UTILIZATION OF GEOTHERMAL SPRINGS AS A RENEWABLE ENERGY SOURCE
Vranjska Banja Case Study

by

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Despite the significant natural potential, geothermal energy in Serbia has traditionally been used in balneology and recreation, while its share in the country's total energy balance is almost negligible (0.05%). The present paper deals with the City Municipality of Vranjska Banja as a pioneer in the territory of Serbia in using geothermal energy for heating. The concept and methodology of the present research are directly related to the utilization of geothermal resources for district heating in the Vranjska Banja area. The presented analysis includes: determining the available amount of energy, identifying the energy needs of selected public facilities, and the estimation of investment necessary for energy utilization. A survey, combined with field research, is focused on four public facilities connected to the heating system relying on geothermal sources, as well as on two facilities that should be connected to the system in the next phases. The results show economic, ecological, and technological advantages of using geothermal heating systems, as well as the acceptable price of equipment maintenance. An economic assessment of the transition of one facility from the existing heating system to a system relying on geothermal energy has also been made. The analysis confirms the cost-effectiveness of using geothermal energy and reveals numerous ecological advantages (safe heating, absence of CO_2 emission) over other energy sources.

Key words: *geothermal energy, renewable energy sources, district heating, survey analysis, Vranjska Banja Spa*

Introduction

Over the past several decades, many countries have undertaken extensive research in the field of new energy sources, especially RES, with the idea of diminishing the dependence on traditional fossil fuels [1]. The use of RES instead of the traditional ones has been accompanied by specific activities and measures of relevant entities at different levels. For instance, at the beginning of 2007, the Council of Europe announced the goal of reaching a 20% share of RES in the total energy production in 2020 [2]. To achieve this, various incentives have been introduced in recent years in the EU, such as subventions by the government, reduced value-added tax rates, tax credits, green marking, and cost reimbursement [3]. In spite of the rapid expansion

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of renewable energy capacity, fossil fuels still prevail in the global total final energy consumption (TFEC). As of 2016, RES (not including the traditional use of biomass) accounted for approximately 10.4% of TFEC: renewable electricity (about 5.4%), renewable thermal energy (about 4.1%), and transport biofuels (about 0.9%) [4].

A distinct source of primary energy is the heat accumulated in water from the magma and the rocky Earth's crust – the geothermal energy. The geothermal energy has number of advantages compared to other RES and fossil fuels: it is clean and environmentally friendly energy [5] because it does not require the combustion process emitting CO_2 (like fossil fuels and biomass) [6]; it is one of the most stable RES [7] because it is not dependent on weather conditions (like solar or wind energy) making its utilization highly reliable; it is widely available; the maintenance costs of geothermal facilities are low; and it is a local resource having a positive impact on local economies [8, 9].

Possible ways of utilization of geothermal energy depend on the temperature of the working fluid and the rock massif. In relation to this, the geothermal energy resources can be used directly and indirectly [10]. The low temperature hot waters have a temperature lower than 90 °C and are used directly or for geothermal heat pumps, medium temperature (90-150 °C) waters are used directly and in the production of electricity, and high temperature (higher than 150 °C) hot waters and steams are used in the production of electricity and for other specific processes (minerals recovery, hydrogen production, *etc.*) [11]. On this basis, the utilization of geothermal energy has been classified into the following three categories [12]. *Direct application and heating systems,* involve direct utilization of geothermal water heat for various purposes such as indoor heating, balneotherapy, swimming pools, greenhouses, fruit and vegetable drying, and application in various industries. *Electricity generation* involves electric energy production from geothermal power plants that require water or steam at high temperatures. *Geothermal heat pumps utilize* constant temperatures near the surface of the earth, mostly for indoor heating.

The energy balance in the Republic of Serbia for the 2007-2017 period shows that coal and coal products fired power facilities dominate in total energy production with a share of around 70% [13]. Although over the past decade the use of coal and coal products has decreased, yet the renewable resources should be used more in order to meet the goal set by the EU (27% by the end of 2020) [14]. Taking into consideration only geothermal energy, its share in the total energy balance is still negligible (average 0.05%) despite the natural potential. The installed thermal power is 116.543 MWt with produced heat of 1808.808 TJ/year [15]. Traditionally geothermal water is used in balneology and recreation (> 45%). The other forms of geothermal energy usage are developed to a lesser degree (space district and greenhouse heating, fish and other animal farming, and agricultural drying) [16].

