat and cooling energy of the earth-sheltered house can be reduced by 26.29% annually (in winter by 33.27% and in summer by 17.78%). Using deciduous trees in front of the building can save up to 5.41% annually, mostly due to the reduction in energy required for cooling. Finally, by combining earth-sheltered house and deciduous trees, savings of up to 31.93% can be achieved.

7. Acknowledgments

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