ISKORIŠĆENJE GEOTERMALNIH RESURSA ZA PROIZVODNJU TOPLOTNE ENERGIJE

HARNESSING GEOTHERMAL RESOURCES FOR THERMAL ENERGY PRODUCTION

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Ispod površine zemlje postoji prirodni izvor energije u obliku bazena vode, geotermalnih rezervoara, zagrejanih magmom (ili istopljenim stenama). Voda ili para mogu izaći iz pukotina u zemlji u obliku gejzira ili kao magma iz vulkana. Geotermalna energija ne zahteva sagorevanje fosilnih goriva. Korišćena topla voda ili para vraćaju se u zemlju nakon upotrebe gde se mogu ponovo koristiti, što je takođe čini obnovljivim izvorom energije. Korišćenje geotermalnih resursa moguće je u različite svrhe. Prema mogućnostima korišćenja, u zavisnosti od njihove temperature, geotermalni resursi se dele na geotermalne resurse za proizvodnju električne energije i geotermalne resurse za proizvodnju toplotne energije. Poseban deo geotermalnih resursa koji se koriste za proizvodnju toplotne energije je primena u sistemima daljinskog grejanja.

Ključne reči: *geotermalni resursi; toplotna energija; obnovljivi izvori*

There is a natural source of power below the surface of the earth in the form of pools of water, geothermal reservoirs, heated by magma (or molten rocks). Water or steam can escape from cracks in the earth in the form of geysers or as magma from a volcano. Geothermal power does not require the burning of any fossil fuels. The hot water or steam used is returned to the ground after it is used where it can be used again, which makes it a renewable energy source as well. The use of geothermal resources is possible for various purposes. According to the utilizing possibility depending on their temperature, geothermal resources are divided into geothermal resources for electricity generation and geothermal resources for thermal energy production. A special part of the geothermal resources use for thermal energy production is the application in district heating systems.

Key words: *geothermal resources; thermal energy; renewable resources*

1 Geothermal Potential

Geothermal resources represent that part of available and accessible resources that could be exploited on economically justified and legal grounds at a certain time in the future (less than 100 years).

Geothermal reserves represent a part of available and accessible resources that can currently be exploited in an economically justified way in relation to other energy resources and which have been determined and proven by drilling and/or other geochemical, geophysical or geological methods.

Geothermal resources are classified and categorized based on several criteria.

According to the temperature of the fluid, ie enthalpy- the internal content of thermal energy, hydrogeothermal resources are classified as:

- Low-enthalpy geothermal resources (fluid temperature below 100 °C)
- Medium-enthalpy geothermal resources of (fluid temperature 100-200 °C)
- High-enthalpy geothermal resources (fluid temperature above 200 °C).

According to the location in the Earth's crust, geothermal energy is classified as:

- Hydrogeothermal energy (accumulated in groundwater)

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- Petrogeothermal energy (accumulated in solid rock masses without water)
- Magma geothermal energy (accumulated in magma)
- Pneumo thermal energy (accumulated in hot gases) [1].

Geothermal potential of Europe, expressed through thermal conductivity, and estimated by means of Geographic Information System (GIS) is illustrated on the thermomap, Figure 1.

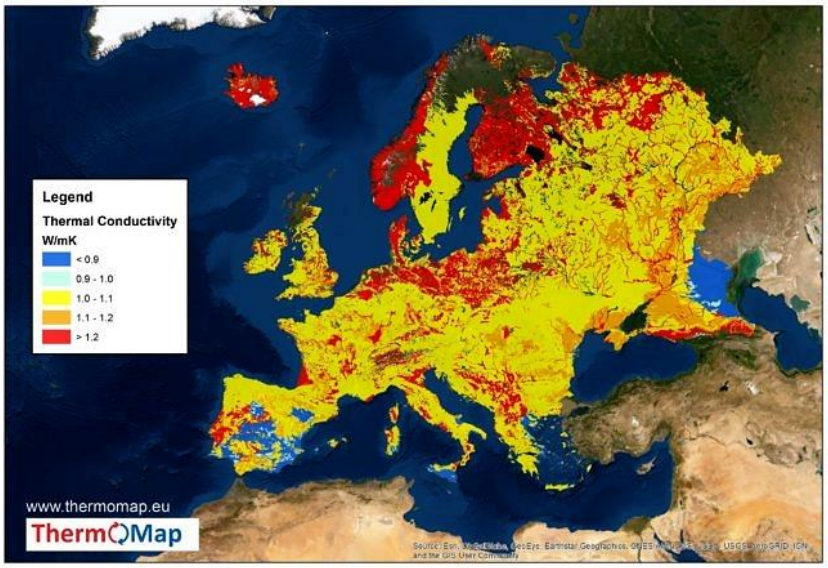

Figure 1. Geothermal Potential of Europe, GIS- based estimation (Thermomap.eu, 2020) [2]

Geothermal resources can be used for various purposes, so there are several classifications of these resources in relation to their usability.