This article deals with the utilization of geothermal resources for district heating in the Vranjska Banja area. The aim of the presented research is defining the available amount of energy, the energy needs of selected public facilities, and optimal investment activities. The paper involves literature-based analysis, field research, and a questionnaire survey. The literature-based analysis gives an overview of previous hydrogeological research (studies, planning, projects, and technical documentation). Based on field research, it was possible to determine the geographical position, climate, and demographic features of the municipality, as well as the number and properties of geothermal sources. The conducted questionnaire survey enabled us to collect data on four public facilities and get an insight in the utilization of geothermal energy in Vranjska Banja, as well to evaluate public facilities intended for connection to the district heating network. Based on the collected data, it was possible to make an economic assessment of the transition of one facility from the existing heating system to another using geothermal energy.

Vranjska Banja Spa – case study

The City Municipality of Vranjska Banja is located in Southeast Serbia and it belongs to the Pčinja Administrative District. It covers an area of 258 km^2 and is located 10 km north-east of the City of Vranje, at the height of 380 m above sea level, at the foothills of the Besna Kobila Mountain (1922 m). The area is marked by the moderate continental climate with some traits of the sub-mountain climate, due to the vicinity of the mountain massif. Based on the 2011 Census [17], 9580 inhabitants lived in 21 settlements (2981 households), out of which 5347 people (1586 households) lived in the municipal centre. The average population density in the Vranjska Banja Municipality is 37 people/km^2, while in the urban area, where 55.8% of the total inhabitants live, it is considerably above the average (705 people/km^2).

Geology and types of geothermal water and wells

Geothermal springs of Vranjska Banja belong to magmatic waters, and they are located in the zone of Serbian-Macedonian Massif [18] and Serbian Crystalline Core region [19]. The thermal springs were formed during Neogene granitoid intrusions with reservoirs in granitoid, metamorphic, and contact-metamorphic rocks [20]. The geological structure of the narrower area consists of gneiss and eruptive rocks. The crystalline terrain was interspersed with deep tectonic cracks, where the spa basin was formed by the lowering of the terrain. The volcanic centre was in the spa area, and modern depression is probably formed due to the sinking of a volcanic crater together with a part of the volcanic pile. The formed rift section, which determines the course of the Banja River, is the main line of hyperthermal springs in the spa [21]. The strongest and highest springs are located at the foot of the north side of Banjsko Brdo, at the place where faults intersect the opposite direction, and where the terrain is most severely disturbed due to this [22]. There are at least three explanations for an extremely high source temperature: the location on the west edge in the Rhodopean Masses in the zone that is still tectonically active; the sources are in large rafts; and the location in the area of young volcanism [23]. All springs of Vranjska Banja originate from the *Surdulički geothermal system*, where the water reservoir is located [22].

Geothermal water occurs in the form of thermal spring zone with several active sources on the surface of 500 × 200 m. The sources and wells that have been captured are named as Upper Spring; A-1, A-2, A-3; B-1, B-1b, B-2; VG-2, and VG-3. In addition to deep wells (VG-2/VG-3), there are several simple shallows (A-1/A-3) and thermometric wells (B) [24]. The source in the park was connected to B-1 (120 m in depth) in 1979. It has a yield of 1.5 L/s and a water temperature of 87 °C. Based on the results of the observation of the volume and temperature of thermo-mineral waters conducted in 1989, VG-2 well was drilled (water yield of 26 L/s; outlet temperature of 111 °C; the pressure of 9.5 bar on the wellhead). Two years later (1991), VG-3 well was drilled, with self-exciting water (yield of 21 L/s; the temperature of 100 °C; the pressure of 11 bar) [25]. These wells are self-extinguishing, and they do not require pumping, tab. 1. Hydrodynamic studies have shown that the above-mentioned wells (VG-2/VG-3) are found in the same fracture aquifer [21]. In the area of the aquifer, in the park, a collection channel was built, up to 3 m in depth. The channel captures the unused water (total yield of 46-50 L/s; average temperature of 85 °C) and delivers it to consumers located within a distance of 2 km. These sources are used for heating several public facilities and for the technological processes. The research conducted in 1984 by the Tex Project (Rijeka) revealed that around 70 L/s of water with a temperature of 88 °C flew through the pipeline [25]. The same research confirmed the geothermal potential of all springs: 100 MWt, with the total water yield of 126 L/s, and the temperature in the 98-125 °C range [26].

