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COMPARATIVE ANALYSIS OF GEOTHERMAL HEAT PUMPS

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Abstract: Geothermal Heat Pumps (GHP) belong to a class of modern sustainable technologies that use energy (heat) available underground for heating or cooling households and residential buildings, as well as commercial and industrial spaces. They are widely deployed across Europe and enable savings in primary energy sources, simultaneously cutting down the costs of heating/cooling. This paper discusses advantages of GHPs, especially the pumps of the type earth-water, and provides a comparative analysis of different types of those pumps currently available on the market according to their coefficient of performance (COP), CO_2 emission footprint, and power. Based on the collected data from 309 different GHP models coming from 32 different manufacturers, we derive expressions for characterizing GHPs of the type earth-water, which can be useful in performing initial feasibility studies and system designs.

Keywords: geothermal energy, heat pump, COP, heating, cooling

INTRODUCTION

Energy consumption poses a major environmental and energy problem, in terms of global warming and limitted availability of fossil fuels. The main advantage of using geothermal energy lies in the fact that this renewable source of energy is freely available as the earth heat or heat from groundwater (whit temperatures between 5°C and 30°C). Estimated installed capacity at world level amounts to nearly 12,000 MWt (thermal energy), so the annual energy need is about 72,000 TJ (20,000 GWh) [1,2].

Heat pumps are widely used because of their high efficiency compared to conventional heating and cooling systems. There are two basic types of heat pumps: those that use air as the heat source and those that use ground, known as geothermal heat pumps (GHP) and ground source heat pumps (GSHP), respectivly [3,4].

An estimated power of all existing geothermal wells in Serbia is about 160 MW, out of which about 100 MW is currently used. Wiht the heat pumps, we can use as much (completely clean) energy from the ground as we need. For example, with installation of 20,000 heat pumps of 20 kW power each for heating residential facilities, the necessary amount of energy for a power plant that produces 300 MW can be taken from the ground.

Europe sets very high goals in terms of renewable energy and reducing greenhouse gas emissions. Geothermal energy is the most appropriate to achieve these objectives and the only one of available renewable energy sources that has entered the legal obligation to be used in heating new buildings in several European countries. By joining the European Union, Serbia would need to follow those obligations regarding the use of renewable energy and reducing greenhouse gas emissions.

Serbian Energy Law [5] regulates the issuance of authorizations for the construction and reconstruction of facilities that produce electricity and thermal energy. Currently licensing is defined by the Rulebook on Criteria for the Issuing of Energy permits, Contents of the Application and the Manner of Issuing the Energy Permit and the conditions for approval of energy facilities for which no energy permits are needed [6,7].

Total installed power in geothermal power plants in the world is presented in Table 1. This Table also shows the short-term forecast for 2020.

During the period of five years, between 2010 and 2015, an increase of 1.7 GW (16%) is achieved, which in the judgment of the linear trend is about 350 MW/year with an obvious increase in the average value of 200 MW/year in the period from 2000 to 2005.

Table 1. The total installed capacity of geothermal energy at the global level from 1995 until the end of 2015 and short-term forecast for 2020 [8]

Year	Installed capacity [MWe]	Produced energy [GWh]
1995	6.832	38.035
2000	7.972	49.261
2005	8.933	55.709
2010	10.897	67.246
2015	12.635	73.549
2020	21.443	

Ruggero Bertani in his research showed that the total amount of electric energy generated by geothermal power station in 2015, in several countries on five continents, is about 12.6 GWh [8].

TECHNOLOGY OF GEOTHERMAL HEATING

The geothermal energy potential is huge. It is estimated that there is multiple times more geothermal energy than the total amount of energy sources based on fossil fuels (coal, oil and gas) around the world. Serbia, ranks among the richer countries on the geothermal potential although this is still an under-utilized resource. The use and exploitation of geothermal energy must become more intense because of a number of factors: a steady growth in the price of fossil fuel, worsening environmental situation, the increase in the cost of protecting the environment.

