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A MULTIDISCIPLINARY APPROACH TO THE USE OF GEOTHERMAL ENERGY FOR THE REMOTE HEATING SYSTEM

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ABSTRACT

The potential of geothermal energy sources and their evaluation in the energy sense is the basis of a sustainable management strategy in a way that does not endanger the resources, while maximizing their potential. Geothermal energy represents one of the most promising potential for renewable energy in the region. The possibility of using warm, geothermal water depends on the temperature and the abundance of the source. The advantage of a particular area is reflected in the fact that sources for use are already available. Geothermal water is characterized by a very favorable chemical composition in terms of use for heating and the absence of aggressive properties. Resource characteristics on the one hand (temperature, pressure) and thermal requirements of facilities on the other, with certain restrictions on existing installations, and the distance of wells from users, determined the type and heating network of the geothermal remote system, which provides for the use of locally available and renewable energy sources.

The effects of this system are multiple, ranging from savings, through increased energy efficiency and sustainable use of geothermal resources, to environmentally positive environmental effects due to the reduction of greenhouse gas emissions.

Key words: Geothermal energy, Renewable energy, Environment.

INTRODUCTION

Geothermal energy represents one of the most promising potentials for obtaining renewable energy in Serbia, especially in Bogatić region. Possibility of using advantage of warm, geothermal water depends on the temperature and the abundance of the source. The geothermal energy potential of a specific area can be represented by the power of the geothermal heat flux (the amount of geothermal heat that reaches the Earth's surface every 1 second through the surface of 1 m^2 from the Earth's interior), the average values in Europe are around 60 mW / m^2, while in Serbia these values are much higher: over 100 mW / m^2. In this paper is given the process of preparation and connection of several public buildings to a geothermal heating system in Mačva, Bogatić. Bogatić's advantage is reflected in the fact that there are already exist sources, ready for use. Geothermal waters in Bogatić are characterized by a very favorable chemical composition in terms of their use for heating purposes, they do not possess aggressive or inscrutable properties.

THERMAL AND THERMOMINERAL WATERS IN MAČVA

The area of Mačva represents in geological terms a large depression that filled with neogeneous and Quaternary sediments which is located in thesouthern edge Pannonian basin (Horvath et al. 2014). About the geological structure can be speak only on the basis data obtained during based on the shallow and deep exploratory drilling , Figure 1.

Figure 1. Locations exploratory wells in the basin of Mačva (Gajić et al., 2011)

Until now, a dozen geothermal wells have been constructed at Machva, one well for exploitation in Dublje (IEDB-1). Beginning of geothermal exploration in Mačva started in 1981, when it was discovered the geothermal anomaly in Dublju, 6 km south of Bogatić. Exploration (D-1) in Neogene sediments, at a depth of 178 m, measured a water temperature of 44 ° C with a self-effusion value of 1.2 l/s. To determine the cause geothermal anomalies and exploitation possibilities thermal waters, in 1982, a new well was drilled DB-1 near previous well. In table 1 is given daat of derived hydrothermals well in Mačva region.

Table 1. Data of derived hydrothermal wells in Mačva

The borehole	The location	The depth of the borehole (m)	years	Amount of self-effusion (l/s)	Temperature (°C)
D- 1	Dublje	178	1981.	1.2	44
DB-1	Dublje	400	1982.	10	50.5
IEDB-1	Dublje	335		15	50.5
BB-1	Bogatić	470	1986.	37	75.5
BB-2	Bogatić	618	1989.	60	78
BeB-1	Belotić	450		20	35
MeB-1	Metković	627	1986.	10	62.8
BZ-1	Zminjak	520		3	40
BZ-2	Zminjak	1500	1991.	-	-
BŠt-1	Štitar	-		-	-
DB-2	Dublje	502	2002.	-	-

The most significant hydrogeological phenomena in Mačva were discovered by drilling in Bogatic. During 1986 in the exploration well BB-1 75 °C water was obtained in the settlement it self, with a self-effusion value of 37 l/s. All thermal water from these wells should be used for heating settlements of the municipality of Bogatić, but this idea was abadoned due to financial problems and local government disinterest (Đokić, 2006). The best results in investigation of thermal water at field were achieved in 1989, when it is 1.5 km north of Bogatić obtained well with water temperature 78 °C, with self-effusion of 60 l/s. The depth of this well (BB-2) was 618 m. This is considered to be one of the most generous exploration well in Europe. The results of the wells explored confirm the wealth of geothermal resources, and represent Mačva as the most promising region in Serbia (Table 1) (Milivojevic et al., 1984).

