C. Description of the pilot area

1. Infrastructural and socio-economic settings

Ljubljana is the capital and largest city of Slovenia with 287,000 permanent residents; 12,000 temporary residents and 56,000 students. It has a positive total population growth of 4.7 per 1000 residents and the population density of 1,041 inhabitants per square kilometre. Ljubljana is situated in central Slovenia in the Ljubljana Basin and the pilot area corresponds to borders of the City of Ljubljana (COL) and covers mainly Ljubljansko polje and in southern part the most northern part of Barje (Fig. 1). The central flat urbanised landscape (altitude 295 m a.s.l.) is divided by hills (Golovec, Grajski hrib and Rožnik) in the middle and surrounded by hilly hinterland. Border of COL follows natural (mainly water divides at W, NW, SE part) and administrative divisions (SW and NE part). Average yearly temperature is around 12 °C and average yearly precipitation around 1400 mm.

The Ljubljana pilot area, covers an area of 275 km^2 and includes 38 settlements, 1,599 spatial districts, 57 cadastral areas, and 17 city quarters. Total number of housing is around 120 thousand. District heating system covers almost all area within the Ljubljana bypass and highway ring and distributes heat to densely populated areas, 74% of all households. The complementary source of heating is natural gas, its network has been extended yearly by 10 km. Around 18 % of the area is covered with infrastructure and objects (buildings, public areas, roads and railways). The length of the road network is 1,152 km (55 km highways).

The City of Ljubljana is a part of the most developed region in Slovenia. In 2015 there were 40,612 companies and freelancers together and their number has increased from 2008 by 22.5 %.