Table 1. Overview of wells according to the selected parameters [25]

Name	Volumetric flow rate, V [s^{-1}]	Depth [m]	Source temperature T_s [°C]	Thermal power Q_t [MW_t]	Energy, E [TJ per year]
Upper Spring	1.2	–	78	2.91	9.18
Spring A-1	0.5	25	91	1.48	4.67
Spring A-2	1.0	25	84	2.67	8.42
Spring A-3	2.1	20	91	6.24	19.67
Spring B-1	1.5	120	87	4.20	13.24
Spring B-1b	2.0	26	92	6.02	18.98
Spring B-2	1.0	7	96	3.18	10.02
VG-2	26.0	1,063	111	9.90	312.20
VG-3	21.5	1,603	98	7.01	221.07
Collection channel	70.0	–	84	18.75	–
Total	126		78-111	62.36	617.45

Note: Thermal power of the source Q_t [W_t] is evaluated considering mean atmospheric temperature T_o = 20 °C as relevant *i. e.* $Q_t = mc_p[T_s - T_o]$ where m [kgs^{-1}] denotes mass-flow rate, determined as product of volumetric flow rate V [m^3s^{-1}], [1 m^3/s = 10^3 l/s], and density r [kgm^{-3}] of water at source temperature T_s, and c_p=4186 J/kgK represents specific capacity of water. The energy delivered by the source during a year E [J] is $E = Q_t\mathrm{D}t$ where Dt [s] = 365 × 24 × 3600

Geothermal water resources and utilization of geothermal energy

The City Municipality of Vranjska Banja is the pioneer in use of geothermal energy for heating in the Republic of Serbia. The practice began in the 1950s when the Rasadnici company was established. From the sixties the numerous hydrogeological and hydrochemical studies have been performed (the depth of the earliest wells ranged from 20-100 m, with water temperature to 99 °C). In 1965, the multidisciplinary project *Research of Thermomineral Waters and Geothermal Energy in the Vranjska Basin and in Particular Vranjska Banja* was implemented under the leadership of Geozavod and the Institute for Hydrogeological and Geotechnical Research in Belgrade [27]. During 1969 and 1986, the first systematic geophysical explorations of oil, gas, and thermal waters were undertaken. The first deep-well drilling was done at the Railway Station in 1980 (code Vr-1/H, depth 2020 m). During the hydrogeological investigation of the Vranjska Banja Spa system, conducted in 1986-1989, more than 150 samples of water, vegetation, soil, and rock were analyzed, revealing the atmospheric origin of thermal waters [22].

Modern explorations of groundwater aimed at their exploitation were carried out by *NIS* (Novi Sad), based on a 2010 decision of the Serbian Ministry of Mining and Energy. The Betec Resources company from China conducted a survey at three sites: the investigation field V-788 (2015-2018); V-880 and V-881 (2017-2019) [27]. Significant projects related to the utilization of geothermal energy include *Heating Study of the Vranjska Banja Spa* (2005) by the *Zavarivač* Independent Craftwork (Vranje) and *Conceptual Design of the Construction of the Main Heating System* by the Institute of Transportation *CIP* (Belgrade), as well as individual solutions in industrial processes (*Preliminary Project on the Exploitation of Hot Water in the Production Technology of the Jumko Company*).