Heat pumps are devices that work on the thermodynamic principle of the heat exchange, i.e. the heat from the lower temperature place shifted to higher temperature place while consuming mechanical work, which is several times smaller than the energy transferred by left-turn circular process of an appropriate working fluid. The share of electrical energy consumption ranges from one-third to one-fifth of the resulting thermal energy, which means that the expenditure of 1 kWh of electricity can be transformed into 3 - 5 kWh of thermal energy.

Geothermal heat pumps use the ground or ground water as a heat source, whose temperature is mostly constant throughout the year. There are three different sources of heat - outside air, earth and groundwater. On this basis, there are three different systems of heat pumps: air - air, water - water and ground - water. The earth is a very good accumulator of solar heat because the temperature at a depth of 1.2 - 1.5 meters throughout the year is constant, ranging between 5 - 15°C.

COP coefficient describes the efficiency of the heat pump, i.e. the ratio indicates how many times more thermal energy is obtained in relation to the electricity consumed by the compressor. The efficiency depends on the type of heat source (ground, water, air), thermal building insulation and heating systems. The most economical use of heat pump is in well insulated buildings with heat losses less than 50 W/m^2 and a low-temperature heating system (floor/wall heating) with a primary flow temperature of 35°C.

Selection of the working fluid used in the heat pump is carried out by considering a number of different aspects. Some of the working fluids which are intensively used in heat pumps have a serious impact on the environment. The working fluid must meet the appropriate set of conditions such as:

» chemical stability (stability of working fluid within the system);
» impact on the environment, health and safety;
» thermodynamic properties.

The CO_2 emissions shall be determined by multiplying the annual primary energy for the operation of the facility, by source of energy, and the appropriate data for specific emissions of CO_2.

Reduction of greenhouse gases emissions (GHG) in the geothermal heat pump is around 44% compared to air-cooled heat pump and even 72% compared to heating systems that use electricity [9].

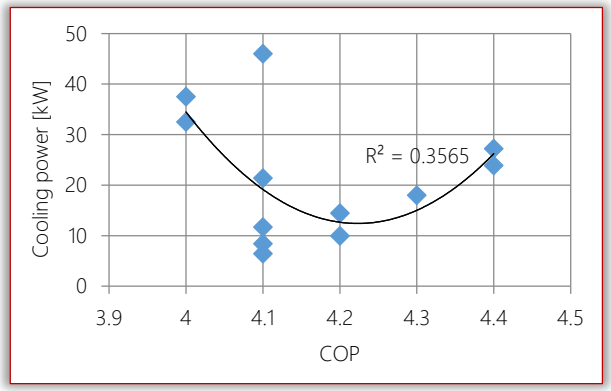
COMPARISON OF TYPES, COP AND POWER OF HEAT PUMP EARTH - WATER BEETWEEN DIFFERENT MANUFACTURERS

In the manufacturers brochures of heat pumps of the type earth – water, the following data is readily available: the coefficient of performance (COP) of heat pumps, the heating and cooling power as well as which medium is used for cooling. The price of heat pumps depends on several factors and it is not available from all the manufacturers.

Based on the available data, in this paper we present the values of COP, cooling and heating power obtained for 309 different models of geothermal heat pumps of the type earth - water (from 32 different manufacturers, [10,11,12,13]).

Figure 1 presents the dependence between the COP and heating and cooling power for several manufacturers. Temperature of the heat source and the heat sink are 5/55°C [10,11].

Efficiency coefficients (COP) of processed heat pumps differ a little bit but, for the purposes of initial studies, the effectiveness of specific model for a given heating or cooling power can be determined based on the diagrams given in Figure 1.



