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Review paper

USE OF DEEP GEOTHERMAL ENERGY AS A LOCAL RENEWABLE ENERGY SOURCE

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Abstract

Abstract text (Style Abstract text) When temperatures of geothermal resource are high enough, i.e. exceeding 150 degrees Celsius, one can engage into electricity production from geothermal. In some cases, lower fluid temperatures are used in so called Organic Rankine Cycle (ORC) or Kalina cycle to generate electricity. This complex mechanical process makes use of turbines which utilize pressurized vapor to produce electrical power. ORCs can also be used in combined heat and power systems to provide city parts with district heating from geothermal energy. The importance of strategical steps for further improvement of such systems aims at lowering the cost of drilling and utilizing primarily natural resources, thus enhancing their level of utilization and more efficient use of energy. As many countries worldwide are not as lucky as geothermally potent countries (Iceland, New Zealand, Italy, The Philippines for once), they would have to utilize lower temperature fluids. If a country has an unstable economy, the upfront costs for GE projects, especially with lower temperature fluids, can be much larger than the same projects in developed countries. More upfront effort for creating suitable incentives is necessary for securing such projects´ successful outcomes, which can be beneficial for the country in stake in terms of local renewable energy source utilization in the long run, as it creates policies and ultimately affects the law and consolidates efficient procedures on planning.

Key words: *cascade system of GE, district heating system, electricity production*

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1. INTRODUCTION

In this paper, a geothermal utilization in terms of highly potent resources is given. The focus is on the geothermal resource as an opportunity for city development in terms of electricity production, district heating and combined systems of these two, within a cascade use of geothermal energy (GE).

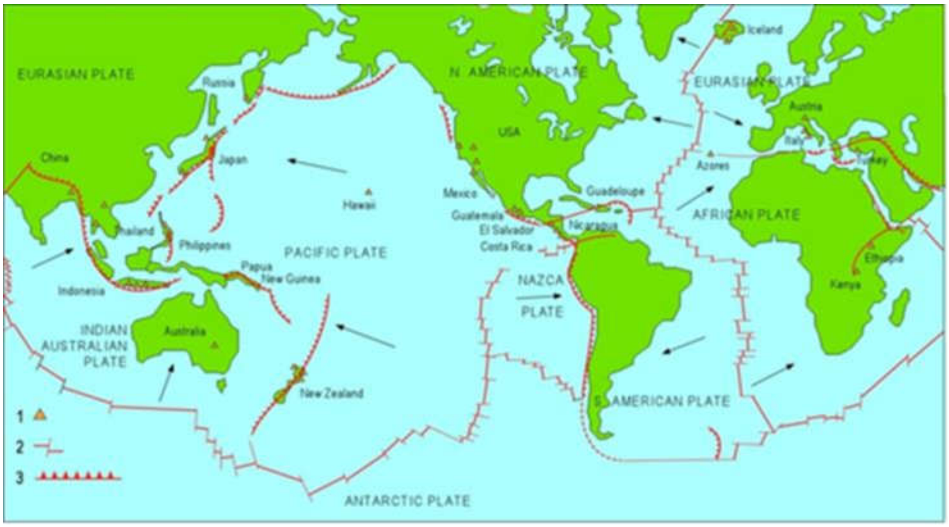

Figure 1. Tectonic plates of the Earth´s crust, the lines represent the plates ‘boundaries, for example, Iceland is between Eurasian and North American plate, a volcanically active region, source: http://www.unionegeotermica.it/images/What_is_geothermal_en_html_2f5bdb15.jpg, accessed 04.03.2018

Geothermal energy is derived from the thermal energy naturally stored within the Earth's crust. It is classified as a renewable energy source due to its vast potential—capable of meeting humanity’s energy needs for centuries—while posing minimal environmental risks compared to fossil fuel exploitation. As a clean energy source, geothermal energy offers significant environmental advantages, particularly when integrated alongside solar, wind, hydro, and biomass energy within urban contexts.

