C. Description of the pilot area

1. Infrastructural and socio-economic settings

Pilot area Bratislava includes Bratislava city and the part of the Austria in the vicinity. The outline of the area is based on the administrative division (outline of the municipal boundaries), respecting national borders of Slovakia, Austria and Hungary, the rivers Danube and Leitha (Fig. 1). The total evaluated area of the pilot region Bratislava is 603 km^2, with area of the Slovak part (Bratislava city) 367 km^2 and Austrian part 236 km^2. Total estimated population in the pilot area is around 450,000 inhabitants (434,000 in Slovakia and 16,000 in Austria). The average population density on Slovak part is 1,183 inhabitants per square kilometre and on Austrian side 68 inhabitants per 1 km^2.

Slovak part is characterized as urban area. City of Bratislava is located in the Central European region, in the southwest of the Slovak Republic. In terms of administrative division of the Slovak Republic is situated in the Bratislava region. City is situated on the trade corridor Budapest - Bratislava - Vienna created by Danube river. Bratislava is industrial town with different types of industry (oil, chemical, automotive, technological) and natural resources (groundwater sources, quarries and gravel pits). The Austrian part of the pilot area is characterized by agriculture, forests and the National Park Donau-Auen. Due to the suitable climate, agriculture is splitting into viniculture and farming. Natural resources include groundwater sources, quarries (granite, limestone) and gravel pits. Austria is known for long term policy in renewable energies that are in this part represented by wind energy plants. The landscape of the area is created by hills and lowlands. Evaluated area is including hills (Malé Karpaty Mts. – SVK and Hainburger Berge - AT) and lowlands Danube basin and Vienna basin. The highest elevation in the Austrian part is the Hundsheimer Berg (480 m a.s.l.) and on Slovak part Bukovec (471 m a.s.l.). The lowest elevation is at the Danube lowland 125 m a.s.l.

Development axes of the city are primarily arranged in radians. There are two rail corridors of the regional significance - the western connection to Austria and the eastern to the North of Slovakia. Road network is developed in the same setup. South development axis was open to urbanization practically in the early 70s at the south expansion of city in “Petržalka” district. This suburb is now one of the most growing part of the city, which is available to develop beyond the borders towards the neighbouring countries.

Figure 1: Outline of pilot area Bratislava and adjacent areas in Austria.

2. Regional geological and hydrogeological characteristics

From the *geological* point of view the area is created by core mountains (with crystalline core and sedimentary envelope) Malé Karpaty Mts. and Hainburger Berge. Lowland belongs to the Vienna basin and the Danube basin with sedimentary fill of Neogene and Quaternary sediments. From the lithological point of view the area has great variety in rock types and sediments that creates different condition for water recharge and ground water circulation, as well as geothermic conditions important for shallow geothermal heat pumps installation.

From *hydrogeological* point of view all kinds of aquifers according to the type of permeability are present. There are fissured crystalline hard rocks, karstified Mesozoic aquifers and porous aquifers of different stratigraphy and permeability value (Fig. 2).