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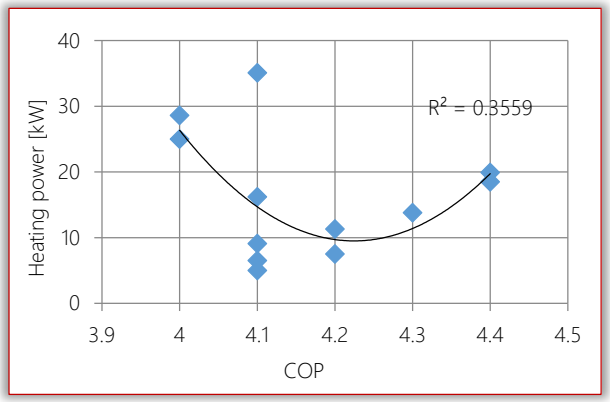

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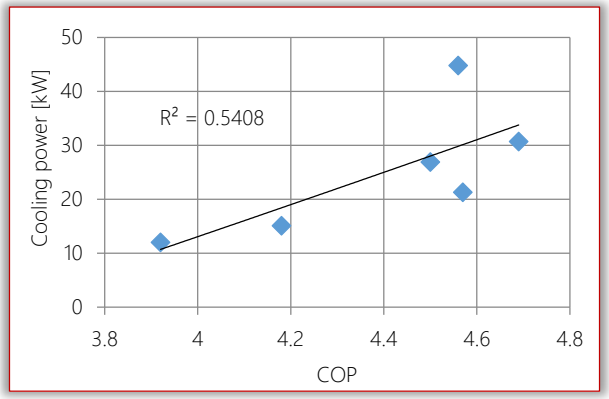
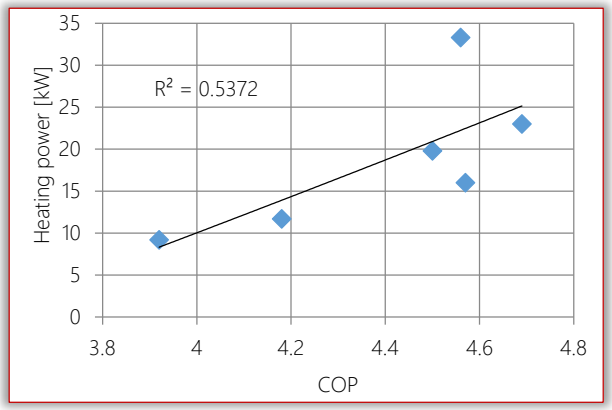


c)

Figure 1. The dependence of the COP of the geothermal heat pump type earth – water on the heat (left) and cooling power (right) (figures formed based on data from [10,11,12,13]). a) Rehau heat pump - the COP dependence on the cooling power; b) Rehau heat pump - the COP dependence on the heating power; c) Bosch Logatherm WPS heat pump - the COP dependence on the cooling power;



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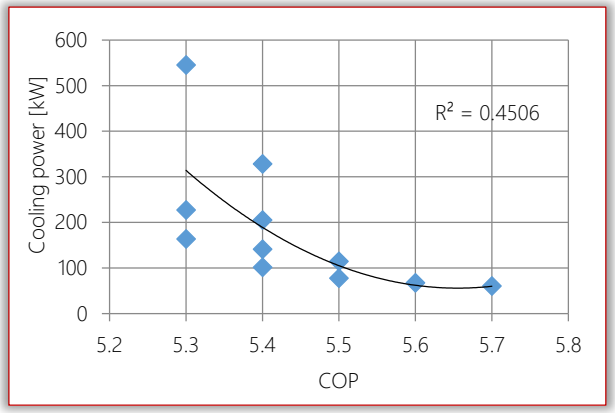