According to one of the most important classifications, geothermal resources are divided into two groups based on the possibility of their use depending on the temperature:

- Geothermal resources for electricity production;
- Geothermal resources for thermal energy production [1].

The lower temperature limit of the hydrogeothermal fluid for electricity production is 100 °C. Below this limit, the exploitation of resources in order to obtain electricity is not economically viable, although binary systems in which it is possible to use lower temperatures have appeared on the market.

The existence of medium and high enthalpy geothermal resources has not been proven in the Republic of Serbia so far. Within the geothermal resources of low enthalpy in Europe, Serbia is characterized by almost the largest number of thermomineral phenomena with temperatures above 20 °C in relation to the number of inhabitants. This fact has provoked detailed research and further classifying geothermal resources of the first group, low-enthalpy geothermal resources with a temperature up to 100 °C.

Based on the presented classification and criteria according to temperature or enthalpy, geothermal resources in the Republic of Serbia are quantified into the following subgroups:

- Subgeothermal resources of temperature of up to 30 °C (sub-hydro-geothermal and sub-petro-geothermal resources),
- Geothermal resources in the strict sense, of temperature between 30 °C and 100 °C,
- Geothermal resources of temperature over 100°C (hydro-geothermal resources and hot dry rock energy- HDR) [1,3].

The upper temperature limit (30 °C) is taken as the temperature above which the so-called direct use of resources begins, ie it's the temperature up to which hydrogeothermal resources are exploited using a heat pump.

The geothermal phenomena identified so far in Serbia are within the hydrogeothermal energy of low enthalpy with a fluid temperature of up to 100 °C.

Subgeothermal energy sources are a type of low enthalpy hydrogeothermal energy, accumulated in groundwater temperatures up to 30 °C, the exploitation and use of which is conditioned by the use of heat pumps [4].

The Republic of Serbia abounds in natural hot water springs or hydro-geothermal resources; however, use of geothermal energy for heating and other energy needs is still in initial stage. Geothermal resources are mainly used in balneology, sport and recreation and in tourism establishments.

The total estimated amount of heat in geothermal waters in Serbia is about two times higher than equivalent amount of heat that could be produced by burning all our coal reserves. There are also 62 artificial geothermal springs (drills) in the territory of Vojvodina and 48 more drills in the Serbian territory south of the Sava and the Danube. These data show that there is a large exploitation potential for geothermal energy in our country.

Geothermal potential of the Republic of Serbia is also evident from numerous spas and natural springs with water temperature over 30 °C. Natural (natural springs) and artificial springs (wells) of thermal water have been identified in more than 60 municipalities. Average water temperature is 40 °C, and only in territories of 6 municipalities/cities water temperature exceeds 60 °C (Vranje, Šabac, Kuršumlija, Raška, Medveđa, Apatin). The highest temperature of thermal water is in Vranjska banja spa (96 °C), Jošanička banja spa (78 °C), Sijarinska banja spa (72 °C), Kuršumlijska banja spa (68 °C) and Novopazarska banja spa (55 °C) [3].

Geothermal potentials are not evenly distributed in the territory of the Republic of Serbia:

- The city of Belgrade, mainly situated in the Šumadija-Kopaonik region and only partially (north of the Danube) belongs to the Pannonian Basin region, has water temperature from 11 to 20 °C and potential quantities of groundwater of up to 26000 l/s.
- The Vojvodina region, mainly situated in the Pannonian Basin and partially in the inner Dinarides, has thermal water temperature from 11 to 17 °C. The Sremski district has the highest subgeothermal potential.
- In terms of hydrogeological regions, Šumadija and West Serbia mainly belong to the inner Dinarides unit and Šumadija-Kopaonik zone. Groundwater temperatures are up to 75 °C, while the Mačvanski district has the highest potential.
- The region of South and East Serbia belongs to the Carpatho-Balkanides region and partially to the Serbian Crystalline Core region. Water temperature ranges from 10 to 15°C, while the Podunavski district has the highest potential.

