UNIVERSITY OF EAST SARAJEVO

FACULTY OF MECHANICAL ENGINEERING

4th INTERNATIONAL SCIENTIFIC CONFERENCE

COMETa2018

„Conference on Mechanical Engineering Technologies and Applications“

PROCEEDINGS

27th-30th November

East Sarajevo-Jahorina, RS, B&H

COMETa 2018
4th INTERNATIONAL SCIENTIFIC CONFERENCE
27th - 30th November 2018
Jahorina, Republic of Srpska, B&H

University of East Sarajevo
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PREFACE

Faculty of Mechanical Engineering East Sarajevo is organizing the 4th International Scientific Conference COMETa 2018 - "Conference on Mechanical Engineering Technologies and Applications". The aim of the conference is to contribute to the implementation of new technologies in production processes by achieving better cooperation between scientific research institutions and companies, and to enable practical application of research results presented in the proceedings.

The main objective of the conference is to bring together eminent domestic and international experts in the field of engineering and the application of new technologies and the development of mechanical systems, and to contribute increasing the competitiveness of the domestic economy through the exchange of experience and knowledge, public presentations of current research and new construction solutions.

The organization of previous conferences COMETa2012, COMETa2014 and COMETa2016, according to the assessments of participants, especially foreign colleagues, were successful.

The efforts were recognized by the Ministry of Science and Technology of the Republic of Srpska, since in May 2018 the COMETa conference was ranked among international scientific conferences of the first category.

The COMETa 2018 conference program consists of the following thematic areas:

- *Manufacturing technologies and advanced materials,*
- *Applied mechanics and mechatronics,*
- *Machine design and product development,*
- *Energy and environmental protection,*
- *Maintenance and technical diagnostic,*
- *Quality, management and organization.*

At this year's COMETa2018 conference, a record number of papers from the country and abroad have been submitted. In total 277 authors from 13 countries participates in the international conference COMETa2018, 112 papers were accepted, including 4 plenary papers. Within the COMETa2018 conference, it is planned to organize two working meetings that will focus on the current topics of the Conference.

With the desire to improve the organizational as well as the scientific effect of the Conferences, and appreciating the contributions made by the scientific community in this way, we want to emphasize that each of your suggestions is more than welcome and will be appreciated in connection with the above.

On behalf of the Organizing and Scientific Committee of the COMETa2018 conference, we would like to express our gratitude to all authors, reviewers, institutions, companies and individuals who contributed to the Conference.

Hoping that the results of our joint work will meet expectations, the organizer of the Conference, Faculty of Mechanical Engineering East Sarajevo, wants you active participation that will contribute to the development of modern ideas and solutions, in the spirit of technical and technological development of the modern world.

We wish you a pleasant stay in Jahorina. Welcome to the COMETa2018 conference.

East Sarajevo, November 21st, 2018.

President of the Scientific Committee

Full Professor Dušan Golubović, PhD

President of the Organizing Committee

Assistant Professor Milija Kraišnik, PhD

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THE INFLUENCE OF THERMAL PARAMETERS OF DIFFERENT TYPES OF SOIL ON THE CONSUMPTION OF FINAL ENERGY FOR HEATING THE LOW-ENERGY RESIDENTIAL BUILDING AND THE INVESTMENT COST OF PLACING GEOTHERMAL VERTICAL PROBES

Aleksandar Nešović[1] , Nebojša Lukić[2] , Novak Nikolić[3] , Marko Radaković[4]

Abstract: Low-energy residential buildings, from active heating systems, most often use heat pump systems in combination with geothermal vertical probes on primary and panel heaters on the secondary side. The number and depth of the wells is usually determined in practice only on the basis of the specific withdrawal rate of the soil, while parameters such as thermal conductivity and specific volume thermal capacity of the soil are neglected. The aim of this paper is to show that the thermal parameters of different types of soil characteristic for Serbia affect the consumption of final energy for heating the low-energy residential building and the investment costs of placing geothermal probes. The research was conducted by simulations in software EnergyPlus. The investment costs of installing geothermal probes are the lowest when the building is built on alluvial soil (near the river).

