What is the potential of shallow geothermal energy in the municipality of Cerkno (the GRETA project)

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In Slovenia, areas with a geological setting as diverse as the Municipality of Cerkno are rare, since as many as 28 different lithological units can be found on a detailed geological map within an area of 6 km^2 around the settlement of Cerkno. Also, the tectonic activity was strong in the past. The results of the diverse geological structure are the variety of possibilities for the geothermal energy use.

The Municipality of Cerkno participates in the GRETA project as an observer through the Geological Survey of Slovenia, which was a project partner. The common challenges in the Alpine Space that gave rise to this project are connected to tourism in the remote hill areas and increasing energy needs, especially for heating, by cutting emissions, in particular of CO_2 and switching to renewable energy sources, in this case to the geothermal ones.

The Municipality of Cerkno already has a rich tradition of harnessing deep geothermal energy. Within the project, the scientific possibilities for harnessing the shallow geothermal energy from the surface down to a depth of 300 m were also explored for the municipality. The geothermal energy constitutes a good combination by harnessing wood biomass and enabling the cooling of buildings and the storage of heat surplus. It represents a good potential for energy independence in future decades.

With the aim of presenting the potential of geothermal energy for heating and cooling via heat pumps in the municipality, we undertook a systematic review of the geological and geothermal characteristics of the municipality.

The largest part of the municipality is composed of clastic sedimentary rocks. Among the carbonate ones, the dolomites of the Triassic age prevail. The alluvial deposits composed of gravel, sand, silt and clay do not cover larger areas and could be found only in relatively thin layers along the rivers and streams. The fracture porosity is mostly typical of the mixed clastic and carbonate rocks in the

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Municipality of Cerkno, while the karst porosity is limited to small areas. The dolomites and limestones can be considered as low permeability aquifers. Moderate permeability can be expected in certain horizons of dolomite, particularly in the tectonic areas. Thus, the clastic rocks only form very low yield aquifers. While the sandstones can still function as aquifers with a low yield, the layers of claystones and tuffs are, as a rule, hydraulic barriers and it is usually not possible to pump groundwater for heat pumps from them. The alternating layers of sandstone are usually less than a meter thick. In general, the groundwater is of good quality and poorly mineralised. Thermal water, i.e. water with a temperature higher than 20°C, is expected at a depth of below 600 m, unless there is a rising current of thermal water through tectonic zones from a deep aquifer located closer to the surface.

Due to the conditions described above, highly favourable aquifers for heat pumps involving the water-water system are not expected in the Municipality of Cerkno, except at the actual springs. The possibilities for the groundwater systems are better. In this area, the heat conductivity of the rocks located in their territory plays the most important role. In order to obtain data on this parameter, laboratory measurements were undertaken on numerous samples of various rocks. The samples were collected from the most typical and widespread rocks or lithological units in the municipality.

The samples were adequately prepared for laboratory measurements using the optical Thermal Conductivity Scanning (TCS) method. We measured 16 samples (with 30 rock pieces) from the area of Cerkno and 16 samples (with 23 rock pieces) from the wider area of the Municipality of Cerkno – 53 rock pieces in total.

Among all the rocks in the Municipality of Cerkno, the dolomites (massive and bedded), quartz sandstones and conglomerates, dolomitized limestones and certain tuffs (keratophyre and porphyre) proved to be most conductive and therefore have the best potential for harnessing the heat of the Earth. Some other types of rocks, such as limestones, carbonate sandstones, siltstones and diabase also showed relatively good thermal conductivities. Smaller potential (but not very bad) was shown by the claystones, siltstone and marlstones.

Slaty claystone
Thermal conductivity:
λ = 1,8 W/(m·K)
Črni vrh

Dolomite
Thermal conductivity:
λ = 3,8 W/(m·K)
Košec

Quartz conglomerate
Thermal conductivity:
λ = 4,8 W/(m·K)
Mlin

Figure 1 – Thermal conductivity of rocks. The size of samples is approximately 10 x 15 cm. Author of photographs: T. Prestor, 2017

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The lithological composition of the ground was interpreted up to a depth of 100 m, which is the most typical depth for making of geoprobes.

Next to the conductivity of the rocks, the ground temperature is the second most important geothermal parameter for planning geoprobes. The typical medium annual temperatures are between 5.6°C (at an altitude of 1291 m – Črni vrh) and 10°C at an altitude of 263 m at Želin. The surface density of the heat flux *q* was only well-determined in terms of calculations concerning the deep borehole Ce-2/95 with a value of 0.054 W/m^2.

All this data was used to calculate the geothermal potential by using the G.POT method. This is an estimate of the thermal energy that a geoprobe at a depth of 100 m would obtain from the ground in a year (Casasso, 2016).

The established geothermal potential P_{BHE} varies between 8 and 15 MWh/year in various areas of the municipality and between 8 and 10 MWh/year in the majority of settlements. If we take 9.375 MWh of energy from the Earth, we can obtain 12.5 MWh of thermal energy for a building using a high-efficiency (COP=4) heat pump. In this regard, a consumption of 3.125 MWh of electricity to run the heat pump is calculated. Comparatively, this would save approximately 1260 m^3 of natural gas, 14 m^3 of firewood, 9 m^3 of logs, 24 m^3 of woodchips, 2.6 ton of pellets, 1900 l of LPG or 1280 l of fuel oil.