In the territory of Serbia, there are sufficient possibilities for exploitation of geothermal energy from dry rocks, using geothermal probes. There has been a boom in this form of exploitation of resources in recent years. The main advantages are relatively shallow drills of 100-125 m and safety of the system, which resulted in many individual residential houses introducing this form of energy for heating/cooling of rooms. In order to use petrogeothermal resources for heating of family households of natural persons, it is necessary to define requirements for the use of heat of the Earth's crust rock mass of temperature of up to 30 °C.

2 Thermal Energy Production

Possible application of geothermal resources is dependent on their temperature. For these purposes, the Lindal diagram is one of the most used criteria that determines the use of geothermal resources in relation to temperature. It illustrates how geothermal energy resources of different temperatures can be applied for a range of applications (Figure 2).

Accordingly, depending on the temperature, geothermal resources can be used for the following purposes in terms of thermal energy sources:

- Indoor and outdoor space heating
- Heating greenhouses and hothouses
- Balneological needs
- Sports and recreational purposes
- Tourist purposes
- Drying vegetables and other needs in agricultural production

• Industrial needs
• Water bottling.

A very important use of geothermal resources for the production of thermal energy is in district heating systems.

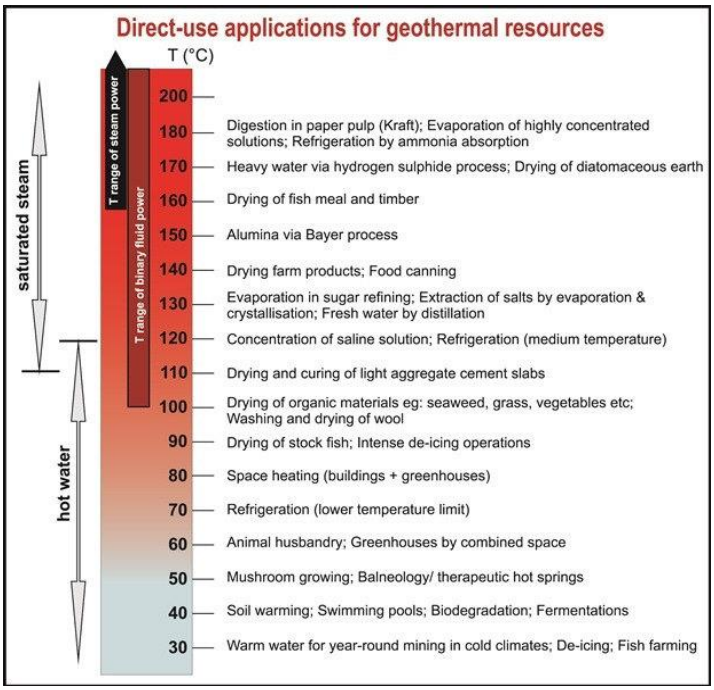

Figure 2. Modified Lindal diagram (after Lindal 1973, modified) [5]

2.1 Use of geothermal energy in district heating systems

The production of thermal energy from geothermal resources and its distribution via a district heating system to residential, commercial or industrial buildings has been successfully applied in Europe for many years. The first geothermal district heating system started operating in 1970 in the territory of France.

The principle of geothermal district heating (GeoDH) is based on the concept of hydrogeological doublets located in terrains with good geothermal potential. The most common are basin structures, such as the Aquitaine Basin (Paris), the Molasse Basin (Munich), and the Pannonian Basin (Szentes). In addition to basin structures in Europe, the trench structure of the Upper Rhine Rift Valley is characterized by great geothermal potential, which extends in the length of about 350 km and about 50 km in width. Along this structure, the so-called "Hot spots", where groundwater temperatures reach 150 °C at a depth of about 2500 m, are located.

Due to the development of heat pump technology, it is possible to construct a geothermal district heating system in practically all parts of Europe, so today every country in Europe has at least one such system.

The size of these systems, ie the installed power of geothermal district heating systems, ranges from 0.2-5 MW, which classifies them in the group of small systems, while systems with larger capacities can reach up to 50 MW.

The scheme of geothermal district heating with a typical system of hydrogeological doublets is shown in Figure 3 [6].

Hydrogeological wells are characterized by a deviation, which enables the required distance between the exploitation and absorption wells, since wells are often located within urban areas, and the space for their construction is limited. The depth of the well usually ranges from 2000 to 3500 m.