Chemical composition of thermomineral waters

In all analyzed thermal water samples the value the pH of the factor is approx same, amounts from 6.85 to 7.15. The thermal water tested in all wells in Mačva belongs to bicarbonate and carbonate type of waters. Water mineralization is small and varies from 807.0 to 1082.5 mg/l. The dry residue is 0.6 to 0.8 g/l according to an amount of individual macro components, it was concluded that the thermal waters, correspond to the quality of drinking water (Table 2).

Table 2. Chemical composition of thermomineral waters (Milivojević, 1990)

The borehole	**DB-1 Dublje**	**IEDB-1 Dublje**	**BB-1 Bogatić**	**BB-2 Bogatić**	**BBe-1 Belotić**	**BM-1 Metković**
Temperature, °C	**50.5**	51.5	65.9	77.8	35	59.8
pH	7.1	6.95	6.9	6.85	7.15	6.95
Na	158.5	163.0	144.0	146.0	158.0	251.6
Ca	50	46.3	33.5	30.6	47.7	34.7
K	13.0	13.9	13.0	13.4	13.9	19.8
Mg	7.3	7.2	6.6	6.5	10.6	7.8
HCO_3	574	578	361	346	470	640
Cl	42.6	42.7	103.4	104.1	106.8	112.7
Fe	1.2	1.0	0.17	0.43	0.57	0.21
Zn	0.01	0.005	0.002	0.002	4.0	0.002
SiO_2	24	22.1	39	43	25	25
B	-	1.1	2.5	2.5	2.4	3.0
F	-	2.3	1.2	1.1	1.2	1.9
$N(NH_4)$	-	4.2	1.8	1.7	2.46	4.92
CO_2	45	44	50	0.0	13.2	96.8
O_2	7.02	1.5	0.5	0.5	0.5	2.5
H_2S	0.1	0.4	2.5	1.8	0.6	0.8

Based on quantity, temperature and the chemical properties of thermal waters, it can be concluded that there favorable conditions for their use. Geothermal anomaly in Machva (Dublje-Bogatić) would obtain the full significance by finding hydrogeological collectors with thermal water a temperature of 90 °C to 100 °C (Đokić, 2006). Thermal mineral waters in Bogatić, have a temperature of about 27 °C. The self-effusion from artesian wells is about 2 l/s. There are several wells in Sabac. The deepest well (230 m) is with water temperature of 24.5 °C and very powerful self-effusion with about 5 l/s (Elliasson, Sundquist and Wallroth, 1988).

Use of thermal and thermal mineral waters

The Mačva area is exceptional hydrogeothermal potential. Hydrogeothermal energy can be used directly as heat and indirectly as mechanical or electrical source. Thermal waters can be used for the requisites of balneology, sports and recreation, for room heating, in agriculture and aquaculture, industry, technology and electricity generation (Milivojević, 1989).

Hydrogeothermal energy, as the cheapest energy source, can be intensively used for plant production (vegetables, flowers, seedlings, garden seedlings) in greenhouses. Greenhouses are especially convenient for the cultivation of cultures that require more light (optimum temperature for growing cucumbers is 25-30 ° C, tomatoes 20 ° C, and lettuces 15 ° C). The greenhouse production in winter, due to the high consumption of fossil fuels, is unprofitable and expensive. Using of hydrothermal energy would reduce costs would be reduced and human work, and the greenhouse could work year-round (Gajić et al., 2011).

One more option for use thermal resources is the district heating of a settlement. Hydrogeothermal energy did not used to heat the settlement, despite the fact that Mačva represents the most perspective geothermal region of Serbia. Thermal mineral water temperature of 80 °C (100 °C) have possibility for heating Bogatić, Šabac, Sremska Mitrovica and Loznica (Đokić, 2006). For direct heating purposes the smallest temperature of water is 70°C. Using heat pumps reheating is possible lower temperature thermal waters to needer temperature. Experiences in other countries, which have a long tradition of use thermal water, these resources show that that the investments made can be repaid in eight years due to fuel savings. Based on existing resources, in Mačva is possible to build 500 MW geothermal power plants.