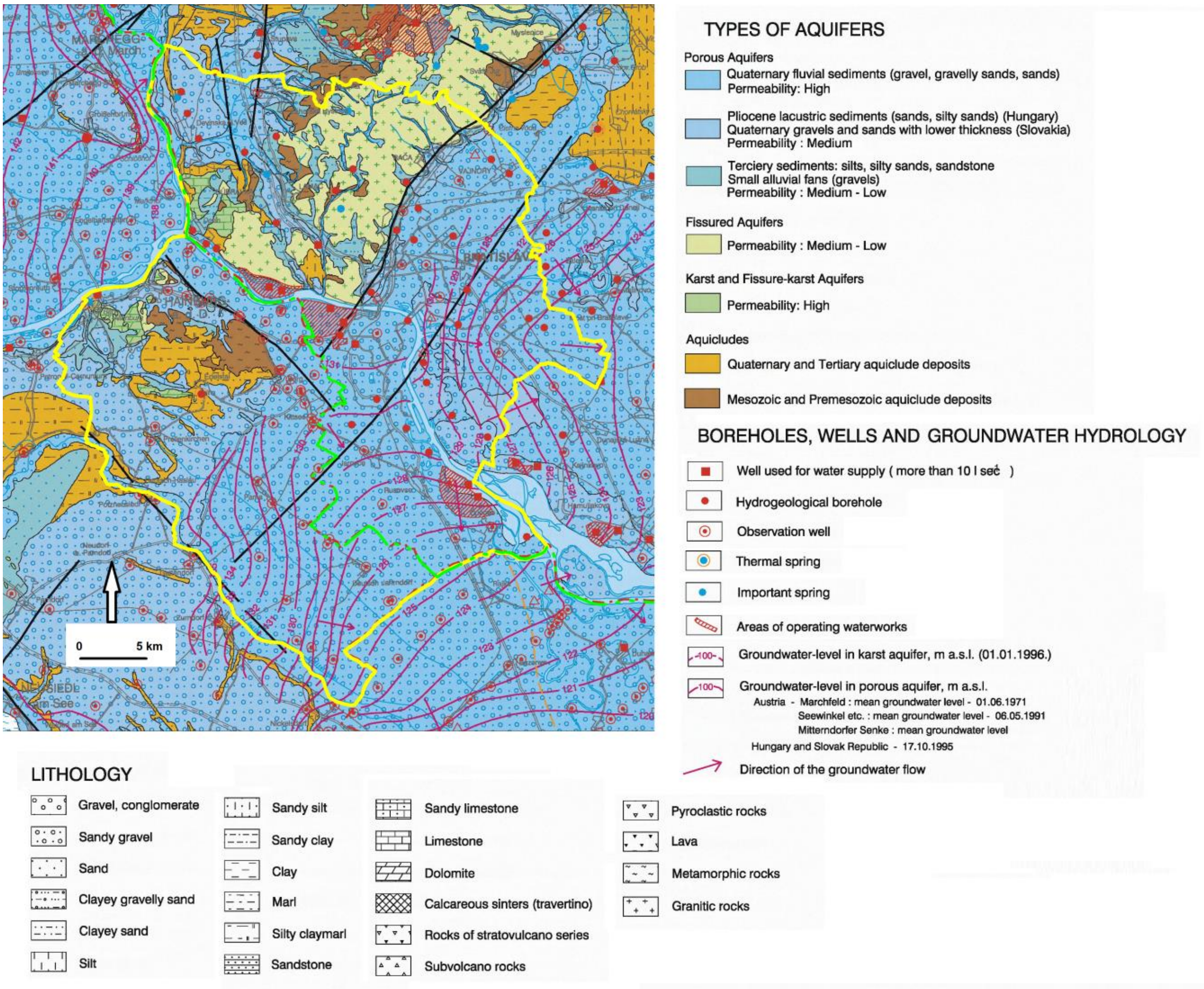

Fig. 2: Hydrogeological settings of pilot area Bratislava and adjacent areas in Austria (based on Malík et al., 2000).

Fissure-type permeability is characterized by fissure aperture closing downwards with resulting decrease of permeability, and improved hydraulic conductivity due to tectonic effects. This type of permeability is present in Crystalline rocks (crystalline schist, gneiss) in Hainburger Berge and Malé Karpaty Mts. with generally low permeability.

The *karst* aquifers within Middle Triassic carbonate rocks having a thickness of several hundred meters are important groundwater sources. These are often draining waters from the neighboring complexes.

Porous aquifers are present in clastic deposits comprising and also in less permeable fine-grained sediments. Their vertical or lateral extent is varying. Thick mass of coarse-grained sediments is serving as an important groundwater source both in Quaternary and Tertiary units, of confined water type, unconfined type that is mostly recharged by bank infiltration.

The Austrian part of the Pannonian Basin (belonging to the Neusiedler Bucht) is mainly filled with Pannonian sediments (Tertiary sedimentary basin). Their thickness increases toward the East. Within the Tertiary sediments in the area the groundwater flow velocity is in general very low.

The Quaternary sediments have sufficient thickness and effective porosity and create background for water sources with high yield and good quality of the water. At the Austrian side the groundwater body has a yearly average value of 12,8 °C, an average thickness of 7 m (range of the aquifer thickness is 3 to 20 m) and it has a small amount of groundwater (Malík et al., 2000). The Danubian deposits (gravels and sands – alluvium in the area between Devín and Bratislava) in this area are 2 to 18 m thick. The direction of groundwater flows, as well as of groundwater levels are connected to the Danube river and its deviation channel. The aquifer has a yearly average temperature 12,4 °C and an average thickness 11 m (Austrian side, Umweltbundesamt, 2016).The Petržalka area is characterized by a smaller thickness of fluvial gravels and sands (around 10 - 20 m) with good permeability. The water quality is at risk due to the extensive urban agglomeration of Petržalka. The fluvial sediments in Čuňovo area have the highest mean values of the transmissivity coefficient in Slovakia, with values of hydraulic conductivity of up to 4. 10^{-2} m.s^{-1}. The average thickness of groundwater body is 100 m and the mean permeability coefficient of 4. 10^{-3} m.s^{-1} (Malík et al., 2000).

