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Geothermal Development in Slovenia: Country Update Report 2010-2014

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ABSTRACT

Geothermal energy use in Slovenia has been followed on regular basis since 1994. A small but constant progress was achieved in geothermal development during the last five years in Slovenia, especially in its northeastern part, belonging to the Pannonian Basin geothermal region. New geothermal boreholes were drilled there with good characteristics and depths between 1.2 and 1.5 km. The one for greenhouse and soil heating of the tomato production has been active since 2013 at Renkovci while two wells (a production and reinjection borehole) for the planned district heating of some parts of the Murska Sobota town are currenty inactive. They all tap thermal water from the Late Miocene (Pannonian-Pontian) sand aquifer with temperatures of 55 to 65°C. Besides the Renkovci tomato company two other new direct heat users appeared, one in the eastern part in Dobova (hotel Paradiso), which uses thermal water of 56°C from the Triassic dolomitic aquifer, and Toplice Kopacnica in the western part, a rather small user, which exploit thermal water of 24°C from the Late Triassic dolomites. The installed capacity and annual energy use of the 32 users amounts to 67.1 MW_t and 636 TJ, including Renkovci. Greater progress is visible in shallow geothermics, where the number of smaller geothermal heat pump (GHP) units of typically 12 kW is around 7,500 with 74.3 MW_t capacity and 415 TJ/yr energy use (May 2014). The number of greater GHP systems with heat pumps of rated power over 20 kW is in constant increase during the last 5-8 years, resulting in 11.3 MW_t and 86.3 TJ/yr, with some 54 systems accounted for so far, however, there are at least 35 such installed systems, mostly in public or private buildings (schools, kindergardens, factories, etc) with currently unknown data. The total incomplete numbers are 153 MW_t and 1,137 TJ/yr. Drilling activity was much lower with ca 5.3 km of new boreholes, both production and exploration, including the temperature gradient boreholes. It's expected that trend of energetic renovation of older buildings and installation of the GHP units will continue in the future as one of the obligations to reach the renewable energy targets.

1. INTRODUCTION

The electricity production in Slovenia amounted to 14,544 GWh/yr, is based, as of December 2012 (Table 1), on domestic and only partly imported fossil fuels (32.3%), domestic hydropower (25.9%), nuclear power (36%), and other renewables (5.9%). Of these, the PV solar units predominate with small hydropower plants following and a certain number of other biomass facilities. Very probably it's not expected that at the present state of knowledge any electricity production from geothermal could be realistic by 2020, despite the data presented in the EGEC report (Dumas et al., 2013a) about geothermal electricity PP investigation near Murska Sobota for an EGS project by Timo ltd. Due to the lack of natural steam reservoirs, geothermal energy in Slovenia cannot be converted in Dry Steam or Flash Steam power plants into electric power. Only binary technology is promising, but it is also disputable, temporal as well as geologically. The government supports in principle the direct use of geothermal energy through different projects where few leading agencies are involved in geothermal development. Two ministries are basically involved: 1. "Ministry of Agriculture and the Environment" (MKO) for the water permits and concessions for thermal water usage for touristic purpose and heat extracting, and 2. "Ministry of Infrastructure and Spatial planning" (MzIP) for concessions for geothermal energetic source. The water permits, important for water source geothermal heat pumps, are regulated by the Environmental Agency (ARSO) of the Ministry of Agriculture and the Environment" (MKO). Some private companies and energy consulting agencies are involved in demonstration projects for greater geothermal heat pump development. The goal of appropriate ministries is also raising the general public awareness to deal more carefully with energy consumption. Leading companies and institutes involved in geothermal development are: Petrol-Geoterm Co., Geological Survey of Slovenia, and several small business enterprises. This paper describes the present status of direct heat use and development in the last five years. Geothermal energy use has been statistically followed by the Geological Survey of Slovenia on regular basis since 1994 with update reports presented at the World Geothermal Congresses (Rajver et al., 2010 and references therein). Emphasis of direct use of geothermal energy in Slovenia is on exploitation of low temperature resources for space and district heating, and for thermal spas. During the last 15 years direct use shows only a slight increase with exception of the geothermal heat pumps. The reasons depend on the locality. The problems are overexploitation of geothermal resources in some localities of the north-eastern part of the country (Kralj and Kralj, 2000a; Rman et al., 2012, Rman, 2014 and references therein), occasional technical problems, and weak incentives for efficient use of the resources. An increase of experience is evident at many direct heat users, notably with introduction of heat exchangers and heat pumps for the improvement of using the available heat in a better way, and not to discard it at a too high temperature. The geothermal (ground source) heat pump (GSHP) sector is the only one showing a significant increase. Main geothermal exploration and drilling activity took place recently in the NE part for direct use purposes. The activities were oriented in drilling new production and reinjection wells to increase and improve the direct use of geothermal heat, notably for district heating, greenhouses and touristic purposes.

2. GEOLOGY BACKGROUND, GEOTHERMAL RESOURCES AND POTENTIAL

A description of geology, resources and potential is given in the previous country updates (Rajver et al., 2010 and references therein). The territory of Slovenia lies in the convergent area of the African and Eurasian tectonic plates, consequently its geological and tectonic setting is complicated. It is subdivided into several tectonic units with different hydrogeological properties and geothermal conditions (Figure 1). In the northeast, the Mura-Zala basin (the southwestern part of the Pannonian basin) and the

Eastern Alps (include magmatic rock complex) are parts of the European plate. Predominately carbonate Southern Alps, the External and the Internal Dinarides and the Adriatic foreland represent parts of the Adriatic microplate. More information on geological aspects is described in papers by Ravnik et al. (1995), Placer (1998) and references therein. The 24 thermal (natural and captured) springs have constant temperature close to or above 20°C, with 36°C as a maximum, however, there are several drilled localities where no surface thermal manifestations existed before and the thermal water was discovered during the oil and gas drillings (Lapanje & Rman, 2009). Details about the geothermal field of Slovenia and geotectonic background are described, for example, in papers by Ravnik (1991), Ravnik et al. (1995), Rajver and Ravnik (2002) and Rajver et al. (2012). Geothermal resources in the Pannonian and Krško basins have been studied in more detail (Rajver et al., 2002; Rajver and Ravnik, 2003).

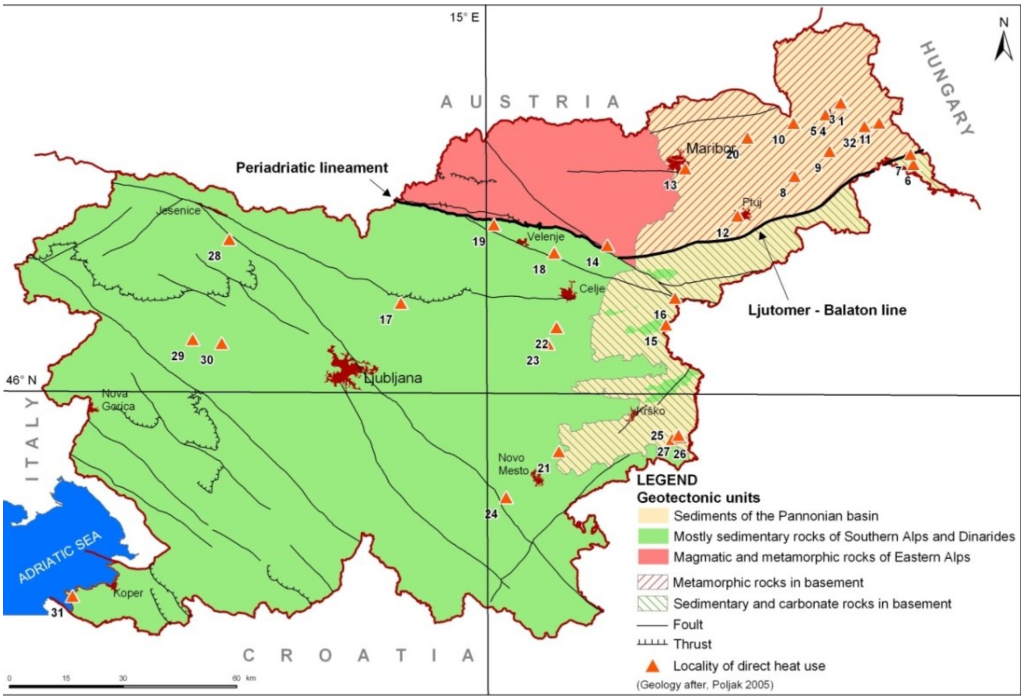

Figure 1: Generalized geological map of Slovenia with localities of direct heat use (see Table 3).