Key words: low-energy residential building, specific withdrawal rate of the soil, temperature conductivity of the soil, GHEV, GSHP.

1 INTRODUCTION

The global definition of a low-energy building does not exist. Because national standards vary considerably, low energy developments in one country may not meet normal practice in another. In Germany a low-energy building has an energy consumption limit of 50 kWh/m² per year for space heating. In Switzerland the term is used in connection with the MINERGIE standard – no more than 42 kWh/m² per year should be used for space heating. Right now, it is generally considered that low-energy building uses around half of energy mentioned in those standards for space heating, typically in the range from 30 kWh/m² per year to 20 kWh/m² per year [1].

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Low-energy buildings typically use high levels of insulation, energy efficient windows, low levels of air infiltration and heat recovery ventilation to lower heating and cooling energy. They may also use passive solar building design techniques or active solar technologies. These homes may use hot water heat recycling technologies to recover heat from showers and dishwashers [1]. Low-energy buildings often use GSHP in combination with a panel heating system in order to reduce operating costs and emission CO_2 [2]. Also, systems with a heat pump are often combined with other energy systems, in order to minimize the consumption of final energy [3, 4]. The operation of the heat pump is influenced by the thermal characteristics of the soil, which depend on the type of soil, which in practice is often neglected in the design phase of the system. The consequences are: oversimination of equipment, higher investment and exploitation costs, higher energy consumption for starting compressors, lower system efficiency, shorter service life. In order to avoid all this, there are works in the literature on thermal characteristics of the soil, vertical geothermal probes and their influence on the operation of the heat pump [5-7].

The aim of this paper is to show that the thermal parameters of different types of soil characteristic for Serbia affect the consumption of final energy for heating the low-energy residential building and the investment costs of placing geothermal probes.

2 DESCRIPTION OF THE BUILDING

The investigated building is a residential house of the total useful area of 198.4 m2. The house consists of two levels, two identical apartments (each of 99.2 m2). The classification number of this building is 112111 [8]. The model of the house is shown in Figure 1. Figure 2 shows the arrangement of rooms with appropriate floor area, identical for both levels.

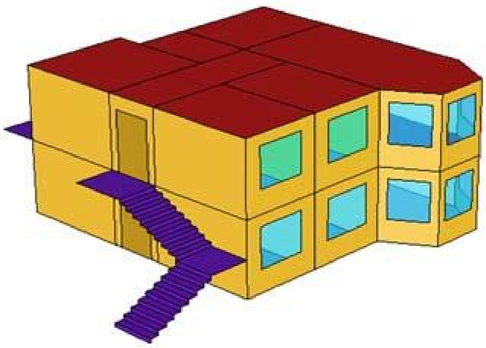

Figure 1. *Low-energy building*

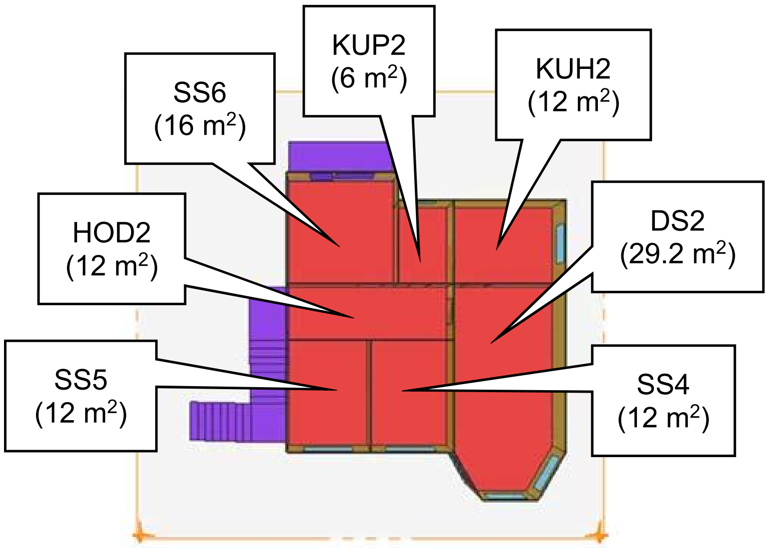

Figure 2. *The base of the second floor*

Thermal characteristics of the building constructions shown in Table 1.