This would create the conditions of intense multipurpose-cascade use of thermal water heat (Đokić, 2006). There are numerous possibilities of use geothermal water in industry, depending on the type of available geothermal water and required temperatures. The heated air can beto dry agricultural products (vegetables, cereals, seeds), medicinal plants, river and marine products, wood, etc. (Martinović, 2008). The greatest economic effects are achieved by using of cascading geothermal resources. This involves reusing the same fluid for maximum utilization, efficiency and economy.

MATERIAL AND METHOD

Well analysis and selection as a source of geothermal energy in the district heating system

The observed location is the place on which geothermal is known source of energy (the amount of ground water, their temperature and hemistry), unlike locations where some exploration must be carried out beforehand including drilling of wells. In such cases, when the source of geothermal energy already caught on location, it is necessary to make the selection geothermal well to be included in the district heating system (Gajić et al., 2011). For choosing well following factors are important (Đokić, 2006):

1. Condition of wells and well structure (well construction period, well structure, wellhead),
2. Quantities of groundwater geothermal waters per object (well),
3. Groundwater geothermal water temperature,
4. Chemical characteristics of groundwater geothermal waters,
5. Operation method (self-effusion, well pump ...),
6. Location of wells and distance from potential users,
7. Location conditions in terms of ownership of the parcel on which the well is located,
8. Location conditions in terms of the construction of a possible handover station,
9. Disposition of waters (proximity to surface recipient, natural flow),
10. Disposition of water-absorbent well.

Table 3. Comparison table factors analyzed for the well BB-1 и BB-2

Factors / wells	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
BB-1	1986	25	75	$NaHCO_3$	self-effusion	~2km	Yes	yes	yes	not
BB-2	1989	35	78	$NaHCO_3$	self-effusion	~5km	Not	yes	yes	not

Based on the analysis (Table 3) wells were found to be BB-1 and BB-2 similar characteristics in terms of temperature and chemistry, and methods of exploitation. BB-2 well is more abundant compared to BB-1 but is more remote compared to potential users, which significantly increases costs. BB-1 well is located on the plot owned by the municipality of Bogatić, and on the plot where BB-2 well is located are unresolved property relationships. This can be a danger in later exploitation district heating system. From all this, it is concluded that inclusion of BB-1 wells in the system geothermal district heating is the better option (Martinović, 2008,Martinović et al, 2000).

Object review and analysis public services in terms of energy needs

The concept of geothermal remote heating in the settlement Bogatić, is based on the principle of connection public buildings, while housing facilities and other purposes were not subject to observation. In Bogatić were analyzed 10 public purposes objects. Facilities have been suggested since foreign municipal administration, table 4.

Table 4. needs analysis of public facilities purposes in Bogatić (data taken from municipal administrations and partly supplemented)

	THE NAME OF THE OBJECT	EXISTING WAY OF HEATING	SURFACE FOR HEATING/m^2
1	KINDERGARTEN	central heating/coal	1 100
2	PRIMARY SCHOOL	central heating/coal	3 918
3	SECONDARY SCHOOL OF MAČVA WITH SPORT'S HALL	central heating/fuel oil	2 460 1 600
4	CENTER FOR SOCIAL WORK	central heating/electric energy	176
5	COURT BUILDING	central heating/electric energy	700
6	MUNICIPAL ADMINISTRATION	central heating/fuel oil	1 594
7	TELEKOM	TA furnace/electric energy	167
8	TAX ADMINISTRATION	central heating/electric energy	248
9	REPUBLIC GEODETIC AUTHORITY	central heating/electric energy	118
10	BANK	central heating/electric energy	123
11	PUBLIC COMMUNAL COMPANY	central heating/coal ,wood	230
12	POLICE STATION	With 11	1 451
13	CULTURAL EDUCATION CENTER	central heating/electric energy	1 750
14	HEALTH CENTER	central heating/coal ,wood	3 200

Users of a geothermal district heating system may have different objects in terms of type, characteristics and purpose (Table 4). In all analyzed objects fossil fuels are used. Users of a geothermal district heating system may have different objects in terms of type, characteristics and purpose (Table 4). For selecting an object, there are criteria that may be affected whether the facility will be attached to the system or not.