GE is generally categorized into two main types: shallow and deep geothermal. Shallow geothermal, typically utilizing low-enthalpy resources, involves extracting thermal energy from depths ranging from the surface down to approximately 400 meters. This form of GE is primarily used for heating and cooling applications. In contrast, deep geothermal systems access higher-temperature resources at greater depths, making them suitable for more intensive energy production [1].

2. CITY VS. GEOTHERMAL USE

The suitability of a city for utilizing shallow or deep geothermal energy—or both—largely depends on local geological conditions and environmental factors. These include soil characteristics, surface solar irradiation, recent volcanic activity, and the natural geothermal heat flow in the region. Very shallow geothermal systems, typically installed at depths up to

200 meters, often rely on heat pump technologies to enhance the relatively low temperatures encountered at those levels.

At greater depths, hydrothermal resources—such as naturally heated water or steam within permeable rock formations—can be directly extracted for use in district heating systems. In areas where subsurface rock temperatures are sufficiently high but natural water is absent, Enhanced Geothermal Systems (EGS) may be implemented. These systems enable the use of high-enthalpy geothermal energy by artificially creating permeability in the rock, often through a process known as hydraulic stimulation or “fracking.”

While EGS can significantly expand geothermal potential, especially in urban settings, it is not without controversy. The process of fracking—used to create fractures in deep rock formations for fluid circulation—has raised environmental concerns, particularly regarding its potential to induce seismic activity. In the U.S., this method has been particularly scrutinized for its environmental implications in urban areas [1].

Deep geothermal systems are usually “open loop” systems, which imply extraction from one place and injection of cooled fluid in another pipe, coming as used from district heating or cascade heating, to the other. This is also called “doublet”, as there are two separate drillings one for extraction, the other for re-injection of the fluid (see Figure 3).

Current capacity of Geothermal District Heating System (GDHS[2]) in Europe (direct use) is estimated at 4400 MWTh with the annual production of 13 000 GWh on European level. There were 250 GDHS installed in Europe up to 2016, with some 200 currently being developed, mostly in central and Eastern Europe [2].

Nevertheless, there are still constraints which limit the use of geothermal energy (GE) for heating, such as low level of incentives for GE and unfair position of it to other fuels, upon which whole cities and communities are largely dependent on. Deep geothermal projects require access to financial incentives, that help reduce the upfront costs and risks related to unsuccessful drilling and they help build necessary infrastructure. EU’s net-zero industry act (adopted in 2024) is one of the acts that supports further GE use, not only its manufacturing but supply chain as well. This indirectly intensifies GE`s relation to the built environment, both in terms of securing heating and resilient electricity networks in the future [3, 4].

3. ELECTRICITY FROM GE

Although the United States is among the leading producers of electricity from geothermal energy, investments in geothermal district heating systems (GDHS) have been limited, largely due to the continued availability of inexpensive fossil fuels. As a result, the current installed capacity for GDHS remains relatively small compared to the country's overall geothermal potential. Nevertheless, certain regions in the U.S. present significant opportunities for future GDHS development [5].

[2] GDHS Geothermal District Heating Systems

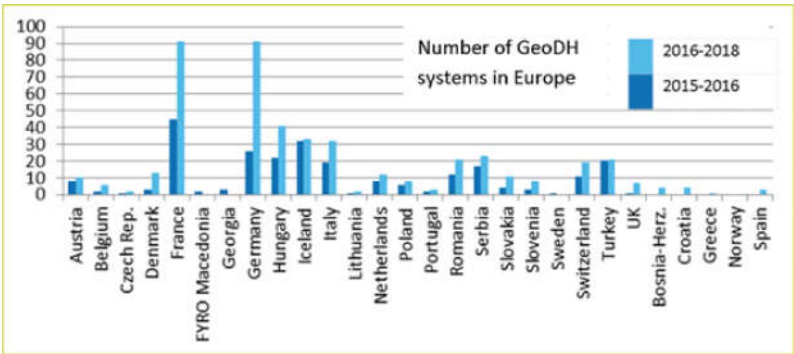

Figure 2. Number of installed GDHS in Europe, source: http://geodh.eu/wp-content/uploads/2012/07/District-Heating-Project-in-Europe-2014-2018-EGEC-market-Report.png, accessed 05.03.2018