At the northwest foot of the Hainburger Berge (Austria) which represent the southernmost branch of the Malé Karpaty Mts there is the thermal water occurrence of Bad Deutsch Altenburg. It is connected with Triassic carbonates, within which the thermal water ascends from the bottom of the Vienna Basin (Wessely, 1983). The whole discharge of the thermal water is several tens of liters per second (Gangl & Hacker, 1990).

3. Market situation and existing shallow geothermal use

The evaluation of the ground source heat pump market situation can be based only on estimates for Slovakia. Probably the most representative statistics is delivered by Slovak Association for Cooling and Air Conditioning Technology (and Tomlein verbal communication and internal manuscript form 2016).

The market for heat pumps in Slovakia is quite limited primarily due to the existence of a dense gas network. The technology is however slowly reaching a level of recognition and acceptance amongst the general public. The general economic downturn adversely affected the rate of new construction in the building sector in recent times and so the Slovak heat pump market stagnated in 2011. It did however grow from this position in the years 2012 - 2015. Sales were not stimulated by any form of subsidy scheme up to the end of 2015, when new incentive scheme for small renewable energy sources, where heat pumps are included, has started.

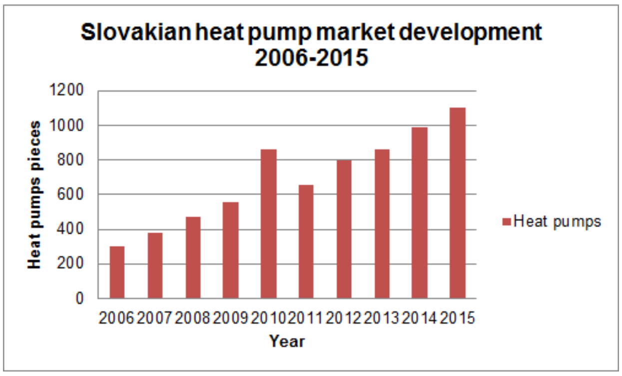

Fig. 3: Slovak heat pump market development 2006-2015 (https://www.szchkt.org/).

Economically profitable investment to heat pumps are for multi-dwelling buildings after disconnecting to central heat supply, what is in lot of cases forbidden by local authorities according to EE regulation and a domestic law for heating energy. Figure 3 shows the heat pump market development with a peak in the year 2010 and a decline in the year 2011, caused by economic situation.

It is reasonable to forecast a growing share mainly of air/water, and then brine/water, and water/water systems in the new construction sector, based on favourable climatic conditions in many locations in Slovakia. The Slovak market by type of heat pump in 2015 is given in figure 4.

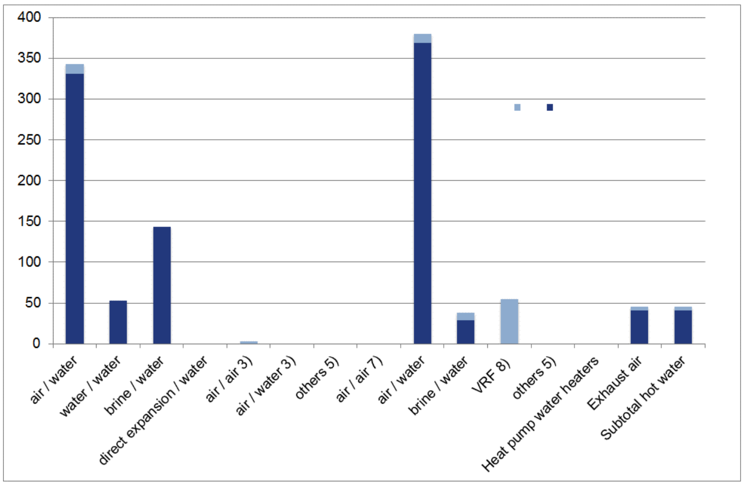

Fig. 4: Slovakian 2015 market by type of heat pump (https://www.szchkt.org/).

The numbers of geothermal heat pumps in Austria decrease since 2006, whereas the numbers of aerothermal heat pumps still increase. Aerothermal heat pumps are more popular, due to their low acquisition cost, and therefore displace the more efficient geothermal heat pumps steadily, as shown in figure 5.

For Austria more detailed data, based on administrative division are available. In Lower Austria there are reported totally 10 water-water heat-pump systems and in Burgenland 55 water-water heat-pump systems. There is a certain inaccuracy because of the area delimitation. As well, there are significant variations regarding information about water-water heat-pumps in the online water registers. The federal state of Lower Austria allows information about water issue quantity and heating capacity of the heat pumps. The federal state of Burgenland allows only information about water issue quantity. In the Lower Austrian part two heat pumps have a heating capacity of < 10 kw and eight heat pumps have a heating capacity of < 50 kw.