Spring water's heat equivalent of around 60 MWt allows for diverse uses of the geothermal potential. At the same time, the total energy of all spring waters in Vranjska Banja ranges between 601.49 TJ/per year [28] and 617.45 TJ/per year (see tab. 1). However, in terms of the exploitation of hydro-geothermal energy, it is 467.20 TJ/per year. The current users of geothermal energy in Vranjska Banja can be divided into three groups: public, service and production facilities: *Special Rehabilitation Hospital* and *the branch of the Vranje Health Center* (healthcare providers); *Predrag Devedžić Elementary School and Naše Dete Kindergarten, Bambi Branch* (educational institutions); several catering facilities and a group of industrial facilities: *Sunce Juga ex Rasadnici* (vegetable farming) and *Simpo cveće* (flower farming). Other users such as *Živinoprodukt* (poultry production), *TIV-Internacional* (manufacture of ropes, twines and nettings) and *Railway reset* (accommodation services), currently, all are in bankruptcy [24]. With these users, the annual amount of exhaust water was approximately 2213568 m^3 in 2005-2007 [26]. The locations of current users are presented in fig. 1. All of the aforementioned consumers use geothermal water indirectly via heat exchangers. Heat exchanger stations are located in the shafts along the route or on the route of the heat channel, or near the source. Thermal water flows from the main sources (VG-2 and VG-3) in the park towards the poultry farm, whence the cooled mineral water goes into the water stream. Geothermal water is guided through a heat channel gravitating to the last consumer. The equipment installed at heat substations is technically poor, not allowing for temperature regulation [25].

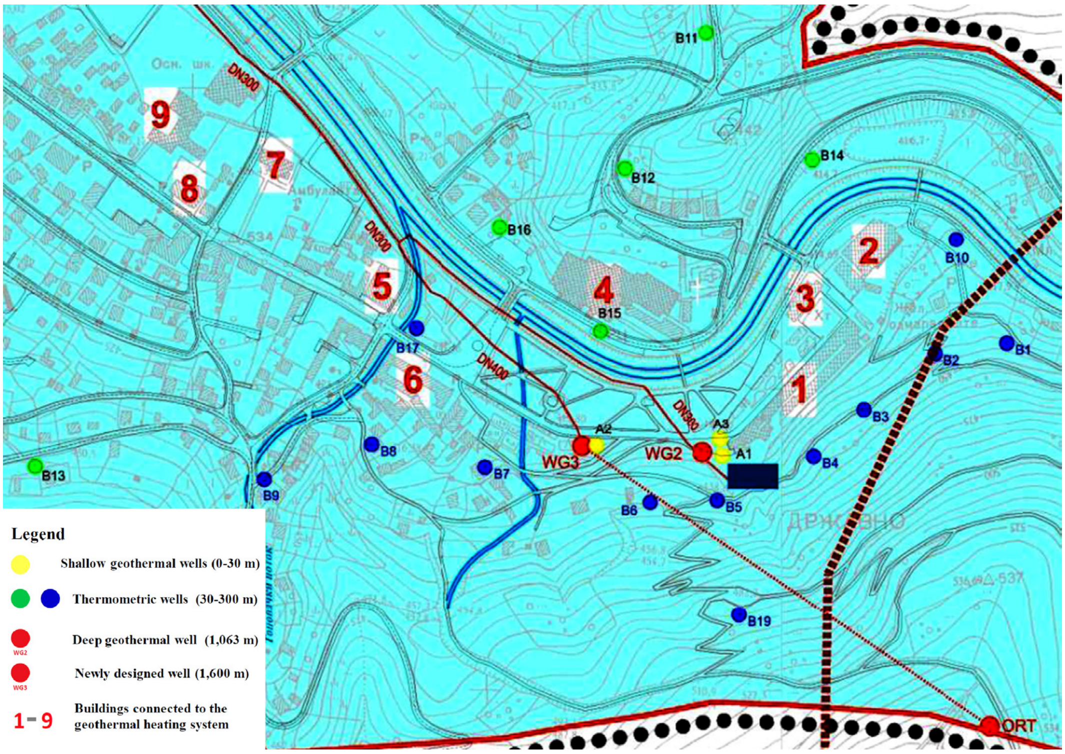

Figure 1. Map of boreholes/wells and geothermal heating system in the City Municipality of Vranjska Banja (adapted from [24])

The survey analysis of public facilities connected on the geothermal sources heating system

The analysis of the existing and newly designed buildings and installations within the system using geothermal water in the Vranjska Banja, City of Vranje, and the heating system on this line presented in this paper is based on the previous research in 1996 [29]. This research determined the required thermal power for the following public and production facilities: a special hospital, a railway resort and the Kičer restaurant (1350 kWt); the Kosovo and Srbija restaurants (170 kWt); a healthcare center (221 kWt); an elementary school (626 kWt); a preschool (200 kWt); a greenhouses in the town and suburb (250 + 9781 kWt); a nursery and a farm (1498 kWt). The required capacity was estimated at 14598 kWt, and with a new hotel and the Jumko factory, an increase of 2800 kWt was foreseen. The construction of the mainstream heating system, the heating of the Jumko and Simpo production facilities (7342 kWt) and the Novi Dom residential area (6850 kWt) in the City of Vranje has not yet been put in practice [29].