Table 1. *Thermal characteristics of the building constructions* [9]

Construction	Exterior wall	Ground floor	Roof	Exterior door	Window	Interior ceiling	Interior wall
U [W/m^{2}K]	0.172	0.203	0.312	4	1.574	0.226	1.47
U_{DOZ} [W/m^{2}K]	0.3	0.3	0.15	1.6	1.5	0.9	0.9

3 LOCATION OF BUILDING

To simulate weather conditions, in the standard heating season (from 15th of October to 15th of April), of the city of Kragujevac (latitude of 44.02˚N, longitude of 20.92˚E, the average height of the above sea level of 209 m) the EnergyPlus weather file was used. The value of heating degree days determined for indoor temperature of 20˚C and heating threshold temperature of 12˚C, for the observed heating period is 2894. The monthly average values of the weather parameters for the city of Kragujevac are given in Table 2.

Table 2. *The monthly average values of the weather parameters for the city of Kragujevac* [10]

Month	t_{ST} [°C]	t_{VT} [°C]	I_{DIF} [W/m^2]	I_{DIR} [W/m^2]	φ [%]	α [deg]	w [m/s]
January	-0.24	-1.44	33.30	63.63	79.92	213.17	2.01
February	0.88	-0.46	49.39	86.66	79.82	210.60	2.02
March	5.57	3.29	77.08	106.12	72.06	207.98	2.35
April	10.87	7.74	92.65	149.02	67.92	209.06	2.27
May	16.06	12.18	113.30	176.45	66.57	210.08	1.77
June	18.85	14.99	109.50	208.94	69.42	209.51	1.69
July	20.78	16.04	110.60	228.12	64.49	198.04	1.62
August	20.38	15.69	96.25	215.40	64.05	211.45	1.51
September	16.68	13.30	75.54	166.92	71.21	203.79	1.68
October	11.18	8.83	57.34	119.43	76.40	222.28	1.69
November	6.08	4.45	39.83	64.51	79.80	210.38	2.06
December	1.13	0.09	28.66	58.86	83.51	208.33	1.87

4 GSHP

The functional scheme of the analyzed heating system is shown in the Figure 3.

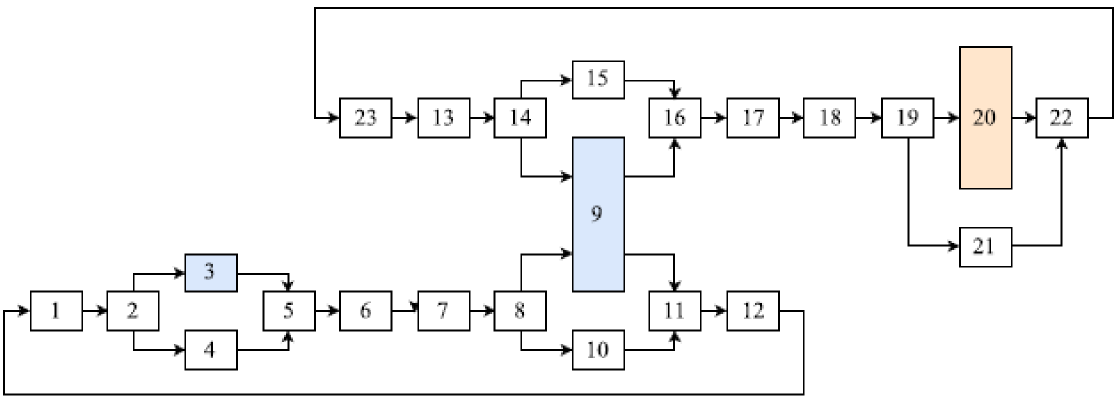

Figure 3. *Analyzed heating system*
1, 13 – circulation pump; 2, 8, 14, 19 – splitter; 3 – ground heat exchanger; 4, 10, 15, 21 – bypass branch; 5, 11, 16, 22 – mixer; 6, 12, 17, 23 – outlet pipe; 7, 18 – inlet pipe; 9 – heat pump; 20 – conditioned zones;

Based on the calculation of the thermal losses of the analyzed building, a heat pump REHAU GEO 7 was adopted. The technical characteristics of this GSHP are given in Table 3.