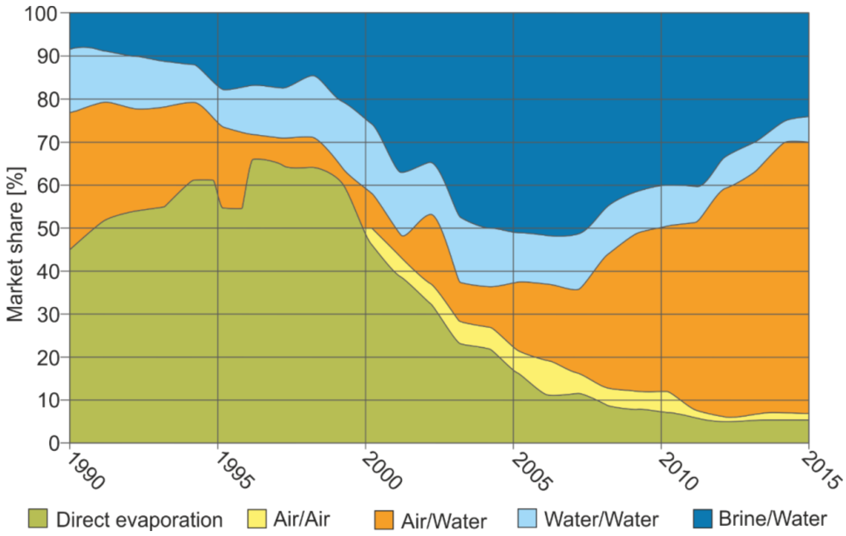

Figure 5 Development of the heat-pump market in Austria, regarding to annual sales and different heat sources. Taken from Biermayr et al. (2015), revised.

4. Main challenges and needs for shallow geothermal use

In the pilot area Bratislava region we can distinguish between two parts. The first is Bratislava representing urban area with higher density of population and building concentration (built-up area). The second part represents rural area on the side of the settlements on Austrian side. The geological and hydrogeological setup (up to investigated depth 400 m) is characterized by various types and regimes of groundwater flow.

In Slovakia there is not enough data for evaluation of the market in terms of statistics of installed heat pumps (open or closed loops). But we can say that in comparison to the other partner countries within GeoPLASMA-CE project the shallow geothermal energy market is low. The installation of the heat pumps and utilization of the shallow geothermal energy is basically connected to the new developments on the banks of the Danube river or in the suburb areas with development plans.

At Austrian side of the pilot area Bratislava the market of shallow geothermal energy is very low (in comparison with Austrian market). The close distance to Slovakia's capital city of Bratislava may require joint future shallow geothermal energy management concepts due to a possible expand of area-of settlements in Austria (transnational suburbs of Bratislava) and due to possible, trans-national conflict of uses regarding the groundwater bodies, not separated by the river Danube in the south-eastern part of the pilot area.

Concerning national challenges in Slovakia and Austria, existing shallow groundwater bodies already play or may play an important future role in agricultural irrigation (Austria) and drinking water supply (Austria and Slovakia), where main groundwater resources for Bratislava are on the right bank of the Danube river. Identification of potential conflict areas and designing sustainable shallow geothermal energy use concepts will play an important role in regions with decreasing availability of groundwater reserves, as this is the case for the eastern part of Austria.

The Bratislava pilot area (and neighbouring Austrian area including Hainburg) may also act as model example in terms of evaluation natural conditions important for geothermal potential (various geological background, hydrogeological conditions). On the other hand it will serve as a model for future management concepts of shallow geothermal energy use in the Austrian regions Lower Austria and Burgenland and in Slovakia. Management concepts in Slovakia were not compiled so far and might serve as future tool for decision making of the authorities.

5. Project objectives

The objective of the project activities in the pilot area Bratislava (and neighbouring Austrian area including Hainburg) is the support of the utilisation of shallow geothermal potential with ground source heat pumps, primary for heating and also cooling. This will be done through:

a) quantification of the shallow geothermal energy potential and

b) design of the recommendation for energy use and management strategies.

Both countries and areas have their own specifics, though harmonized approach will be set up 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
- elaboration of geoscientific models which will enable estimation of geothermal potential, description of the main processes important for water circulation and regime in the aquifers.
- elaboration of the outputs that will be accessible and easily readable by public authorities or public itself (potential maps).

Evaluation of the environment will serve as input for management of the resources. This will be done by elaboration of the tools that will include recommendations for a sustainable and efficient use of shallow geothermal energy, summarized into guidelines.

Due to the transnational character of the project GeoPLASMA-CE, the elaborated management systems will be harmonized with respect to:

- The methodological approach
- The selection of input parameters
- The derived output parameters and results
- Recommendation on energy use strategies and policies connected to that.

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