Some of the criteria are: position of the object relative to other objects that are the subject of analysis; the position of the object relative to the geothermal energy source; existence and type of interior installation; temperature control heating; heat losses (needs for thermal energy) (Elliasson, Sundquist and Wallroth, 1988).

RESULTS AND DISCUSSION

Following the principle of optimization initial construction costs, geothermal remote system heating on one side, and the quantities available geothermal energy, it is suggested connecting the following objects to a future remote system: Kindergarten; Primary school; Secondary school of Mačva with hall of sports; Municipal administration; The courtcenter for social work and Public communal company.

Selection of geothermal remote system in Bogatić area

According to the experience of developed countries that use geothermal energy in the district heating system, return period of investments can be classified into three categories:

- Good return period (less than 7 years),
- Favorable return period (between 7 and 20 years),
- Bad return period (for over 20 years).

As not all elements of the project cycle investment are known yet, only a preliminary cost-benefit assessment is made in this case. Based on cost data for fossil fuels for the heating season, which have been obtained from users, a preliminary analysis was done economical construction of grid and heating equipment. (Table 5) (Milenić et al., 2017).

Table 5. Energy consumption in selected facilities / year

TYPE ENERGY OF FOSSIL	CONSUMED QUANTITIES OF ENERGY PER SEASON	COSTS (eur)
Coal	450 t	35 000
Fuel oil	50 t	50 000
Wood	30 m³	1 250
Electricit	*	1 750
		88 000

Comparison with energy consumption fossil fuels and investments in the geothermal system, a profitability of 6.5 years was obtained. In addition to its economic viability it is important to state i immeasurable environmental effects, which are expressed through reduction of emissions and improving the quality of the environment.

Selecting the type of hot water network

Distribution of hot water network represents an important part of the geothermal district heating system. On the characteristics of the hot water system it is affected by quantity, temperature and chemistry of geothermal resource, as well as terrain configuration, layout and consumer needs. It is very important to reduce losses resource temperature in the process transportation of resources from source to consumer. In the process of transportation it can occur up to temperature loss and up to 10 ° C, depending on the climate conditions of the location. Geothermal Source - BB-1 well is approx 2 km to the first consumer. Choice of heat pipes for geothermal remote system for heating in Bogatić, was done in way to fulfill the basic condition, which is reliability and safety in terms of temperature losses and amount of resources.

Disposal of used geothermal waters

Disposal of using of geothermal waters is accompanied by some legislation. Legislation of Republic of Serbia in this area not yet defined. In the EU it does not exist uniform regulation. Management conditions of geothermal resources are different from country to country. There are three basic ways for disposal of energetical resource used: return to the geo-environment via absorbent wells; discharge into an open flow channel and further use.

The first variant with aspects of sustainable use of resources is the most optimal, but also the most expensive, because it requires the construction of absorbent wells. The second variant is the cheapest, but from an environmental point of viewand least acceptable, because it is expected that water temperature for discharge into the channel is nearly 50 °C. The third variant of resource utilization has the highest cost-effectiveness, because it satisfies a larger number users relative to the first two variants (Milivojević, 1993).

CONCLUSION

Geothermal energy is used today in district heating systems in over a hundred cities in Europe, among the countries leading France, Germany, Hungary and Italy. There are several types geothermal remote systems, whose technical characteristics depend of resource characteristics (temperature and quantities available geothermal waters), as well as user needs. These systems are in use over thirty years, so they are their performance well known. The system is complete and moving with work from the fall of 2019. The results showed and confirmed the justification of the construction and one such system, so the municipality of Bogatić started realization of a project that envisages use locally available and renewable energy sources. The effects of this system are multiple, starting with savings, over increasing energy efficiency and sustainable use of geothermal resources to environmentally positive effects on the environment due to the reduction of greenhouse gas emissions.

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