Our research was focused on the characteristics of facilities (existing and potential users), as well as the economic and environmental aspects of using this RES for heating purposes. In order to do the analysis for each institution, it was necessary to collect the following data [30]: *Basic information about the facility* (purpose, surface, heated surface, the type of heating, ventilation, air conditioning, central heating of hot water or electric water boilers); *Energy status of the building* (construction year, description of the facility – the type of windows, façades, thermal insulation, *etc.*); an energy passport or energy efficiency study; *Description of mechanical heating installations* (the type of the system, the type of fuel, the existence of regulation devices on boilers and heating bodies; installation and heating body data, the age of the existing system, energy consumption per year, heating mode).

The public facilities connected on the heating system in Vranjska Banja were included in the analysis of the advantages and disadvantages of using geothermal energy. Two educational institutions were analyzed (Predrag Devedžić Primary School and the Bambi Preschool), as well as two health centres (Special Rehabilitation Hospital and a health station). Most buildings covered by the analysis were built in the 1970s and 1980s. The exception is the Special Rehabilitation Hospital, which dates back to the end of the 19th century. Most of these are one-story buildings, while the Predrag Devedžić Primary School is a two-story building. The thickness of façade walls ranges from 20 cm to 50 cm, while most of the above-mentioned structures do not have insulation. In the Bambi Preschool, walls have stone insulation. All institutions have wooden windows, mostly contemporary to the construction/renovation period; 25-40% of their wall surfaces are glazed. The common feature is the lack of a ventilation system and air conditioning (the exception is the Bambi Preschool, which has three units with a capacity of 10 kWt, tab. 2).

Table 2. Overview of the construction features of analyzed facilities

Object name	Construction year	Number of floors	Wall thickness [cm]	Window coverage [%]	Ventilation	Air-conditioning
S.H.R. "Vranjska Banja"	1890/1930	GF + 1	50	40	No	No
E.S. "Predrag Devedžić"	1968/1982	GF + 2	25	25	No	No
Health Care Center	1977	GF	25	25	No	No
K.G. "Bambi"	1989	GF	20	–	No	Yes

Note: S.H.R (Special Hospital for Rehabilitation), E.S. (elementary school), K.G. (kindergarten), GF (ground floor)

Geothermal water with a temperature of 80-90 °C may be used to heat an area of 600-3000 m^2 by means of a heat exchanger. All buildings were connected to the heating network during construction, while the subsidiary building (kitchen) of the elementary school was added in 1982. Cast iron and aluminium radiators, 20-50 years old, are used, while floor heating is also installed in one part of the Special Rehabilitation Hospital. In this way, 24-hour heating with an optimal temperature of 23-25 °C is ensured. At the same time, a number of storage and flow boilers are heated using the same system. Under winter consumption conditions, the necessary power for facilities is estimated to range from 200 kWt (preschool) to 1630 kWt (hospital and the adjacent catering facilities).

Bearing in mind that all analyzed buildings are energetically inefficient, the heating system on geothermal energy has numerous economic, ecological and technological advantages. Economic benefits are so apparent that some facilities (*e. g.* Rehabilitation Center) would not have been able to financially survive due to high expenses of conventional sources bearing in mind their energy inefficiency. Depending on the size of the institution, this new type of heating system results in total annual costs of 2670-15254 EUR (222-1271 EUR a month), tab. 3. Technologically, all mentioned users stated the ease of the system maintaining. On the other hand, one of the shortcomings of using hyperthermal water is additional investment in heat exchangers, which need to be replaced every 6-7 years due to the tendency of sedimentation. However, compared to other hypertherms (*e. g.* the Sijarinska Banja Spa), the water from Vranjska Banja spa (source VG-2) is less prone to the precipitation of minerals on pipes and other installations, which makes it very suitable for the mentioned purposes [31].