Energy-generating product:	Heat pump – geoprobe	Natural gas	Firewood	Logs	Woodchips	Pellets	LPG	Oil
Unit:	[kWh]	[m^3]	[m^3]	[m^3]	[m^3]	[t]	[l]	[l]
[.../year]	3,125	1,260	14	9	24	2.6	1,900	1,280

Higher values of potential can be found in the area covered by the very conductive dolomite (3.7 to 5.6 Wm^{-1}K^{-1}), for example in small villages of Bukovo, Kojca and Žabče (15 MWh/ year), Šebrelje (16 MWh/year), Orehek and Reka (14 MWh/year), as well as Jagršče, Police and Jazne (12 MWh/year). In general, the high thermal conductivity of the grounds compensates for the relatively low temperatures (due to the altitude), thus the geothermal potential of the municipality is rather high for such a hilly area.

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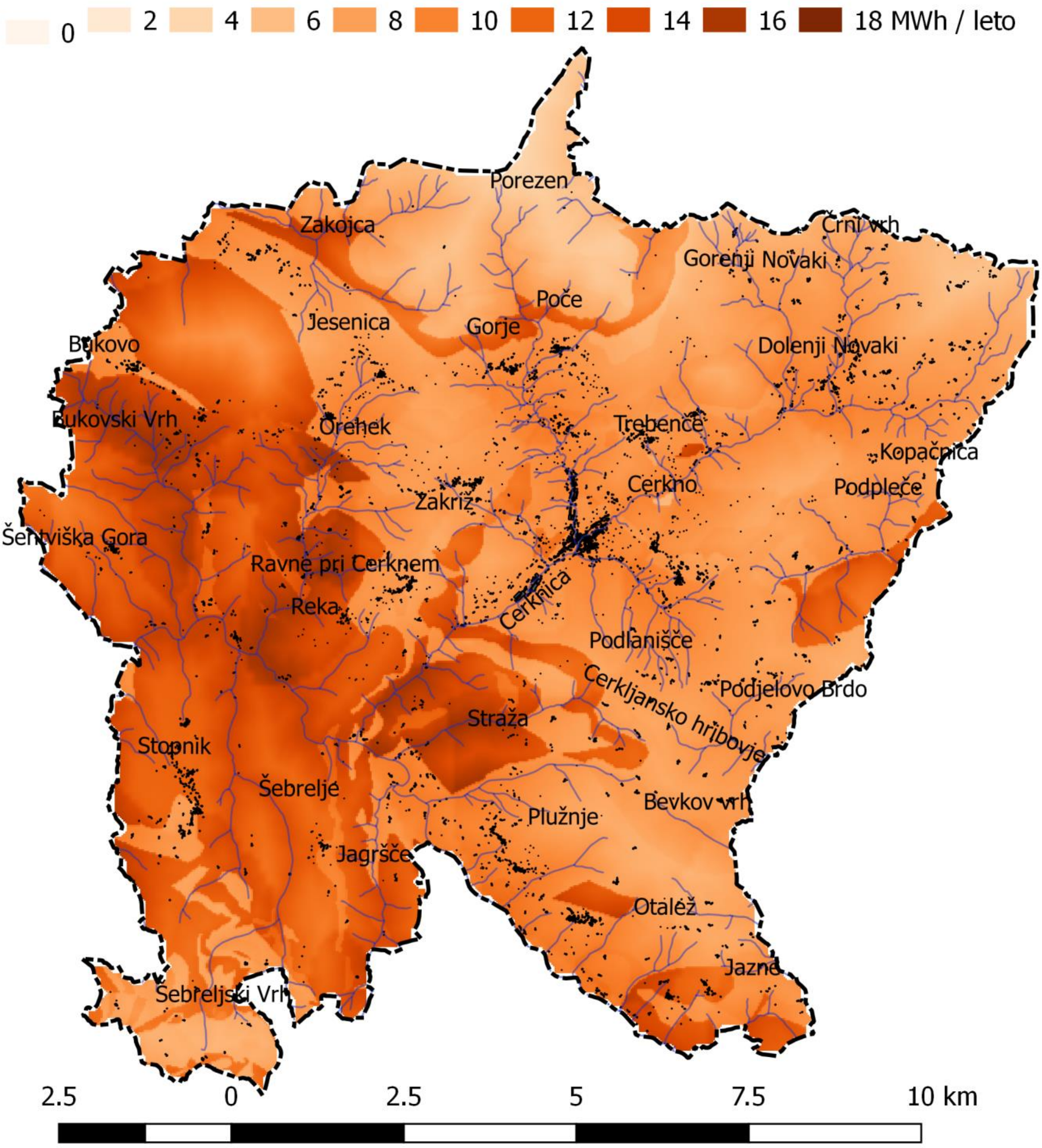

MWh/year

Figure 2 – Map of potential shallow geothermal energy according to the G.POT method. How much heating energy can be obtained annually from one borehole at a depth of 100 m is evident from this figure. This can be directly compared with the annually consumed energy, calculated in MWh.

The shallow geothermal potential affects the costs of drilling for the installation of geoprobes and the common costs of geothermal heat pumps, and thereby its economic appropriateness. For example, taking a building with a thermal need of 75 MWh and covered by a heat pump of 30 kW of

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power, it is demonstrated that 8 geoprobes will be necessary in the settlement of Cerkno, where the potential is 9.5 MWh/year, while 5 geoprobes would be sufficient in the village of Bukovo, where the geothermal potential is 15 MWh/year. The Cerkno Curricular and Extracurricular Activities Centre, which is pumping heat from underground via 11 geoprobes installed under the parking area, can be used for comparison. Geoprobes with a double U-tube are installed 96 m deep and 6 m apart. The average power of consumption amounts to 22 kW and the average energy use to approximately 100 MWh/year. The total savings using this system is 8.6 tonnes of petroleum oil per year.

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