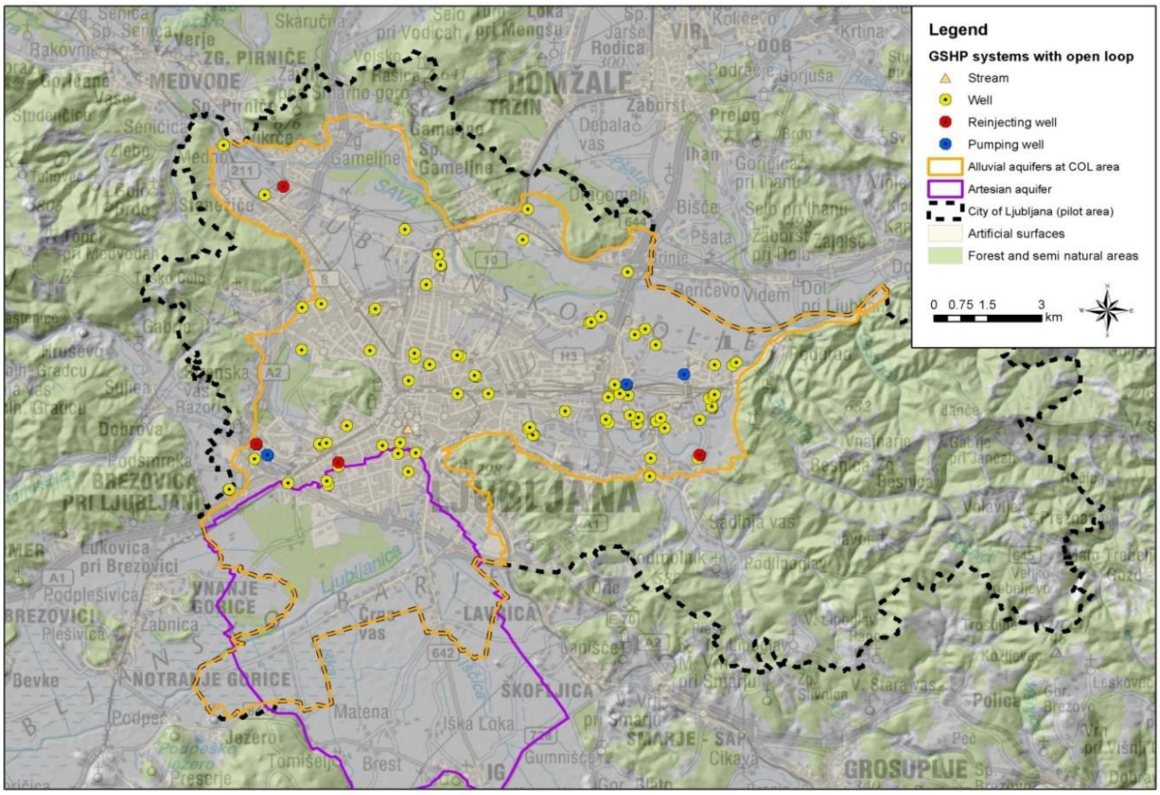

Figure 1: The Ljubljana pilot area and locations of open loop ground source heat pump (GSHP) systems.

2. Regional geological and hydrogeological characteristics

The areas of Ljubljansko polje and Barje were formed by tectonic subsidence and gradual filling with alluvial and lacustrine sediments (Fig. 2). Bedrock of quaternary aquifer Ljubljansko polje, located in the northern part of the pilot area, is composed of Carboniferous and Permian rocks. Bedrock of quaternary aquifer Barje, on the southern part of the pilot area, is composed in the northern part of Carboniferous and Permian shale and in southern part of Triassic and Jurassic carbonate rocks. Hilly hinterland and hills in the pilot area have the same composition as the bedrock. The sediments of Ljubljansko polje are composed of permeable gravel and sand beds with lenses of conglomerate. Due to great thickness (which exceeds 100 m in the deepest parts) (Žlebnik, 1971; Janža, 2009; Šram et. al., 2012) and favourable permeability, this sandy-gravel quaternary aquifer contains significant quantities of groundwater which is the main resource exploited for the public water supply of the city Ljubljana. The Ljubljansko polje aquifer is unconfined, recharged from Sava River and rainfall, percolating through unsaturated zone which is on average 25 m thick.

The Ljubljansko Barje is composed of alternating fluvial and lacustrine deposits with a heterogeneous composition (silt, clay, sand, gravel). The top clay layer in northern part of Ljubljansko Barje is 10 - 20 meters thick. Heterogeneous and low permeable upper Pleistocene aquifer thick about 20 meters is situated below. It is separated by a thick clay layer from lower Pleistocene aquifer that consists of gravel and contains groundwater of good quality. It is a confined or semi-confined aquifer with artesian to subartesian conditions.

Ljubljansko polje and Barje aquifers are part of the groundwater body 1001 Savska kotlina in Barje. There are four waterworks at Ljubljansko polje and one at Ljubljansko Barje. 31 million m^3 of groundwater is pumped annually for the needs of water supply.