2.1 Potential for geothermal power production

Natural steam reservoirs at relatively shallow depths haven't been detected yet. In the SE part of the Pomurje area (NE Slovenia) high temperature resources are unproven but hypothetically expected in deeper fault zones in the Pre-Neogene basement. It is the area south of the Ljutomer-Balaton fault where the Pre-Neogene basement consists of clastic and carbonate rocks, expected to be more fractured in places for eventual exploitation of medium or high enthalpy geothermal resources. Geothermal and hydrogeological characteristics of the NE part of the country indicate potential geothermal resources, technically exploitable for electricity production, but only with restrictions (Rajver et al., 2012; 2013). The perspective geothermal reservoirs are:

(a) hydrothermal reservoirs in depths less than 3 km and at temperature high above 80°C: aquifers of the Lendava, Špilje and Haloze formations, NE of Murska Sobota and at Lendava.

(b) hydrothermal reservoirs in depths of 3 to 6 km and at temperature above 150°C: carbonate rocks of the Pre-Neogene basement in the Radgona-Vas tectonic half-graben and in the Boč-Ormož antiform.

(c) EGS (HDR systems) at least 4 km deep in low permeable metamorphic or magmatic rocks: the Pohorje granodiorite massif and the Pre-Neogene basement of the Mura-Zala basin.

According to the current geological knowledge these reservoirs are very limited in space. New geological investigations and geothermal wells should be targeted on finding a geothermal aquifer with a wellhead fluid temperature high above 90°C and a yield above 25 kg/s which allows the binary cycle utilization. This may also be achieved by using EGS technology. Deeper wells would be, however, needed to reach the 150°C isotherm.

2.2 Resources and potential for direct use

Some general characteristics of the geothermal resources and potential for direct use are explained, based on the division of the country into simplified tectonic units.

The northeastern area of the country has been intensively investigated in recent years within the European projects Transthermal (Lapanje et al., 2007), T-JAM (Lapanje et al., 2010; Nádor et al., 2012) and TRANSENERGY (Goetzl et al., 2012). The results give better insights in characteristics of the geothermal field and hydrogeological conditions of the Mura-Zala sedimentary basin (Rman, 2014). The area has an elevated surface heat flow density (HFD), above 100 mW/m^2, with expected temperatures above 80°C at 2 km depth east of the Maribor and Ptuj towns line (Rman et al., 2012). All production wells exploit thermal water from Neogene aquifers with exception of those in Maribor and Benedikt (No. 13 and 20, respectively in Figure 1). About 19 inactive and potential wells in the area exhibit the wellhead temperatures of 28 to 62°C, and have a total yield of 68 l/s, resulting in the ideal thermal power of 9.4 MW_t. The geothermally most utilized northeastern area that belongs to the Mura-Zala basin is filled by Neogene marine and fresh water sediments. Clays and marls predominate, with intercalations of porous sands and sandstones, where mineral, thermal and thermo-mineral waters are found. The most extensive Upper Pannonian-Pontian geothermal sandy aquifers, which are widely utilized by Hungary and Slovenia, are composed of 50 - 300 m thick sand-prone units that are found in a depth interval of about 700 - 1400 m in the interior parts of the Pannonian basin, with temperatures from 50 to 70°C (Nádor et al., 2012 and references therein).

Hydraulically connected sandy lenses of the Upper Pannonian-Pontian Mura Fm. represent the best yielding low temperature geothermal aquifer in the sedimentary basin in Slovenia, which is utilized at Banovci, Dobrovnik, Lendava, Mala Nedelja, Moravske Toplice, Murska Sobota, Petišovci, Ptuj and Renkovci (Table 3). The best production wells have flow rates at a maximum utilization of a few tens of l/s, for example in Moravske Toplice with over 30 l/s, however, the average flow rate barely exceeds 10 l/s per well. Isolated turbiditic sandstone aquifers of the Middle and Upper Pannonian Lendava Fm. are exploited at Banovci, Lendava, Mala Nedelja, Moravske Toplice and Murska Sobota in depths of 0.8 to 1.6 km (Rman et al., 2012). The share of this water with temperature as high as 68°C in the mixture produced from multiple-formations screened wells is less than 5% mostly. The rather limited Badenian to Lower Pannonian Špilje formation sandstone aquifer discharges thermomineral water rich in CO_2 and organic substances at temperatures up to 72°C.

In the SE part of Slovenia the thermal water is mostly found in the Krško sedimentary basin along its southern edge in the Mesozoic carbonate rocks beneath the Tertiary cover. A small Čatež geothermal field in the eastern part of the basin is characterized by elevated geothermal gradient (>60 mK/m). The maximum depth of the wells is 0.7 km, and they produce thermal water from Triassic dolomite with yields ranging from less than 10 l/s to several tens of l/s.

2.3 Potential for ground-source heat pumps

2.3.1 Ground - water systems (GCHPh and GCHPv)

Clastic rocks cover over half of the Slovene territory, carbonate rocks about 40%, while pyroclastic, metamorphic and crystalline rocks less than 8%. More suitable rocks for horizontal heat exchangers are: sand and sandy clay, flysch rocks such as sandy marls or loose sandstone, sandy claystone. For vertical heat exchangers the most suitable are: dolomite, dolomitic limestone and limestone, and majority of magmatic and metamorphic rocks. Figure 2 shows geological and hydrogeological potential for the GSHP applications. Shallow karstic underground is neither very favourable for vertical systems presenting the uncertainty in drilling, prediction and higher drilling costs.

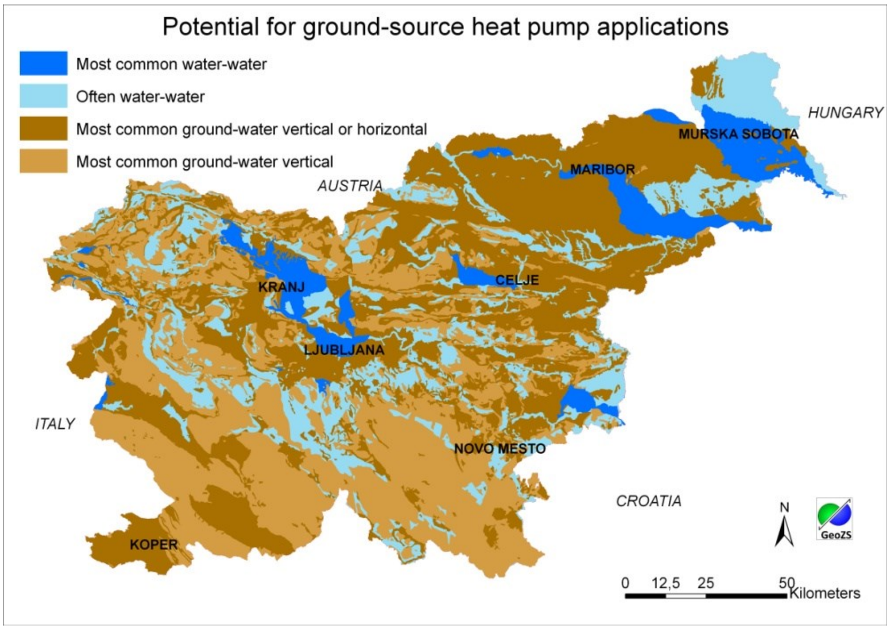

Figure 2: Potential for the GSHP applications in Slovenia (Prestor et al., 2012).

2.3.2 Water – water systems (GSHPw)

The northeastern part of Slovenia (Pannonian basin) appertains to a major groundwater basin with relatively high recharge (100 – 300 mm/year) in Quaternary and shallow Tertiary layers. The rest of the Slovene territory is of complex hydrogeological structure with very high recharge (> 300 mm/year). About 7% of the territory is covered by extensive and highly productive gravel and sand alluvial aquifers which are very favourable for wells and thus for open GSHP systems. The major cities' agglomerations are situated on these alluvial plains. The temperature of groundwater is characteristically between 10 and 15°C. Groundwater table is 2 m to 25 m deep and the water quality is rarely aggressive (see more details in Rajver et al. 2013). Individual open vertical systems can be successfully used also in the areas of inter-granular aquifers of medium hydraulic conductivity and also above the fissured aquifers of medium hydraulic conductivity (dolomitic aquifers). 35% of the territory is covered by limestone aquifers, where the groundwater accessibility is rather low and conditions not favourable for open vertical systems. Closed vertical systems are more applicable. Similar conditions are for the other 35% of territory with only minor and discontinuous aquifers (flysch layers, marl, sandstone, siltstone, claystone) where closed vertical and horizontal systems are mostly applicable. Temperature distribution at a depth of 100 m below the surface (Figure 3) shows the best conditions for GSHP systems (mostly >14°C) in the NE part, and elsewhere only average temperatures between 8 and 14°C.