Table 3. Overview of the heating system in the analyzed facilities

Object name	Heating area, [m^2]	Year of connection	Number of water heaters	Number of radiators	Heating mode [°C]	Required consumer power [kW]	Monthly costs [€]
S.H.R. "Vranjska Banja"	3000	–	–	130	25	1350	1271.00
E.S. "Predrag Devedžić"	2939	1968	3	150	23	626	1271.00
Health Care Center	720	1978	10	–	25	221	242.37
K.G. "Bambi"	596	1989	7	–	18-25	200	222.23

Note: Data obtained from questionnaire survey

The analysis of potential users and investment activities

The existing planning documents for the territory of the Pčinja District emphasize the use of alternative sources, and stress is especially laid on Vranjska Banja [22]. The Sustainable Development Strategy of the City of Vranje [26] planned the amount of 8.05 million EUR for the heating of the City Municipality between 2010 and 2015. However, despite the plans the results were lacking. In June 2018, the Novi Dom Public Company undertook the construction of a 190 m long new hot water, worth more than 40 thousand EUR. In order to prevent heat loss, pre-insulated pipes were used to provide a constant temperature of 70 °C necessary for vegetable production. At the same time, further activities related to building a heating system will be focused on the remaining public buildings, primarily the municipal building and the safe house. A budget of around 68 thousand EUR has been planned for these activities.

Therefore, the analysis is focused on the safe house (*Prihvatilište za žene i decu žrtve porodičnog nasilja*) as part of the public facility *Centar za razvoj lokalnih usluga socijalne zaštite* in Vranje. This is a new building (2014), reconstructed and refurbished in 2018, when the external and internal hydrant networks and a stable fire alarm system were constructed. The building consists of a basement (63.02 m^2), a ground floor (137.14 m^2), and an upper story (150.59 m^2). This is a masonry structure with horizontal and vertical ferroconcrete ring-girders. The facade and interior walls are made of hollow clay bricks, stiffened with horizontal and vertical ferroconcrete ring-girder. A massive reinforced concrete floor slab (14 cm thick) divides the ground floor and the first floor. The basement slab is 12 cm thick. The roof is covered with a 1.5 mm thick PVC membrane. The roof panels are tilted by 1% and vertical gutters are located within the building. Windows with PVC profiles have been installed. There are 11 air conditioners in use and the building does not have a ventilation system. Four storage boilers with the capacity of 80 L are also in use. The facility has an energy passport. There is a central heating system for the whole building (350.75 m^2), and the pellet is used as the fuel. A 30 kWt boiler with the maximum operating temperature of 90 °C is used. Bearing in mind that the building was constructed recently, aluminium radiators are connected on the heating system and it is possible to regulate temperature both on the boiler and on the heating bodies. This heating regime ensures an optimal temperature of 22 °C.

The last public facility planned for connection on the heating network is the local self-government unit, housed in the Mozer Villa since 2010, together with Uprava Banje Public Company. The building was erected late in the 19th century (1887). It has a ground floor, an upper story and an attic, and a total area of 506.90 m^2. The building was made of brick and stone, with decorative mouldings around wooden windows (about 50% of the wall surface is glazed). Wooden materials were used to construct the porch. It is assumed that some construction works were carried out in the 1930s and 1950s; in 2014, the attic and the roofing were reconstructed. Façades do not have thermal insulation and there is no ventilation system, due to which the building does not have an energy passport. Besides, there are 11 air conditioners with a capacity of 36.7 kWt in use, as well as two electric flow boilers with a capacity of 16 L. The area of 341.60 m^2 has been heated using the electric boiler (24 kWt). The maximum operating temperature of the boiler is 90 °C with regulation. Regulation devices are also installed on heating bodies (12 cast iron radiators and 10-panel radiators). The floor heating system is 14 years old and it ensures a temperature of 21 °C.