Table 3. *GSHP REHAU GEO 7* [11]

Parameter	$\dot{Q}_{KON}$ [W]	COP [-]	$\dot{Q}_{KOM}$ [W]	t_{S-MAS} [°C]	t_{S-I} [°C]	p_{S-MAX} [bar]	Δp_{S-MAX} [Pa]	$\dot{V}_{S-MIN}$ [l/h]	$\dot{m}_{P-MIN}$ [kg/h]
Value	7300	4.1	1600	55	37	3	15000	1100	1300

In the Energy Plus program package, a mathematical model of geothermal vertical probes developed by Yavuzturk and Spitler [12] has been implemented. They developed a model that has the ability to evaluate the probe characteristics at low time intervals. Parameters of geothermal probes are shown in Table 4, while the thermal characteristics of the working fluid on the primary side are given in Table 5.

Table 4. *Parameters of the vertical geothermal probe* [11, 12]

Parameter	R_B [m]	d_C [m]	δ_C [m]	l_C [m]	λ_I [W/mK]	λ_C [W/mK]	t_Z [°C]
Value	0.0889	0.04	0.0037	0.03	1.47	0.39	13.37

Table 5. *Operating fluid parameters on the primary side (water and antifreeze)*

Parameter	$\dot{V}_{P-MAX}$ [m^3/s]	c_P [J/kgK]	λ_P [W/mK]	ρ_P [kg/m^3]
Value	0.00036	4066	0.513	1016

5 RESULTS

According to the German standard VDI 4640 [13], which defines the orientation values of specific withdrawal rate for some types of soil (Table 6) and the thermal properties of the soil available in [14, 15], Table 7 shows the consumption of heat final energy and investment costs of installing geothermal vertical probes for 6 characteristic soil types for the Republic of Serbia.

Table 6. *Specific withdrawal rate of the soil (German standard VDI 4640)* [13]

Soil types	$\dot{q}_Z$ [W/m]	
	For 1800 h	For 2400 h
Gravel, sand, dry	< 25	< 20
Gravel, sand, water conducting	65 – 80	55 – 85
For high groundwater flow in gravel and sand	80 - 100	
Clay, loam, moist	35 – 50	30 – 40
Limestone, massive	55 – 70	45 – 60
Sandstone	65 – 80	55 – 65
Sour magnets	65 – 80	55 – 70
Base magnets	40 – 65	35 – 55
Gneiss	70 – 85	60 – 70

The investment costs for all examined cases (Table 7), including the transport of drilling equipment, drilling of the exploratory well, expansion of the exploration well, procurement, preparation and installation of the necessary equipment and trial work were determined by the company GEOING SYSTEM D.O.O [16] from Kragujevac.

Table 7. *Specific withdrawal rate of the soil (German standard VDI 4640)* [13]

Scenario	Soil types	$\dot{q}_Z$ [W/m]	n [-]	H [m]	λ_Z [W/mK]	$c_Z \cdot 10^6$ [J/m^{3}K]	Q_{KON} [kWh/y]	Investment costs [€]
S1	Dry clay	15	3	127	1.4	2.75	5065.59	18507.18
S2			4	95	1.4	2.75	5065.54	18462.95
S3			5	76	1.4	2.75	5065.41	18462.95
S4			6	64	1.4	2.75	5065.27	18639.88
S5	Sandy gravel		3	127	1.1	1.7	5064.51	18507.18
S6			4	95	1.1	1.7	5064.4	18462.95
S7			5	76	1.1	1.7	5064.19	18462.95
S8			6	64	1.1	1.7	5064.16	18639.88
S9	Clay	30	2	95	1.52	4.086	5060.65	10058.73
S10			3	64	1.52	4.086	5060.47	10147.19
S11	Limestone	45	1	127	2.54	2.16	5055.4	7272.06
S12			2	64	2.54	2.16	5053.04	7316.30
S13	Very soft and fine sandy clay	70	1	82	3.57	3.373	5048.65	5281.6
S14	Dark gray clay, sand and silt	80	1	72	4.2	4.366	5046.91	4839.26