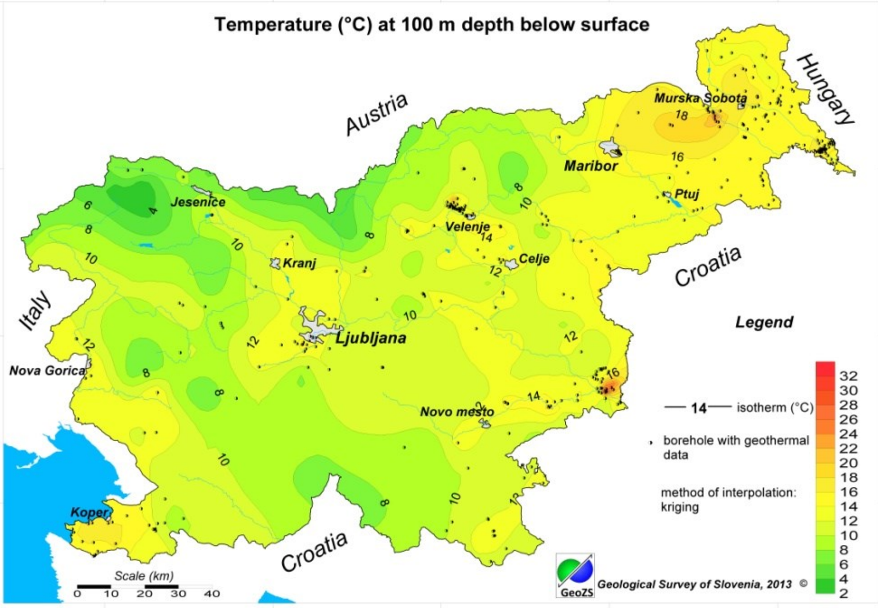

Figure 3: Temperature distribution at a depth of 100 m depth below the surface in Slovenia.

2.3.3 Thermal energy storage

Aquifer thermal energy storage systems (ATES) are weakly applied so far or not exploited at all. Very few attempts were made to explore this possibility in Slovenia up to date. Groundwater flow velocities are characteristically rather high in most alluvial aquifers. They reach the magnitude of 10 m/day which could not be very favourable for conventional ATES. Nevertheless, specific conditions should be explored locally. According to the hydrogeological setting in Slovenia and pretentiousness of ATES technology, borehole thermal energy storage (BTES) could be applied in higher extent than ATES.

3. GEOTHERMAL UTILIZATION

There is no electricity generation from geothermal resources in Slovenia up to date. Geothermal utilization is based on direct use from 53 production wells plus 3 thermal springs, implemented at 32 localities, while at 2 localities (Medijske Toplice and Vrhnika) it has been stopped for unknown time due to economic reasons (Tables 3 and 5). Four new direct users emerged since 2009, and two are located in the north-eastern Slovenia (Fig. 1 and 4). One of them uses the regional Upper Pannonian-Pontian sand and loose sandstone aquifer, while the production well at Benedikt has been finished into Paleozoic metamorphic rocks (Kralj, 2009).

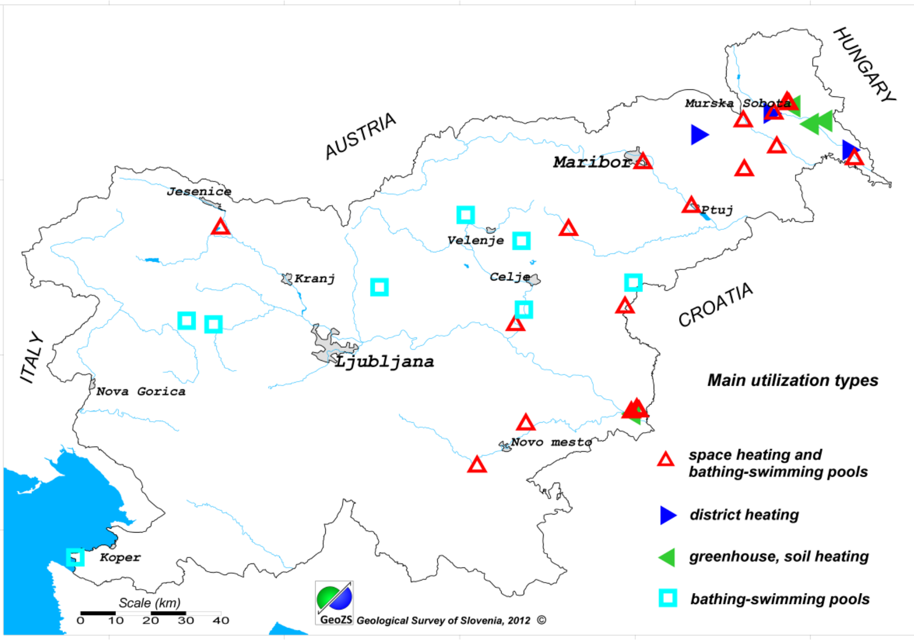

Figure 4: Main utilization types for direct heat use of geothermal energy in Slovenia (status Dec. 2013).

In Slovenia, geothermal energy is estimated to currently supply for direct heat uses and geothermal (ground-source) heat pump (GSHP) units at least 1,137 TJ/yr of heat energy with corresponding installed capacity of 153 MW_t. Of these values direct use is 67 MW_t and 636 TJ/yr, and the remainder (86 MW_t and 501 TJ/yr) are GSHPs (Table 5). The main application of use turns out to be now the GSHPs, followed by resort and spa use for space heating and for bathing and swimming (Fig. 4, 5, 6). It should be noted that the values for capacity and energy supplied by the GSHPs are approximate owing to difficulties in determining more exact number of units installed.

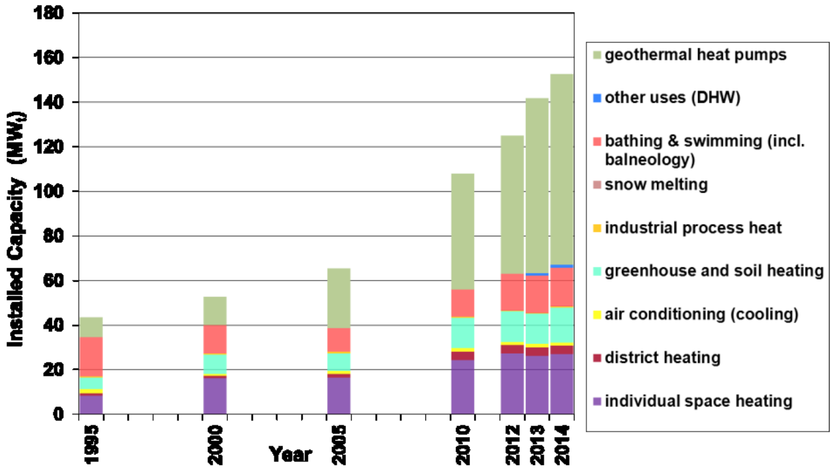

Figure 1: Geothermal direct use applications in a period 1995-2014 (total capacity in 2014: 153 MW_t).

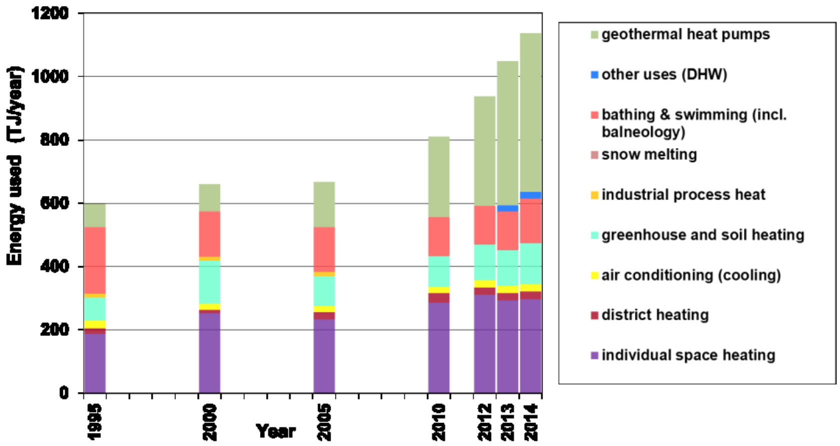

Figure 6: Geothermal direct use applications in a period 1995-2012 (total energy used in 2014: 1137 TJ).