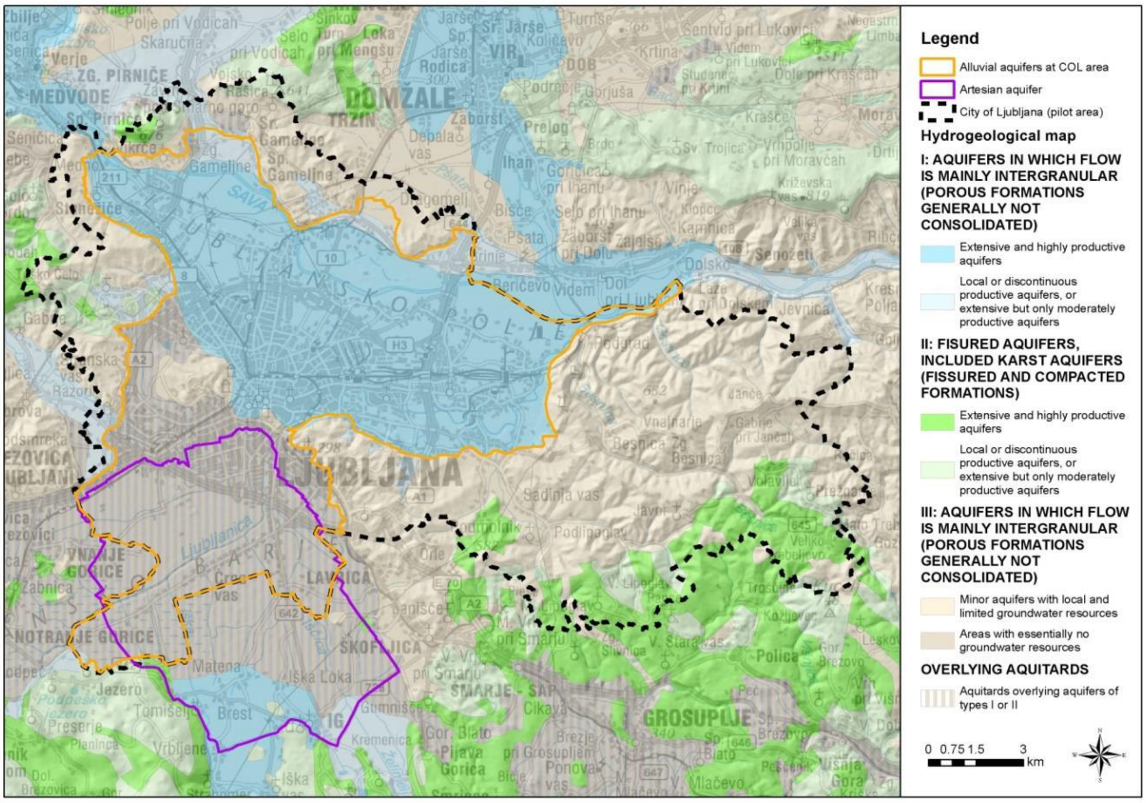

Figure 2: Hydrogeological map of the Ljubljana pilot area (adapted after Prestor et al., 2008).

3. Market situation and existing shallow geothermal use

For the Ljubljana pilot area only rough estimate of existing shallow geothermal use exists. It is based on interviews with ground-source (geothermal) heat pump providers (producers and/or sellers), who occasionally report the numbers of sold units on a voluntary basis. Approximate number of the open loop systems was estimated on the basis of issued water permits (Fig. 1), however this number could be higher. The number of the closed loop systems is just the best estimate, based on the total number of the operational GSHP units for Slovenia.

Approximate total amount of installed capacity at Ljubljana pilot area for heating is 2,554 kW, and for cooling 670 kW, respectively, while approximate produced energies are 2.9955 GWh (=10.7838 TJ) for heating and 0.3534 GWh (=1.27217 TJ) for cooling, respectively. Of these, 74 small size GSHP units of open loop system account for roughly 888 kW and they extract approximately 0.9768 GWh (=3.5165 TJ) of shallow geothermal energy in heating mode, while in cooling mode they account for 148 kW and produce 0.09472 GWh (=0.34099 TJ) for cooling needs. Approximately 10 big size GSHP units of open loop system account for roughly 869 kW and they extract roughly 1.37052 GWh (=4.9339 TJ) of shallow geothermal energy in heating mode, while in cooling mode they account for 405 kW and produce 0.1782 GWh (=0.64152 TJ) for cooling needs. There are also closed loop systems with BHEs, in total above 48 small size ground-coupled heat pump (GCHP) units account for 480 kW and they extract roughly 0.528 GWh (=1.9008 TJ) of shallow geothermal energy in heating mode, while in cooling mode they account for ca 48 kW and produce 0.03072 GWh (=0.110592 TJ) for cooling needs. Perhaps only 2 big size GCHP units of closed loop system with BHEs account for roughly 81 kW and they extract roughly 0.107207 GWh (=0.385946 TJ) of shallow geothermal energy in heating mode, while in cooling mode they account for 69 kW and produce 0.04974 GWh (=0.1791 TJ) for cooling needs. We assume there are roughly 20 GCHP units with horizontal collectors of about 236 kW, and their contribution in heating mode is about 0.2596 GWh (=0.9346 TJ).