In accordance with the plans, the economic justification of the usage of different heating sources was assessed and compared with the utilization of geothermal energy. During the heating season in Serbia (October 15-April 15) the safe house needs 14 tones of wooden pellets on average. As the market price is 170-220 EUR per tone, it is necessary to provide 2730 EUR for one season (455 EUR per month). Further, a district heating system in the city of Vranje, relying on six-block boilers using oil as fuel, was evaluated. This type of heating was not cost-effective because it was necessary to pay 193.50 EUR per month (2316 EUR/year) throughout the year (the price for privileged consumers was 1.10 €/m^2). The assessment also included a system relying on electric power. Taking into account the Energy Agency of RS's data according to which about 150 kWh/m^2 (16 h a day) is usually spent during the heating season, the safe house would consume 52612 kWh during the season (8768 kWh monthly). It would cost around 4000 EUR during the season, which is economically nonviable for this facility, tab. 4.

Furthermore, an energy assessment of the building that houses the Municipality of Vranjska Banja was carried out. The building's consumption power is 34.50 kWt and the average total annual consumption is 44901 kWh (in 2017): 32476 kWh in the high and 12425 kWh in the low tariff. The combination of an electric boiler and air conditioners is used during the eight-hour working cycle; some savings are achieved and the monthly expenses for the heating amount to 275.60 EUR (1653.40 EUR for a whole heating season). Also, if the services of Vranje's central heating system were used, the city municipality would pay 188.45 EUR monthly throughout the year (2261.51 EUR for the entire heating season), tab. 4.

Finally, an analysis of the utilization of thermal water for heating by the aforementioned institutions was performed. According to the data provided by the Uprava Banje Public Company, the cost of connecting on the system for individuals would be 3.05 EUR/m^2. If we assume that the price for legal entities is 5.08-6.10 EUR/m^2, the expenses for the safe house and the Mozer Villa would amount to approximately 2000 EUR. With a heating price of 0.37 EUR/m^2, monthly expenditures would be around130 EUR (1570 EUR per year) for the safe house or 127.37 EUR per month (1526.72 EUR per year) for the municipal building. With that goal, in the budget of the City Municipality in 2019, an amount of 93 thousand EUR is

Table 4. Estimated heating costs for various energy sources (in EUR)

		Fuel oil (Districts heating Vranje)	Wood pellet	Electricity	Geothermal energy
Safe house	Monthly costs	193.51[b]	455	664.6	130.79[b]
	Total season[a]	2322.08	2730	3987.60	1569.46
Municipality	Monthly costs	188.45	–	275.6	127.37
	Total season[a]	2261.51	–	1653.40	1526.72

Note. [a] Heating season lasts six months; [b] These types of energy sources are paid during the whole year.

allocated for the implementation of capital projects, the rehabilitation of the head of geothermal wells VG-2 and VG-3, the replacement of the associated equipment.

Additional activities will be focused on finding the optimal solution for using geothermal water. Therefore, a sustainable model, the cascade system should be developed in the future to enable further use of the resources, fig. 2. This multilevel concept includes the production of electricity (1st level), freezing or cooling processes using thermally activated technologies such as absorption or adsorption effect machines (2nd level), while in other levels the fluid can be used for other purposes. Temperatures lower than 70 °C can be used in numerous ways. In the primary sector, this energy source can be used in agricultural production, vegetable, poultry and fish farming (*e. g.* Sunce juga; Hibrofarm) floriculture (Simpo cveće) and further in food tech-