In addition to the presented geothermal district heating systems that use high enthalpy hydrogeothermal energy, systems that use low enthalpy hydrogeothermal resources and with the help of heat pumps produce thermal energy are also being developed.

As is the case in Milan, the installation for systems with lower temperature assisted by heat pumps can be seen. This system uses groundwater formed in the alluvium of the river Po to produce thermal energy. The depth of the well is 40 m, the groundwater temperature is 15 °C, and the total yield is 1150 m^3. The thermal power supplied is 15.5 MW [1]. In several instances (Denmark, Germany, Iceland) absorption heat pumps, often associated with geothermal Combined Heat & Power plants (CHP), have been successfully installed and operated.

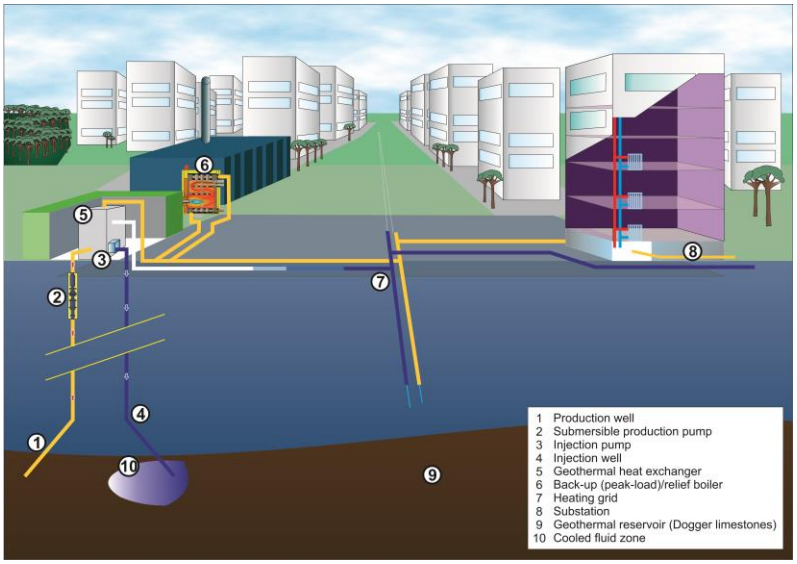

Figure 3. Scheme of geothermal district heating [6]

Unlike geothermal district heating systems, geothermal district cooling systems are not so developed in Europe.

2.1.1 Heat pumps

- Use of heat pumps in the world and in Serbia

Heat pumps are devices that provide energy for heating and cooling of residential, commercial and industrial buildings. They have been in use for more than 80 years.

The theoretical foundations of heat pumps were laid by Kelvin on the basis of the Carnot cooling cycle (Carnot, 1850), and heat pump technology is constantly evolving, performance is improving, and the number of installed pumps in Europe is about 15 million now [7].

Heat pumps use free energy from the environment to provide consumers with complete heating and cooling in an environmentally friendly, reliable and economical way. The main advantage of using heat pumps is shown in Figure 4.

Figure 4. Advantages of using heat pumps [1]

According to the European Heat Pump Association (EHPA), heat pumps for heating and cooling are used by at least 40% of the total number of energy consumers within the EU, and the substitution of oil and gas boilers, as well as electric heating with heat pumps can significantly contribute to the development of a strategy for renewable energy sources within the EU.

The use of heat pumps with a locally available energy source is constantly increasing with the aim to improve energy efficiency, which is legally encouraged by the directives of the European Parliament and the Council.

- The principle of the heat pump operation

Heat pumps provide heat exchange. Depending on the fluid used to exchange heat, there are water-to-water, water-to-air and air-to-air heat pumps, with other fluids being used instead of water and air.

The pump works by supplying the fluid, from which heat is subtracted, from the evaporating side of the device; the fluid to which the heat is transferred is supplied from the condenser side (Figure 5).