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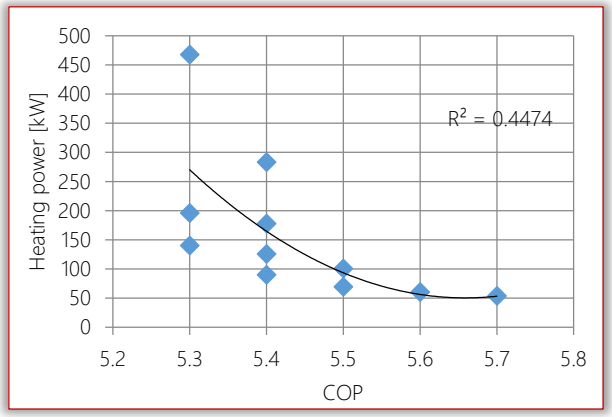
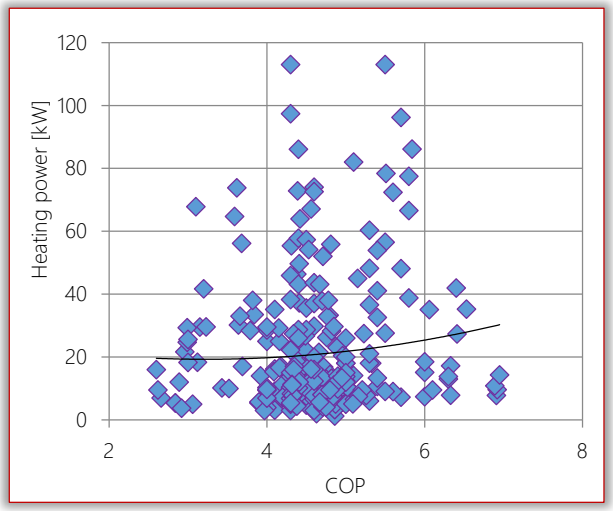


f)

Figure 1 (continuing). The dependence of the COP of the geothermal heat pump type earth – water on the heat (left) and cooling power (right) (figures formed based on data from [10,11,12,13]). d) Bosch Logatherm WPS heat pump - the COP dependence on the heating power; e) Hidros heat pump - the COP dependence on the cooling power; f) Hidros heat pump - the COP dependence on the heating power

Figure 2 presents the total dependence of the COP of heat pumps and heating and cooling power for collected data from available manufacturers.

The market offers a relatively large number of geothermal heat pumps of the type earth - water of different heating/cooling powers and the efficiency of heating/cooling, so that an appropriate model for almost any requirement of potential users can be found from above Figures.



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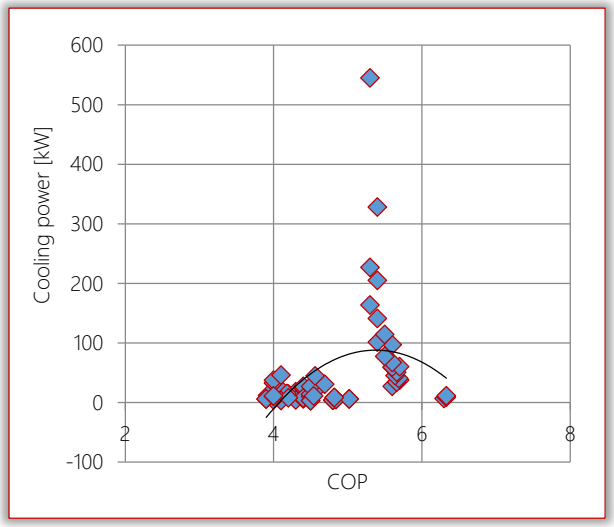

b)

Figure 2. Dependence of the COP of the geothermal heat pump type earth - water on the heating and cooling power for all manufacturers (figures formed based on data from [10,11,12,13]). a) The COP dependence on the heating power for the collected data from 32 manufacturers of geothermal heat pumps; b) The COP dependence on the cooling power for the collected data from 32 manufacturers of geothermal heat pumps

CONCLUSIONS

This paper presents a total installed capacity [MW] and the total electricity production [GWh] in geothermal power plants worldwide, as well as the short-term forecast for 2020. The paper also shows 32 manufacturers (309 models) of geothermal heat pumps of the type earth - water. The prices of geothermal heat pumps are not presented because the relevant data was not available for all the heat pumps. Models of geothermal heat pumps that are discussed in this paper are available on the market and are suitable for use in family homes, apartment buildings, public buildings, hotels and small industrial plants.

Based on the analysis of the characteristics of geothermal heat pumps, the conclusion is that the use of geothermal energy reduces the need for primary energy sources by half, compared to traditional heating systems, and reduce

emissions of greenhouse gases. In other words, heat pumps contribute to reducing the demand for energy from fossil fuels.

Acknowledgements

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Note

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