3.1 Individual space heating and domestic hot water

Space heating is implemented at 19 localities, predominantly thermal spas and resorts, mostly through heat exchangers (e.g. Moravske Toplice, Banovci, Terme Lendava) or geothermal heat pumps (e.g. Cerkno, Hotel Diana in Murska Sobota). The GHP units usually of bigger capacity are installed only in the case of too low thermal water temperature for this type of use. The total geothermal energy used for space heating is about 297 TJ/yr as compared with 286 TJ/yr in 2009. During the last five years space heating with geothermal heat was introduced at several localities: Radenci, Mala Nedelja, Ptuj, Maribor, Bled and a new user at Dobova (Paradiso). The heating of domestic (sanitary) hot water is included at least at nine localities, and it contributes separately to 21.5 TJ/yr.

3.2 Bathing and swimming

After individual space heating at thermal resorts and spas this is the second most important type of direct use of geothermal energy. There are 18 thermal spas and health resorts, and additional 9 recreation centres (4 of them as part of the hotels' accomodation) where swimming pools with a surface area of about 45,500 m^2 and volume of 61,200 m^3 are heated by geothermal water directly or indirectly through heat exchangers or geothermal heat pumps. Wellhead water temperatures in thermal spas range from 23 to 62°C. The total geothermal energy used for bathing and swimming is estimated at 140 TJ/yr in comparison with 123 TJ/yr in 2009. At some localities improvements were achieved by better temperature range utilization, first of all at Moravske Toplice (Terme 3000), and at Banovci using heat exchangers, while at Dobrna using GHPs. New direct heat users of geothermal for swimming pools are a rather small recreation center Kopačnica in western Slovenia, and Hotel Paradiso in Dobova in eastern Slovenia, while utilization in Portorož and especially at Rimske Terme has been established again following a general reconstruction of swimming pools and resort/health centers.

3.3 District heating and snow melting

There are only three geothermal district heating (DH) systems in Slovenia at present. In Murska Sobota the residential areas (ca 300 flats with 16,000 m^2) and a new theater under Komunala authority are heated geothermally through heat exchangers, especially from October to April, while in Lendava a greater number of public buildings (school, kindergarten, etc.) and blocks of flats (total 50,000 m^2) are heated under the Petrol Geoterm Co. authority. District heating is a small scale in a village Benedikt with few public buildings (4,222 m^2) in operation since 2010. The total geothermal energy used for district heating is 23.5 TJ/yr, and is lower compared with 29.2 TJ/yr in 2009. The reason is lower use in Murska Sobota and improved monitoring of measured used energy in Lendava. As new direct use application in the country also snow melting of the sidewalks using geothermal heat from the already utilized thermal water is applied within the doublet system in Lendava, with about 0.23 TJ/yr.

3.4 Air conditioning

Air conditioning (cooling) of the hotels' spaces using geothermal energy is not well documented as it is in operation presumably only at three localities: Terme Vivat, Moravske Toplice Terme 3000 and Bled, contributing about 23.1 TJ/yr of extracted energy, compared to 20.9 TJ/yr in 2009.

3.5 Greenhouses

In eastern Slovenia the heating of greenhouses using geothermal water began in 1962 at Čatez (No. 25 in Figure 1). It was performed there by the Flowers Čatez Co. on 4.5 ha for cultivation of flowers mostly for the domestic market. At Tešanovci near Moravske Toplice, the Grede Agricultural Co. uses the already thermally spent water flowing from Moravske Toplice (Terme 3000) with 40°C to heat 1 ha of greenhouse for tomato production. At Dobrovnik, the greenhouses of 4 ha were constructed by Ocean Orchids Co. for orchids cultivation, both for domestic and foreign markets. At Renkovci, new greenhouses of 4 ha were built recently for tomato and also exotic fruit cultivation. Geothermal heat use runs there since autumn 2013. The total geothermal energy used in the greenhouses (13.5 ha) is 130.3 TJ/yr, which is much higher compared with 97 TJ/yr in 2009. At Čatež ,the Terme Čatež Co. acquired the Flowers Čatež Co. and it has all production boreholes closely spaced which exploit the same fractured Triassic dolomitic aquifer.

3.6 Industrial process heat

Industrial use of geothermal energy at Vrhnika no longer exists since Jan. 1, 2009, when the Leather Industry Co. (IUV) went into bankruptcy. It is not foreseen that the production there will commence in short term again. At Trbovlje, thermal water from two shallow boreholes is used for cooling the Lafarge Co. cement works, and therefore, is not considered as geothermal energy use. A small winter swimming pool that used thermal water before within the cement works was closed more than 7 years ago.

3.7 Geothermal heat pumps

At eight health or spa resorts and at Hotel Diana in Murska Sobota, the GHPs, typically of greater capacity (5.7 MW$_t$ altogether), are used in an open loop system for raising the thermal water temperature for further use in swimming pools and space heating or just to maintain the water temperature in swimming pools, and for DHW heating. Their contribution in used geothermal energy is already taken into account within other applications.

Geothermal energy use for space heating in small decentralized units in Slovenia is becoming more popular and widespread. The market penetration in larger scale began obviously during the last 8-10 years following some »lazy« period in the early 1990's, when there was low interest in GHPs owing to high initial costs, high price of electricity and low prices of oil and gas. The ubiquitous heat content within the uppermost part of the Earth crust is available practically everywhere in Slovenia except in the mountainous region. Technical, environmental and economic incentives can be considered advantageous for more rapid introduction of GSHP systems in the country. This is also backed by support programs from utilities and from the government through subsidies or credits. These units consist of ground-coupled closed loop heat pumps (horizontal and vertical heat collectors), or groundwater open loop heat pumps, depending on local conditions.

The exact number of GSHP units presently installed in Slovenia is difficult to estimate, since no national statistics are available. The numbers of heat pump sales give almost all the quantity for their estimation, but are difficult to get because domestic producers and numerous merchant agents of imported units are usually not willing to fork over such numbers. Currently there are about 7,500 small operational GSHP units (typical 12 kW) that extract 415 TJ/yr of geothermal heat. Of these, we estimate that 52% are open-loop systems that extract annually about 210 TJ from shallow groundwater, 40% are horizontal closed-loop (145 TJ), and 8% are vertical closed-loop systems (60 TJ). Closed-loop units together remove 205 TJ/yr from the ground, while 30 TJ/yr of heat is rejected to the ground in the cooling mode, presumably by vertical systems (Table 4). There are also greater capacity GSHP units (>20 kW) installed within at least 54 systems in public and other buildings. Of them 33 are open-loop water-water type, 18 vertical closed-loop, and 3 horizontal closed-loop systems. Capacity factor for the small GSHP units is 18%, the lowest among all the application types and for the greater units (>20 kW) is 24%, reflecting that small units usually utilize a rather narrow temperature difference (< 4 deg.) and for individual heating also the shortest time of full load operating hours, which means not more than 6 months with 12 h/day in Slovenian climate conditions, therefore usually less than 2200 h/year.

4. DISCUSSION

The distribution of capacity and annual energy use for various direct use applications as presented in Table 5 are based on data from the users and best estimates of the missing data. The total thermal capacity currently installed for direct use of geothermal energy in

Slovenia amounts to roughly 67 MWt, including GSHPs at thermal spas, but without numerous mostly small GSHP units. The annual energy use at 32 localities amounts to 636 TJ, which is by 14% higher than in 2009 (556 TJ as corrected value), which is a consequence of new direct heat users. Annual energy use (Figure 7) is slightly higher for individual space heating (26.1%) and bathing and swimming (12.3%), and considerably higher for greenhouses and soil heating (11.5%), on the other hand it is lower for district heating (2.1%) in comparison with situation five years ago. The use for industrial process heat is suspended. However, the GSHP sector exhibits the largest share (44.1%) in direct use, albeit incomplete at moment.

Considerations on high enthalpy geothermal resources in Slovenia have been initiated whether there are possibilities for electricity production in the north-eastern part (Pannonian basin) where the highest temperatures at depths of 3.5 to 4.5 km are encountered.

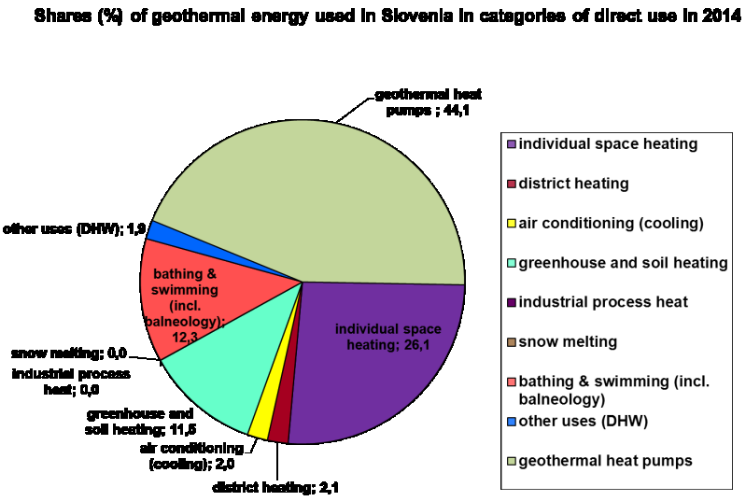

Figure 7: Shares of geothermal energy used in Slovenia in categories of direct use in 2014 (status May 2014).