In the U.S. or western European countries, such as Germany, the risks and upfront costs are even less for large district heating geothermal projects, compared to non-Eu countries, such as Serbia for example. Here, the investors are faced not only with large geothermal upfront costs, but are faced with hardship regarding bank loans and state incentives, as Serbian economy is considered unstable and too risky for financial institutions to allow for geothermal projects. Another obstacle is that larger geothermal projects are not realized in major cities in Serbia and geothermal energy is mostly considered as balneological resource here. On the contrary, the EU policy and conclusions from December 2024, mainly determine GE` s role as net-zero energy source of the future on the European territory. In this aspect, the conclusions indicate necessity to continuously educate for securing skilled force for GE utilization, and this aspect is even more vital for European countries in the South-East of Europe, as the upfront costs and at the same time risks are larger there and current fossil fuels infrastructures need to be strategically converted into geothermal energy systems over time. However, the EU or countries such as Serbia, have to develop a special incentive strategy which is even more profound and viable in terms of luring investors and securing energy stability through focused mindset change among the population, in terms of combined efforts both of the state and industry in Serbia and the EU [6].

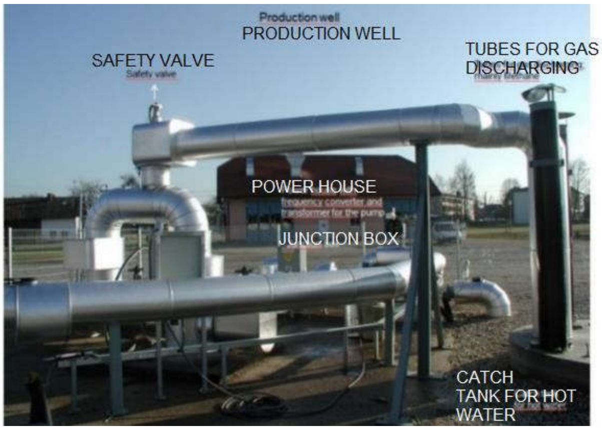

Figure 3. Geothermal system (doublet) in the Austrian town of Altheim, showing its main components, other than district heating piping, source: G. Pernecker, presentation of the project at the GeoCalgary conference [7]

Figure 4. Installment of the Geothermal District heating piping in Iceland, source: www.verkis.is presentation by T. Johanesson, Cornell 2016, used by courtesy of the presenter

Figure 5. Usual size of the piping within the geothermal system based on hot water, Iceland, www.verkis.is, presentation by T. Johanesson at Cornell, 2016

4. FUTURE RESEARCH

A comparative analysis of the literature demonstrates that cascade use of geothermal energy is among the most effective approaches. In addition to electricity generation, geothermal energy can be utilized for district heating, agricultural applications, spa and wellness facilities, aquaculture, and aquaponics. Evidence shows that such multi-use systems are already successfully implemented in Iceland, various parts of Europe, and other geothermally active regions worldwide. These findings highlight the potential of cascade systems as a promising model for countries that have yet to fully develop their geothermal resources, among which Serbia is [8].

5. CONCLUSIONS

There are several constraints to large geothermal projects, that include large upfront cost of GDHS or combined heat and power systems. They require access to financial schemes and more elaborated incentives. Not only do they supply the financial part, they also help to lower the risks related to drilling and exploration, and, help build the necessary GDH infrastructure, which is largely undermined but determining factor for a successful GE project implementation.

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