The thermal characteristics of the soil (thermal conductivity, specific volume thermal capacity, specific withdrawal rate of the soil) significantly affect the investment costs of placing geothermal probes. For example, for the building that is built for limestone soil (eastern Serbia), the investment costs of installing geothermal probes would be 7272.06 € (1 bore hole 127 m, for house S11) or 7316.3 € (2 bore holes of 64 m, for house S12). The best option is to have a residential building built on an alluvial soil (near the river), because the investment costs of the works would amount to 4839.26 €.

6 CONCLUSION

The global definition of a low-energy building does not exist. Because national standards vary considerably, low energy developments in one country may not meet normal practice in another. Right now, it is generally considered that low-energy building uses around half of energy mentioned in those standards for space heating, typically in the range from 30 kWh/m² per year to 20 kWh/m² per year. This paper examined how the thermal properties of the soil affect the investment costs of placing geothermal probes and the consumption of final energy for heating the low-energy building during the heating season. The results showed that the investment costs of installing geothermal probes are the highest for building S1 (dry clay, 3 bore holes, 127 m) and amount to 18507.18 €. In that case the final energy consumption is 5056.59 kWh. The best case is S14 (dark gray clay, sand and silt, 1 bore hole, 72 m) because the investment costs are 4839.26 €.

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NOMENCLATURE

GSHP	ground source heat pump
GHEV	ground heat exchanger vertical
U	heat transfer coefficient, W/(m^2 K)
U_{DOZ}	permitted heat transfer coefficient for new buildings according to the Rulebook, W/(m^2 K)
t_{ST}	outdoor air temperature measured with a dry thermometer, °C
t_{VT}	outdoor air temperature measured with a wet thermometer, °C
I_{DIF}	diffuse solar radiation, W/m^2
I_{DIR}	direct solar radiation, W/m^2
φ	relative humid outdoor air %
α	wind direction, deg
w	wind speed, m/s
$\dot{Q}_{KON}$	heat power *GSHP*, W
COP	coefficient of performance *GSHP*
t_{S-MAS}	maximum water temperature at the entrance to the floor panel, °C
t_{S-I}	water temperature at the entrance to the floor panel, °C
p_{S-MAX}	maximum operating pressure on the secondary side, bar
Δp_{S-MAX}	maximum pressure drop on the secondary side, Pa
$\dot{V}_{S-MIN}$	minimum volume flow of the working fluid on the secondary side, l/h
$\dot{m}_{P-MIN}$	minimum mass flow of the working fluid on the primary side, kg/h
R_B	bore hole radius, m
d_C	pipe out diameter, m
δ_C	pipe thickness, m
l_C	u-tube distance, m
λ_I	grout thermal conductivity, W/(m K)
λ_C	pipe thermal conductivity, W/(m K)
t_Z	ground temperature, °C
$\dot{V}_{P-MAX}$	maximum volume flow on the primary side, m^3/s
c_P	specific heat of the working fluid on the primary side, J/(kg K)
λ_P	thermal conductivity of the working fluid on the primary side, W/(m K)

ρ_P	density of the working fluid on the primary side, kg/m^3
$\dot{q}_Z$	specific withdrawal rate of the soil, W/m
n	number of bore holes
H	bore hole lenght, m
λ_Z	thermal conductivity of the soil, W/(m K)
c_Z	specific volume thermal capacity of the soil, J/(m^3 K)

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