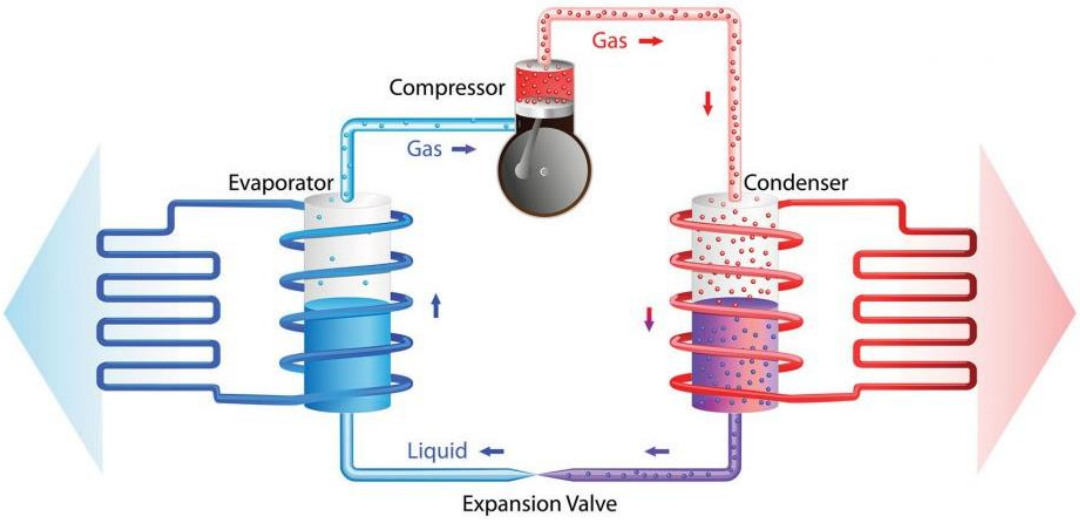

Figure 5. Heat pump operating cycle [8]

Depending on the energy source, there are water-water, ground-water and air-water heat pumps.

- Sizing and selection of the heat pump

The characteristics and capacity of the heat pump are defined according to the energy needs of the building, as well as according to the available quantities of subgeothermal energy.

The characteristics of the future pump will also determine the degree of efficiency of the entire system, and it can also have a significant impact on the resource, ie on the required quantities. Three groups of criteria should be considered when choosing a pump:

1. The needs of the facility
- Energy requirement of the heating facility
- Energy requirement of the cooling facility
- The need for domestic hot water
- Other consumers (pool equipment).

2. Resource availability
- Available groundwater quantities (in case of open loop system)
- Groundwater temperature (in case of open loop system)
- Thermal conductivity and energy yield per geoprobe (number of geoprobes).

3. Characteristics of heat pumps
- Heat capacity
- Degree of efficiency in different operating modes
- Possibility of automatic control
- The price.

2.1.2 Indoor installation systems

Based on the minimum inlet temperatures, the following classification of heating systems was performed:

1. High temperature systems (water temperature above 65 °C)
- Radiator system
2. Medium temperature systems (temperature above 50 °C)
- Convectors with forced circulation - fan coil systems
- Convectors with natural circulation
- Central air system
3. Low temperature systems (minimum temperature 30 °C)
- Floor heating
- Wall-panel heating and cooling
- Ceiling heating and cooling (no longer in use).

The use of subgeothermal resources is most energetically and economically justified in low-temperature indoor installation systems. Opposite them are conventional radiator installations of high-temperature systems, which cannot be compared to low-temperature ones in terms of function or efficiency.

The best energy performance is achieved by the optimal mode of operation of heat pumps, which is influenced by the inlet and outlet temperatures and the projected groundwater flow.

Tempering of the concrete core is a special type of indoor installation in the field of building construction, which is based on the passing of hot/ cold water through a network of polyethylene pipes built into the ceiling, thus providing pleasant air conditioning of business facilities.

3 Conclusion

Geothermal generation has its roots in Europe. More than 25 % of the European population lives in areas directly suitable for Geothermal District Heating.

According to the map of the geothermal potential:

- GeoDH can be developed everywhere;
- Geothermal can be installed with existing district heating systems during extension or renovation, replacing fossil fuels;
- New GeoDH systems can be built in many regions of Europe at competitive costs;
- The Pannonian basin is of particular interest when looking at potential development in Central and Eastern Europe.

Although the potential of deep geothermal is significant, geothermal district heating technology is not fully developed. The key points to improve the present situation are as follows:

- To remove the regulatory barriers, and simplified procedures for operators and policy makers.
- To develop the innovative financial models for GeoDH projects, which are capital intensive.
- To train the technicians and decision-makers of regional and local authorities in order to provide the technical background necessary to approve and support projects.

In addition, it is important that a level playing field is established by liberalizing the gas price and taxing greenhouse gases emissions in the heat sector appropriately.

The main benefits of geothermal heating and cooling are provision of local, baseload and flexible renewable energy, diversification of the energy mix, and protection against volatile and rising fossil fuels prices. Using geothermal resources can provide economic development opportunities for countries in the form of taxes, royalties, technology export, and jobs.

4 Acknowledgement

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5 References

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