The capacity of deep wells, also existing ones, is yet to be determined and tested, or new deep wells have to be drilled at appropriate localities, which have to be previously confirmed by better geophysical (seismic, microseismic, MT) investigations with a goal to create EGS.

The total number of professional personnel in geothermal activities in the period 2009-2014 (Table 7) is enlarged by a few technician-engineers at thermal spas in a previous 5-year term. The investments in geothermal (Table 8) are just approximate and incomplete, as many users don't report such data. Nevertheless, the trend was slowed down with little research and surface exploration including exploration and production drilling. Also, there was much less construction of new buildings and swimming pools at thermal resorts or spas (e.g. Kopačnica). For the past five years drilling activity was slower compared with earlier periods. So far rather incomplete data shows that at least 6 boreholes have been drilled with a total depth of 5.3 km (Table 6). Of these, 3 are geothermal gradient boreholes, 2 wells are production oriented with a total depth of 3.01 km, and one well is dedicated for reinjection in Murska Sobota (see Section 5.1).

5. RECENT DEVELOPMENTS AND FUTURE PROSPECTS

A few projects for further geothermal direct use development are planned or under way. In the NE part of the country the Petrol Geoterm Co. (in Lendava) has improved a few old oil wells into geothermal ones for aquaculture or greenhouses. The exploration wells at Janežovci near Ptuj and at Mislinjska Dobrava still wait for appropriate financial support to develop the site and to start producing.

5.1 Thermal water direct use

A doublet scheme is operational in Lendava downtown. In the north-eastern Slovenia the localities are the most vulnerable to overexploitation of thermal water as most users capture water from the same aquifer. The problem has yet to be tackled with needed care. In this sense the Murska Sobota community achieved a good success with drilling the two new boreholes (Table 6), a production (SOB-3g/12 with 1.5 km depth) and a reinjection one (SOB-4g/13 with 1.2 km depth) for enlarging the district heating purpose in the northern parts of town (Rman et al., 2012). Their testing was done in 2012/13. It showed slightly better performance in SOB-4g with the maximum flow rate of 43 l/s and wellhead temperature of 57°C (but this is planned to be a reinjection well), with ideal thermal power of 5.4 MW_t at a temperature drop of 30°C. Thermal capacity of the new doublet could reach 4 MW_t and geothermal energy use 8.8 GWh/year. It will be the second doublet system operating in the country when it becomes active. Another new exploitation drilling, a geothermal well Re-1g of almost 1.5 km depth, was completed in Renkovci at the end of 2011, and after a testing phase it is used for greenhouse heating.

European projects T-JAM and TRANSENERGY, running between 2009 and 2013, significantly contributed to a better resource assessment of NE Slovenia. It was the first time that geothermal aquifers in the Mura-Zala basin were treated as transboundary, and their potential for higher geothermal development was precisely evaluated using a unified and systematic approach of the Slovene and Hungarian as well as Austrian Geological Surveys. Within that activity, the 3D geological model of the subsurface was elaborated and new geothermal, chemical and isotopic measurements were executed. These were used to update geothermal maps of the region (Figure 8) and to set a sound hydrogeological conceptual model of the groundwater flow (Figure 9). The T-JAM project investigated the Upper Miocene porous geothermal aquifer in the Mura formation (Nádor et al., 2012), while TRANSENERGY was more focused into the Pre-Neogene carbonate and metamorphic aquifers in the sedimentary basin basement (http://transenergy-eu.geologie.ac.at/).

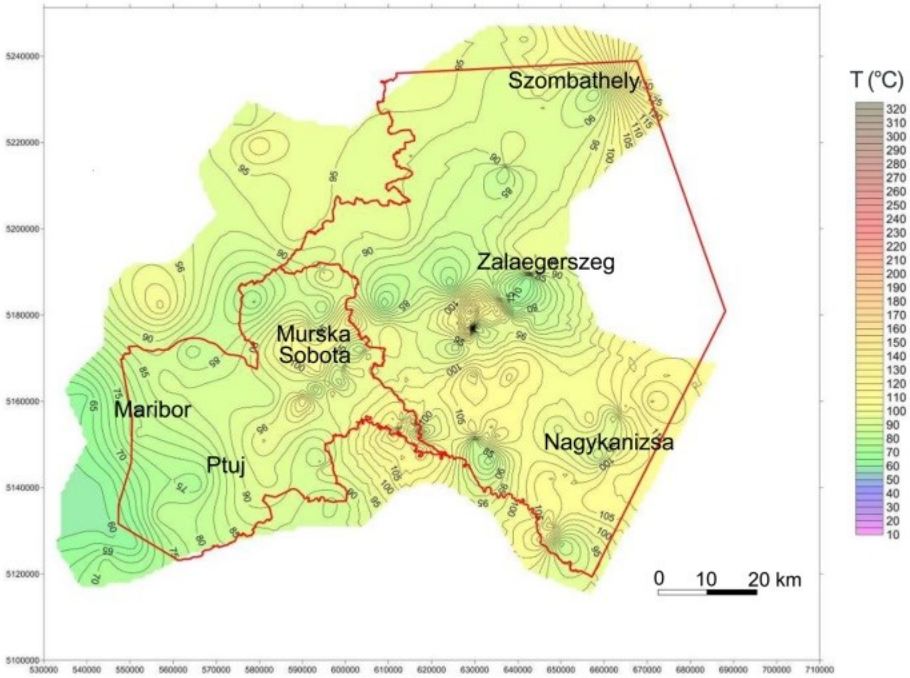

Figure 8: Temperature distribution at a depth of 2000 m below the surface (Nádor et al., 2012).

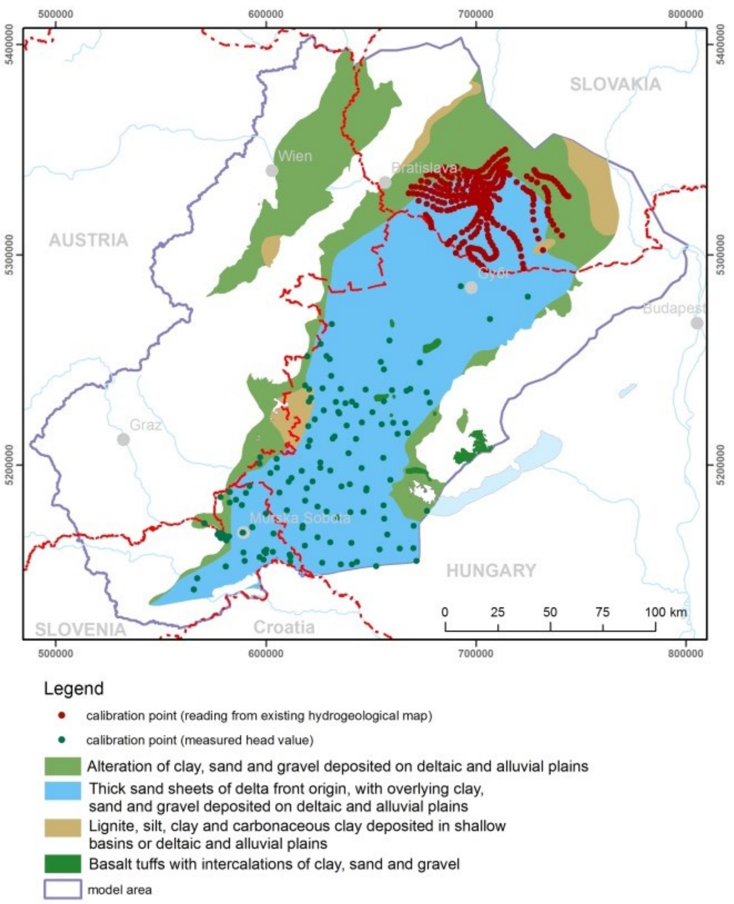

Figure 9: The extent and lithology of the Upper Miocene delta front sand as used for a supra-regional model of groundwater flow (Tóth et al., 2012).