With regard to the share of different application systems, we may just state very approximate figures. According to above mentioned source at least 84 open loop systems are operational, and also approximately 70 closed loop systems, and of these some 50 systems with borehole heat exchangers (BHEs), while the rest 20 systems represent probably GCHP units with horizontal collectors, but the number of all GCHP units is much less certain, since they are not documented anywhere. We estimated these numbers for the Ljubljana pilot area from the total numbers for the country.

As a typical system installed we may state something only about a big size GSHP unit (>20 kW). An average picture from some 10 such open loop GSHP units documented so far shows that their HP (heat pump) rated power ranges from 30 to 344 kW (the latter in 2 units of 172 kW each). About half of them use the shallow geothermal energy beside for the heating purposes also for the cooling needs. Within the heating mode some of them also have a domestic hot water preparation (half of them).

From the total number of the open loop GSHP systems it is assumed there are 10 units with HP rated power over 20 kW, and 74 with less than 20 kW. Of these 10 big units we assume that 3 units have HP rated power between 20 and 50 kW, and the rest over 50 kW. As regard the closed loop GCHP systems, it is assumed that among the HP units with horizontal collectors almost all are with HP rated power between 8 and 20 kW (of them some 80% with power between 10 and 20 kW). As for the HP units with BHEs we may just assume that 60 % of them have the HP rated power less than 20 kW, and the rest with over 20 kW.

4. Main challenges and needs for shallow geothermal use

The City of Ljubljana set in Sustainable Energy Action Plan the following goals to be achieved by the year 2020 (baseline year 2008):

- substitution of the fossil fuels with renewable energy sources (25 % share of renewable energy in the final energy consumption),
- improvement of the energy efficiency (20% less energy use),
- reduction of the greenhouse gas emissions by 35%,
- intensification of research and introduction of new technologies for the utilisation of renewable energy sources.

The local heat/cold production is a sector, where the largest share of greenhouse gas emissions (65 %) reduction is expected. Shallow geothermal energy will have important role in this respect and an integrative development and management strategy to foster the use of shallow geothermal energy is needed.

At the moment the share of geothermal energy use for heating and cooling is very low (few percent). One of the important reasons for this is a lack of information on shallow geothermal potential and barriers for its utilisation. To provide this information in a quantified form that could be used as a solid base for planning and designing geothermal systems is a great challenge. Especially if taking into account conflicts arising from a multiple use of the subsurface in this densely populated area and use of groundwater below the city as a main drinking water resource.

5. Project objectives

The objective of the project activities in the Ljubljana pilot area is to support the city of Ljubljana with information on shallow geothermal energy and integrate this information into development and management strategies of the city.

Quantification of shallow geothermal potential for utilisation with ground source heat pumps, primary for heating and also cooling purposes will be achieved through the following steps:

- Analysis of existing data and identification of gaps in data
- Collection and organisation of data on hydraulic parameters, thermal parameters and barriers for implementation of geothermal utilisation systems, including new measurements:
    - thermal conductivity measurements of soils and rocks (field and lab measurements)
    - long-term groundwater temperature, electric conductivity, level measurement
    - long-term groundwater temperature-depth profile measurements
    - area wide groundwater temperature measurements
    - geochemical analysis of groundwater
- Collected data will be used for set-up, calibration and validation of 3D models which will enable estimation of geothermal potential for the use and simulation of periodical behaviour of the aquifer, including estimation of potential hydraulic and thermal mutual impact of existing and planned geothermal use.
- Results of the modelling will be elaborated and presented in the form that could be used by local stakeholders for management of shallow geothermal use in Ljubljana pilot area.

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