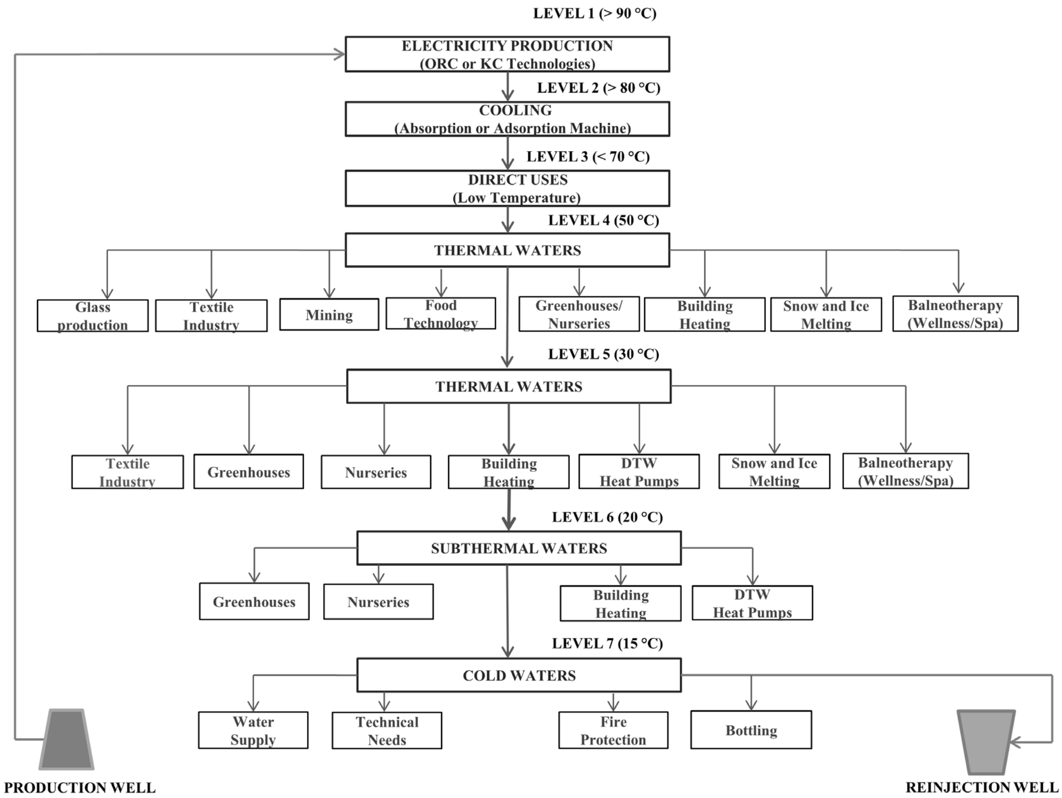

Figure 2. Scheme of the possible cascade use of geothermal energy in the Vranjska Banja area, according to [30]

nology. Next, it is possible to use it in intensive mining (*e. g.* Grot – lead and zinc mines; Zeoben non-metals) and manufacturing industry such as glass production (Simpo staklo) and textile production (Diva divani, *etc.*). Also, this system should be expanded to the heating of private households and public areas (snow and ice melting). In the tertiary sector, this resource should be used more in balneotherapy, but also in the development of spa and wellness programs. At the seventh level, the sodium hydro carbonate, sulphate, fluoride, and sulfide waters with a temperature below 15 °C can be used for bottling. Finally, in the era of water shortages, mineral water can be used for water supply and for technical purposes (*e. g.* fire protection).

Conclusions

Increasing attention is paid to renewable sources as an alternative to traditional forms of energy. In this respect, a special emphasis is placed on geothermal energy as one of the most environmentally friendly resources. However, both globally and in Serbia, this resource is insufficiently used. Therefore, the study outlines the global trends, as well as the position of Serbia and its enormous potential in this field. The paper presents an analysis of the utilization of geothermal resources for heating public facilities in the Municipality of Vranjska Banja. The evaluation of the natural conditions was followed by a survey that revealed the advantages of this energy source. The Vranjska Banja is an illustrative example of possible (but still suboptimal) uses of this type of energy. Therefore, in the forthcoming period, efforts should be made towards modernization and devising the so-called cascade system of geothermal energy use. Apart from heating industrial plants and public facilities, the scheme should include households not only in the City Municipality but also throughout the City of Vranje. The idea is supported by the fact that only 5% of households are connected to the district heating system using oil boiler rooms with an estimated power of 33 MW. At the same time, most users (about 90%) have individual furnaces using firewood or coal as the fuel. The application of heat exchangers and heat-circulation pumps, as well as a better organization, would enable the heating of the entire Vranje region with an open system. The main advantages of using geothermal energy and investing in this type of heating system are reflected in economic (replacement of imported liquid energy sources; saving 70% of energy required for heating; reducing the share of electric power to 20%) and ecological benefits (reducing drinking water consumption in industrial processes; reducing the number of boiler rooms using fossil fuels; reduction of CO_2 emissions by 30%), while the whole process is marked by simple maintenance and is based on fully automated operation. Further activities will be directed towards other prospective areas (*e. g.* Raška, Toplica, and Mačva District). The research should also be extended to the possibility of producing electricity in single-cycle or binary cycle power plants.

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