The effects of current thermal water abstraction onto the hydraulic state of the Mura Fm. aquifer were simulated by a regional mathematical model of groundwater flow enabling calculation of different development scenarios, predictions and control of impacts (Nádor et al., 2012, Rman et al., these proceedings). Transboundary effects of abstraction from the carbonate aquifer in Korovci were tested by a pilot flow and heat model of the Bad Radkersburg-Hodoš area, plus the convection cell in Benedikt was confirmed by a local numerical model (Fuks and Janža, 2013). It was also the first time a comprehensive overview of the actual thermal water utilization was made (Rman et al., 2013), as well as comparison of the EU, national and local legislation and its effects on the observed geothermal development (Prestor et al., 2013). The research showed that currently exploited aquifers were highly stressed and had to be carefully monitored and effectively managed to enable their further development.

Trends in geothermal are focused on enhancing the cascade direct use, lowering emitted thermal water temperature, promoting higher efficiency of installed capacity for direct use, effective problem solutions, regarding thermal water scaling and degassing, as well as performing new research for potential geothermal sites. As the number of users increases, interference between them has already been noticed. Besides, increased demand for thermal water from the same aquifers causes negative quantitative trends, and potential disputes between nearby users. Some direct heat users in northeastern Slovenia have been monitored for groundwater level, temperature, yield, and chemical composition of thermal water since 2009 by a research monitoring network (Rman, 2014), but national monitoring is not yet operational. Reinjection should become obligatory and also nationally supported in order to preserve the existent capacities of thermal water, as the doublet system proves to be effective in Lendava.

The EGEC market report shows the planned extension to about 7 geothermal DH systems in Slovenia by 2016 (Dumas et al., 2013b). The table "planned GeoDH plants" on page 68 therein presents some new possible developments in the country, e.g. extensions at Murska Sobota and Benedikt with 3.3 and 3 MW_t, respectively, and new plants at Turnišče and Ormož. We are not confident about reality of the latter especially Ormož, as the latest exploration well there was not positive.

5.2 Ground source heat pumps

There are several projects focused on promotion and fostering of utilization of shallow geothermal sources:

(a) Geo.Power (Geothermal energy to address energy performance strategies in residential and industrial buildings, Programme: INTERREG IVC), already concluded.

(b) Ground-Med (Advanced ground source heat pump systems for heating and cooling in Mediterranean climate, Programme: Seventh Research Framework Programme),

(c) Legend (Low Enthalpy Geothermal ENergy Demonstration cases for Energy Efficient building in Adriatic area, Programme: IPA Adriatic) and

(d) GeoSEE (Innovative uses of low-temperature geothermal resources in South East Europe, Programme: target 3 – SouthEast Europe).

The project Ground-Med concerns the development of the advanced generation of GSHP systems, aiming to deliver heating and cooling to buildings with a measured year round seasonal performance factor (SPF) above 5 (Mendrinos et al., 2010). The Ground-Med technology is demonstrated and monitored at the demo buildings of South Europe, and of them is a Municipal Hall in Benedikt (No. 20 in Fig.1) where a GSHP unit is coupled to three borehole heat exchangers (BHEs) of total length 390 m. The system provides heating and cooling to the whole building.

Application of larger and more advanced systems is evident by good practices of GSHPs in the last years, as for example:

The Pipistrel Research & Development building (footprint 2,400 m^2) in Ajdovscina (W Slovenia) uses GCHP and BTES in a highly advanced and sophisticated technology. The building incorporates BHEs in symbiosis with a large geothermal accumulation field. The solar power plants combined with a cogeneration module covers all energy needs of the building, electricity and thermal energy conditioning included. The BHEs placed around the building are the primary source of thermal energy. A total of 1,200 meters of vertical BHEs provide approximately 36 kW of thermal energy. The geothermal accumulation field is a ground collector which functions as a storage for exchange and deriving of thermal energy at rate of 25 W/m^2. The accumulation field measures 5,000 m^3 and is placed underneath the whole building in the form of 4 collectors each 250 m^2 in footprint. The BHEs are connected to the geothermal accumulation field so it is also possible to run the system without using the heat pump (HP) on days when pumping the heat transfer medium around the building suffices. Spare heat is accumulated inside the geothermal accumulation field. As requirements for the higher or lower temperature of the medium arise, the HP is activated by the system automatically. A rough estimate for yearly savings of energy is 95,000 kWh. The settlement "15. maj" in Koper comprises three apartments buildings with privately owned apartments (67 apartment units) and an office building. The vertical structural piles /deep foundation/ down to 40 meters depth are equipped with heat exchangers and consist of a total of 50,000 meters of vertical geothermal pipes that provide a capacity of approximately 340 kW.

As regard to GSHPs contribution the EGEC market report (Dumas and Sanner, 2013) showed some strange numbers for Slovenia to our opinion, more exactly too high values for renewable heat produced in 2011-2012 by GSHPs (graph 6 therein). Also data after EurObserv'ER 2013 are not realistic in table on page 43 therein, namely the production of about 25 ktoe/yr from 4,669 GSHP units in 2012 is too high.

6. CONCLUSIONS

Increasing contribution of direct use from thermal water is evident, about 16 TJ (0.38 ktoe) every year, and estimated GSHP market growth is rising for about 49 TJ every year in the last 5-year period. Actual (May 2014) contribution from geothermal energy is assessed to be 636 TJ from thermal water direct use and 501 TJ from GSHPs, all together 1,137 TJ (27.2 ktoe). Nevertheless, target values from NREAP-SI 2010 (in: Rajver et al., 2013) are still far distant and a lot of effort will be needed in the next programming period 2014 - 2020.

The years 2009 and 2012 were special milestones for the country's natural resources management, when the pressures and impacts had to be evaluated, significant water management issues had to be identified, and program of measures designed and then implemented, all in the frame of the Water Framework Directive (common EU water policy). We were faced with ample lack of data and information that are needed to reveal the environmental status of geothermal groundwater resources, to set the environmental goals, to set the critical points when the additional or supplementary measures would have to be implemented and to set up the sustainable management of these resources. For the first time, neighbouring countries (Slovenia, Austria and Hungary) discussed about the management of the geothermal resources that appertain to the common cross border sedimentary basin.

Activities in the last years revealed deteriorating status of thermal water resources at different locations and also negative trends at a regional level in northeastern and eastern parts of Slovenia. Negative trends were observed also on individual localities in other neighbouring countries. It was recognized that the common understanding of natural systems extending across the state borders was essential for sustainable transboundary resources management. In the frame of the above mentioned projects, very important progress was made where common characterization of actually the most important cross border geothermal reservoirs was effectuated on the high expert level. This is the basis for self-confidence and encouragement to develop these resources till 2020 following both, energy and environmental goals. We can conclude that without these activities any further development of cross border thermal reservoirs would be highly unpredictable or unsecure. In the next programming period 2014 – 2020 we can expect successful development towards common transboundary management.

Further development in the next programming period should provide best practices of doublet technologies in the Pannonian basin sediments, monitoring and reporting and also benchmarking of sustainability of the resources managements. Supporting the research and development activities focused on reinjection technology/well completion in Neogene intergranular aquifers of the Pannonian basin is highly expected.

REFERENCES

Dumas, P. and Sanner, B.: Geothermal Heat Pumps. Analysis of Shallow Geothermal Market in Europe. EGEC market report 2013/2014, third ed. (2013), 34-45.

Dumas, P., Angelino, L., Boissavy, C.: Geothermal District Heating. Analysis of Geothermal District Heating market in Europe. EGEC market report 2013/2014, third ed. (2013b), 21-33.

Dumas, P., Angelino, L., Uhde, J. and Bertani, R.: Geothermal Electricity. Analysis Geothermal Electricity market in Europe. EGEC market report 2013/2014, third ed. (2013a), 7-20.

Fuks, T., and Janža, M.: Utilization potentials of the low-enthalpy geothermal aquifer of the Bad Radkersburg – Hodoš pilot area – based on 3D modelling results of the Transenergy project, *Proc. of the European Geothermal Congress 2013*, Pisa, Italy (2013), 1-10.

Goetzl, G., Zekiri, F., Lenkey, L., Rajver, D. and Svasta, J.: Summary report: Geothermal models at Supra-Regional Scale for Transenergy project, *MAFI, GBA, GeoZS, SGUDS*, (2012), available on http://transenergy-eu.geologie.ac.at/.

Kralj, P. and Kralj, P.: Overexploitation of geothermal wells in Murska Sobota, northeastern Slovenia, *Proc. of the World Geothermal Congress 2000*, Kyushu-Tohoku, Japan, (2000a), paper #0434, 837-842.

Kralj, P.: Three years of Benedikt geothermal heating system - stage 1 operation, in: International geothermal days Slovakia 2009, Conference and summer school, Session 2: Geothermal district heating projects, (2009), 1-5.

Lapanje, A., Baek, R., Budkovič, T., Domberger, G., Goetzl, G., Hribernik, K., Kumelj, Š., Letouze, G., Lipiarski, P., Poltnig, W. and Rajver, D.: Geothermal resources of northern and north-eastern Slovenia, *RRA Koroška*, *GeoZS*, Dravograd, Ljubljana, (2007), 126 p.

Lapanje, A. and Rman, N.: Thermal and thermomineral water, in: The geology of Slovenia, Pleničar, M., Ogorelec, B. and Novak, M. (Eds.), *Geological Survey of Slovenia*, Ljubljana, (2009), 553-560.

Lapanje, A., Rajver, D., Székely, E., Kumelj, Š., Mozetič, S., Juhász, I., Bányai, P., Tóth, L. and Hamza, I.: Review of geothermal energy utilization in north-eastern Slovenia and south-western Hungary, *GeoZS*, *MAFI*, (2010), available on http://www.t-jam.eu/.

Mendrinos, D., Karytsas, C. and Rosca, M.: The European project Ground-Med "Advanced ground source heat pump systems for heating and cooling in Mediterranean climate". *Proc. of the World Geothermal Congress 2010*, Nusa Dua, Bali, Indonesia (2010), paper #2912, 1-7.

Nádor, A., Lapanje, A., Tóth, G., Rman, N., Szöcs, T., Prestor, J., Uhrin, A., Rajver, D., Fodor, L., Muráti, J. and Székely, E.: Transboundary geothermal resources of the Mura-Zala basin: a need for joint thermal aquifer management of Slovenia and Hungary, *Geologija*, **55/2**, Ljubljana, (2012), 209-224. doi:10.5474/geologija.2012.013

Placer, L.: Contribution to the macrotectonic subdivision of the border region between Southern Alps and External Dinarides. *Geologija*, **41**, (1998), 223-255.

Prestor, J., Rajver, D., Pestotnik, S. and Lapanje, A.: Low-temperature geothermal energy. Inexhaustible energy source just below our house (in Slovene), *Geological Survey of Slovenia*, Ljubljana, (2012), booklet.

Prestor, J., Nádor, A., Lapanje, A., Rman, N., Szőcs, T., Černák, R., Marcin, D., Benkova, K., Götzl, G., Weibold, J., and Bruestle, A.-K.: A comprehensive overview on the existing regulatory and financial barriers on geothermal energy utilization in Austria, Hungary, Slovakia and Slovenia. *Proc. of the European Geothermal Congress 2013*, Pisa, Italy (2013), 1-14.

Rajver, D., and Ravnik, D.: Geothermal pattern of Slovenia-enlarged data base and improved geothermal maps. *Geologija*, **45/2**, (2002), 519-524.

Rajver, D., Ravnik, D., Premru, U., Mioc, P., Kralj, P.: Slovenia. In: *Atlas of Geothermal Resources in Europe*, S. Hurter & R. Haenel (Eds.), - European Commission, Research Directorate-General, Publ.No. 17811, Luxembourg, 92 p., 89 plates, (2002).

Rajver, D., and Ravnik, D.: Geothermal characteristics of the Krsko basin, Slovenia, based on geophysical research. *Phys. Chem. Earth*, **28**, (2003), 443-455.

Rajver, D., Lapanje, A. and Rman, N.: Geothermal development in Slovenia: Country update report 2005-2009. *Proc. of the World Geothermal Congress 2010*, Nusa Dua, Bali, Indonesia (2010), paper #0130, 1-10.

Rajver, D., Prestor, J., Lapanje, A. and Rman, N.: Geothermal energy use, Country update for Slovenia. *Proc. of the European Geothermal Congress 2013*, Pisa, Italy (2013), 1-17.

Rajver, D., Lapanje, A. and Rman, A.: Possibilities for electricity production from geothermal energy in Slovenia in the next decade, *Geologija*, **55/1**, Ljubljana, (2012), 117-140. doi:10.5474/geologija.2012.009

Ravnik, D.: Geothermal investigations in Slovenia (in Slovene, with English summary). *Geologija*, **34**, (1991), 265-301.

Ravnik, D., Rajver, D., Poljak, M., and Zivcic, M.: Overview of the geothermal field of Slovenia in the area between the Alps, the Dinarides and the Pannonian basin. *Tectonophysics*, **250**, (1995), 135-149.

Rman, N., Lapanje, A., Rajver, D.: Analysis of thermal water utilization in the northeastern Slovenia, *Geologija*, **55/2**, Ljubljana, (2012), 225-242. doi:10.5474/geologija.2012.014.

Rman, N.: Analysis of long-term thermal water abstraction and its impact on low-temperature intergranular geothermal aquifers in the Mura-Zala basin, NE Slovenia, *Geothermics*, **51**, (2014), 214-227.

Rman, N., Gál, N., Marcin, D., Benkova, K., Weilbold, J., Schubert, G., Fuks, T., Rajver, D., Lapanje, A., and Nádor, A.: Current and future trends in geothermal energy utilization in the western part of the Pannonian basin, *Proc. of the European Geothermal Congress 2013*, Pisa, Italy (2013), 1-14.

Tóth, G., Rotár-Szalkai, Á., Kerékgyártó, T., Teodóra Szőcs, Gáspár, E., Lapanje, A., Rman, N., Svasta, J., Černak, R., Remsik, A., Schubert, G., Berka, R., and Goetzl, G.: Supra-regional hydrogeological report (http://transenergy-eu.geologie.ac.at/): Budapest, Ljubljana, Vienna, Bratislava, MFGI, GeoZS, GBA, SGUDŠ (2012), 1-67.

STANDARD TABLES

TABLE 1. PRESENT AND PLANNED PRODUCTION OF ELECTRICITY

	Geothermal		Fossil Fuels		Hydro		Nuclear		Other Renewables (specify)		Total	
	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr
In operation in December 2012			1258	4691	1142	3768	696	5232	486	853	3582	14544
Under construction in December 2014												
Funds committed, but not yet under construction in December 2014												
Estimated total projected use by 2020												

Remark: One half of the Nuclear Gross Production goes to Croatia.
Legend:
Capacity: Net Power of plants
Gross Production: production on generator
Other Renewables: small HydroElectric (mostly < 10 MW), solar (PV and others), biomass (only those not included under Fossil Fuels), wind
Data source: Public agency of Republic of Slovenia (july, 2013): Report on state in a field of energetics in Slovenia in 2012.

TABLE 3. UTILIZATION OF GEOTHERMAL ENERGY FOR DIRECT HEAT AS OF 31 DECEMBER 2014 (other than heat pumps)

[1] I = Industrial process heat; H = Individual space heating (other than heat pumps)
C = Air conditioning (cooling); D = District heating (other than heat pumps)
A = Agricultural drying (grain, fruit, vegetables); B = Bathing and swimming (including balneology)
F = Fish farming; G = Greenhouse and soil heating
K = Animal farming; O = Other (please specify by footnote)
S = Snow melting

[2] Enthalpy information is given only if there is steam or two-phase flow

[3] Capacity (MW_t) = Max. flow rate (kg/s)[inlet temp. (^oC) - outlet temp. (^oC)] x 0.004184 ($MW = 10^6$ W)
or = Max. flow rate (kg/s)[inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg)] x 0.001

[4] Energy use (TJ/yr) = Ave. flow rate (kg/s) x [inlet temp. (^oC) - outlet temp. (^oC)] x 0.1319 ($TJ = 10^{12}$ J)
or = Ave. flow rate (kg/s) x [inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg)] x 0.03154

[5] Capacity factor = [Annual Energy Use (TJ/yr)/Capacity (MWt)] x 0.03171
Note: the capacity factor must be less than or equal to 1.00 and is usually less, since projects do not operate at 100% of capacity all year.

Note: please report all numbers to three significant figures.

Locality	Type[1]	Maximum Utilization					Capacity[3]	Annual Utilization		
		Flow Rate	Temperature (^oC)		Enthalpy[2] (kJ/kg)			Ave. Flow	Energy[4]	Capacity
		(kg/s)	Inlet	Outlet	Inlet	Outlet	(MWt)	(kg/s)	(TJ/yr)	Factor[5]
1 Moravske Toplice Terme3000	H,C,B	87	61,2	15			10,61	30,16	98,06	0,29
2 Tesanovci	G	27,8	40	30			1,16	8,33	11	0,30
3 Moravske Toplice Vivat	H,C,B,O	21	58	26			2,82	5,44	23,86	0,27
4 Murska Sobota, H Diana	H,B,O	6,5	43	22			0,59	5,01	13,68	0,73
5 Murska Sobota, Komunala	D,B	14	49	42,5			0,94	6,45	6,34	0,21
6 Lendava Terme	H,B	14	59	30			1,49	6,36	22,46	0,48
7 Lendava town	D,S	25	66	46			2,75	6,79	18,15	0,21
8 Mala Nedelja	H,B,O	22	48,4	27			1,69	7,26	17,31	0,32
9 Banovci	H,B	23,5	61,8	15			3,78	3,52	10,5	0,09
10 Radenci	H,B	6,5	42	28			0,38	0,61	1,11	0,09
11 Dobrovnik	G	30	62	15			5,90	5,52	34,22	0,18
12 Ptuj	H,B,O	23	41	29			1,16	13,71	18,44	0,51
13 Maribor	H,B,O	1,5	39	13			0,16	0,9	3,14	0,61
14 Zrece	H,B	27	30,7	25,7			0,57	15	9,89	0,55
15 Podcetrtek Olimia	H,B,O	17,2	38,8	26			0,92	16,7	22,94	0,79
16 Rogaska Slatina	B	10,5	32	28			0,18	0,31	0,16	0,03
17 Snovik	B	19	26,5	22,5			0,32	5,8	3,06	0,31
18 Dobrna	B	12	35,9	17			0,97	2,78	7,32	0,24
19 Topolsica	B	38,1	32	28			0,64	5,53	2,92	0,15
20 Benedikt	D	10	72	55			0,71	2,1	3,05	0,14
21 Smarjeske Toplice	H,B,O	33,6	32,7	25			1,08	15,21	14,05	0,41
22 Lasko	B	18	33	29			0,30	8,84	3,5	0,37
23 Rimske Terme & Aqua Roma	H,B,O	18	39,8	21,8			1,49	0,65	3,35	0,07
24 Dolenjske Toplice	H,B	30	32	24			1,15	14,44	14,28	0,39
25 Terme Catez & greenhouses	H,G,B	140	58,6	29			17,57	61	193,63	0,35
26 Dobova Paradiso	H,B	15	56	20			2,26	9,7	26,97	0,38
27 Dobova AFP	H,B	10	63	38			1,05	7	23,08	0,70
28 Bled, Golf & Park, GH Toplice	H,C,B	21	19,5	17,1			0,21	8,08	4,42	0,68
29 Cerkno	B,H,O	30	27,6	16			1,30	5,7	7,78	0,19
30 Kopacnica	B	6,5	23,7	22,5			0,03	0,6	0,10	0,09
31 Portoroz	B	0,83	23	15			0,03	0,59	0,62	0,71
32 Renkovci	G	17	60	30			2,13	5	16,5	0,25
Vrhnika	I	12,4	21,9	15	not in use since Jan. 2009		0,36			0,00
Medijske Toplice	H,B	35	23	20	not in use since Nov. 2009		0,42			0,00
TOTAL		822,9					67,1	285,1	635,9	0,30

O = Other (domestic or sanitary hot water)

TABLE 4. GEOTHERMAL (GROUND-SOURCE) HEAT PUMPS AS OF 31 DECEMBER 2014

This table should report thermal energy used (i.e. energy removed from the ground or water) and report separately heat rejected to rejected to the ground in the cooling mode as this reduces the effect of global warming.

1) Report the average ground temperature for ground-coupled units or average well water or lake water temperature for water-source heat pumps

2) Report type of installation as follows: V = vertical ground coupled (TJ = 10^{12} J)
H = horizontal ground coupled
W = water source (well or lake water)
O = others (please describe)

3) Report the COP = (output thermal energy/input energy of compressor) for your climate

4) Report the equivalent full load operating hours per year, or = capacity factor x 8760

5) Thermal energy (TJ/yr) = flow rate in loop (kg/s) x [(inlet temp. (°C) - outlet temp. (°C)] x 0.1319
or = rated output energy (kJ/hr) x [(COP - 1)/COP] x equivalent full load hours/yr

Note: please report all numbers to three significant figures

Locality	Ground or Water Temp. (°C)[1)]	Typical Heat Pump Rating or Capacity (kW)	Number of Units	Type[2)]	COP[3)]	Heating Equivalent Full Load Hr/Year[4)]	Thermal Energy Used (TJ/yr)	Cooling Energy (TJ/yr)
open loop:	water temp:	small units: 6 to 15 kW						
water-water	3 to 15	typical 12 kW	3900	W	2.5 to 6.0	1000 - 2500	210	
closed loop:	ground temp:	small units: 3 to 15 kW						
ground coupled	0 to 13	typical 11-12 kW	3000	H	2.9 to 4.5	1200 - 2500	145	
ground coupled	3 to 15		600	V	3.0 to 4.9	1800 - 2000	60	
small units **Total**		**total: 74.3 MWt**	7500				**415**	30
								to be determ. later
		large units:						
		typical > 20 to 100 kW	at least 53		SPF only:	1000 - 6500	**86,3**	
		maximum: 800 kW	systems with		2.8 to 5.0			to be determ.
		total: 11.34 MWt	1 or more unit					later
TOTAL		86 MW	7500 small min. 53 large	W,H,V	2.5 to 6.0	1000 - 6500	501,3	30

TABLE 5. SUMMARY TABLE OF GEOTHERMAL DIRECT HEAT USES AS OF 31 DECEMBER 2014

1) Installed Capacity (thermal power) (MWt) = Max. flow rate (kg/s) x [inlet temp. (°C) - outlet temp. (°C)] x 0.004184
or = Max. flow rate (kg/s) x [inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg)] x 0.001

2) Annual Energy Use (TJ/yr) = Ave. flow rate (kg/s) x [inlet temp. (°C) - outlet temp. (°C)] x 0.1319 (TJ = 10^{12} J)
or = Ave. flow rate (kg/s) x [inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg) x 0.03154

3) Capacity Factor = [Annual Energy Use (TJ/yr)/Capacity (MWt)] x 0.03171 (MW = 10^6 W)
since projects do not operate at 100% capacity all year

Note: please report all numbers to three significant figures.

Use	Installed Capacity[1)] (MWt)	Annual Energy Use[2)] (TJ/yr = 10^{12} J/yr)	Capacity Factor[3)]
Individual Space Heating[4)]	27,0	297,2	0,35
District Heating [4)]	3,72	23,5	0,20
Air Conditioning (Cooling)	1,57	23,1	0,47
Greenhouse Heating	15,7	130,3	0,26
Fish Farming			
Animal Farming			
Agricultural Drying[5)]			
Industrial Process Heat[6)]	0,36	0	0,00
Snow Melting	0,03	0,23	0,27
Bathing and Swimming[7)]	17,3	140,1	0,26
Other Uses (domestic HW)	1,43	21,5	0,48
Subtotal	67,10	635,9	0,30
Geothermal Heat Pumps	85,64	501,3	0,19
TOTAL	152,74	1137,2	0,24

4) Other than heat pumps
5) Includes drying or dehydration of grains, fruits and vegetables
6) Excludes agricultural drying and dehydration
7) Includes balneology

TABLE 6. WELLS DRILLED FOR ELECTRICAL, DIRECT AND COMBINED USE OF GEOTHERMAL RESOURCES FROM JANUARY 1, 2010 TO DECEMBER 31, 2014 (excluding heat pump wells)

1) Include thermal gradient wells, but not ones less than 100 m deep

Purpose	Wellhead Temperature	Number of Wells Drilled				Total Depth (km)
		Electric Power	Direct Use	Combined	Other (thermal gradient)	
Exploration[1)]	(all)		0		3	1,08
Production	>150° C					
	150-100° C					
	<100° C		2			3,01
Injection	(all)		1			1,20
Total			3		3	5,29

TABLE 7. ALLOCATION OF PROFESSIONAL PERSONNEL TO GEOTHERMAL ACTIVITIES (Restricted to personnel with University degrees)

(1) Government
(2) Public Utilities
(3) Universities
(4) Paid Foreign Consultants
(5) Contributed Through Foreign Aid Prograr
(6) Private Industry

Year	Professional Person-Years of Effort					
	(1)	(2)	(3)	(4)	(5)	(6)
2010		3	1			11
2011		3	1			11
2012		3	1			10
2013		3	1			10
2014		3	1			11
Total		15	5			53

TABLE 8. TOTAL INVESTMENTS IN GEOTHERMAL IN (2014) US$

Period	Research & Development Incl. Surface Explor. & Exploration Drilling	Field Development Including Production Drilling & Surface Equipment	Utilization		Funding Type	
			Direct	Electrical	Private	Public
	Million US$	Million US$	Million US$	Million US$	%	%
1995-1999	1.94	4.08	13.33		99	1
2000-2004	2.56	4.43	45.7		96	4
2005-2009	8.5	7.89	53.1		90	10
2010-2014	2	4.0	20.0		92	8