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D.5.2.1 Summary report on the current status of thermal water uses

December 2017

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Authors: Nina Rman (GeoZS) with the help of (alphabetically): László Ádám (Mannvit), Ivana Bobovečki (ZARA), Željka Brkić (HGI), Krisztina Demény (MBFSZ), Radu Farnoaga (IGR), Nora Gal (MBFSZ), Boban Jolović (GSRS), Katja Koren (GeoZS), Mladen Kuhta (HGI), Andrej Lapanje (GeoZS), Ozren Larva (HGI), Tamara Marković (HGI), Tamás Medgyes (MBFSZ), Enikő Mérész (Mannvit), Dejan Milenić (FMG), Ágnes Rotár-Szalkai (MBFSZ), Natalija Samardžić (FZZG), János Szanyi (InnoGeo), Teodóra Szőcs (MBFSZ), Dragana Šolaja (HGI), Filip Šoštarić (ZARA), Eszter Tihanyi-Szép (MBFSZ), Nenad Toholj (GSRS), Anca-Marina Vijdea (IGR), Ana Vranjes (FMG).

Maps were elaborated by Simon Mozetič (GeoZS).

DARLINGe project is co-funded by the European Regional Development Fund (1612249.99 €) and by the Instrument for Pre-Accession Assistance II (534646.60 €) under Grant Agreement no DTP1-099-3.2.

Contents

1. Introduction

The main aim of the DARLINGe project is to support the enhanced and efficient use of geothermal energy. To set the project targets and to evaluate the progress, we need quantification of the status quo, and not to exaggerate or underestimate the possibilities for further development. The question we want to answer in the long-term is – how much capacity is available for new, more efficient or larger extraction of geothermal energy. In order to answer this question, a survey must be carried out which interprets well characteristics, type and efficiency of thermal water use, waste water management including reinjection and possible environmental impacts of current uses.

A minimum thermal water outflow temperature of 30 °C was selected as a threshold value usable for heat extraction and this analysis. Data was collected based on unified code-lists to enable a rapid and transparent comparison among the target countries. Current utilization data from 6 countries, covering the project area, were collected: Hungary, Slovenia, Croatia, Serbia, Bosnia and Herzegovina and Romania. In 2018, a detailed survey will be carried out in the pilot areas to complement this dataset.

The main aims of this report are to:

- Identify sites where geothermal objects produce thermal waters with 30 °C and above. In other words, regions with proven high geothermal potential which may help to reduce geological risk of new investments,
- Provide a comparison on current utilization practice among countries and reservoirs,
- Identify how different thermal waters are utilized with emphasis on geothermal heat production,
- Provide an inventory of existing databases on exploitation of geothermal objects.

These results will serve to:

- Identify regions where increased use of geothermal energy at existing sites is worth considering for future uses,
- Plan more detailed investigation on exploitation practice in pilot areas (to learn about the risks of overexploitation and operational issues),
- Develop an indicator-based benchmark evaluation of current uses,
- Educate stakeholders on the need for careful planning of maintenance and new investments.

The gathered data will be transferred and stored in the project database.

2. Methodology

2.1. Collected parameters

Development of the methodology runs simultaneously with the WP 4.1 DARLINGe data model (common database) as data collected will be stored in this database. Over 50 parameters were collected per each geothermal object (Table 1), which is either a natural phenomenon – a thermal spring, or a man-made object – a geothermal well. The selection criteria were:

- Objects have to be able to produce thermal waters with 30 °C and above. Data collection in Hungary and Serbia was also carried out for wells with now outflowing temperatures lower than 30 °C, but which had temperature of 30 °C or above at the time of their drilling.

- Objects have to have active production or reinjection of thermal water. Those wells were also included in this overview, which do not yet hold a permit for thermal water exploitation.
- Inactive wells were included in two cases: if they have been granted a permit for thermal water exploitation, or if they belong to a national monitoring network for geothermal aquifers, as for example in Hungary.

One or more geothermal objects in the same utilization system can be situated at each user site. One user (company) can manage several sites. For example, a Slovenian user named Sava Turizem d.d. manages several sites e.g. Terme Lendava with three wells in Lendava, Sava Hoteli Bled with a spring and two wells in Bled etc. Most parameters are object-specific; however, some are characteristic to the user site, e.g. average temperature of emitted waste water, waste water treatment and cascade use, which will be collected only in pilot areas. Several examples occur also where fluid from one object is used by two or more users, e.g. Sava Turizem d.d. Terme 3000 and Grede Tešanovci in Slovenia, and Terme d.o. o. Gračanica and Messer BH Gas d.o.o Sarajevo - podružnica Sočkovac in Bosnia and Hercegovina.

The reference year for which data was collected is mostly 2015, as in most countries at least one year is needed to update the national databases (if they exist). However, in some countries more recent data were available:

- In Croatia most of collected data refers to year 2015 and some (such as type of utilization, does it cascade system exist etc.) was collected in 2017 during interviews.
- In Federation of Bosnia and Herzegovina, data on currently exploited amounts of thermal water refer to the year 2015, except for well EB-1 Bosnaprodukt-Gradačac where the given amount is estimated. Data on licensed maximum annual production (m^3/year and l/s) relate to A+B reserves that were verified (licensed) in different years (for B-6 Gradačac in 2017, PEB-4 Ćelahuša in 2015, BZ-1 Mliječna industija 99 in 2014).
- In Hungary, about 90% of the data refer to 2015, while 66 wells (about 10%) refer to 2016 and 2017. In this latter case data were provided by the regional Water Directorates and by users.
- In Romania, most recent geothermal documentation was compiled at an authority but information on flow rate, licenced annual production and reinjection quantity and discharge are confidential, and therefore were not provided.
- In Serbia, collected data range is various as consequence of "closed" access to monitoring data accompanied by poor users response at the time of writing the report. The majority (80%) refer to 2014/2015. Granted exploitation concessions dating from 2011 until 2016 (validity of concessions is five years, after reissuing is need), which means some of the collected data are from period 2012/2013.
- In Slovenia, most thermal water users have been granted water concessions at the end of 2015, and therefore reliable monitoring data exist since 2016 and were used for the overview. These are: object activity, outflow temperature and waste water temperature, type of utilization permit and licenced quantities which are reported as valid in 2016/2017.

Table 1: List of collected parameters

No.	Parameter	Parameter description or sub-division
1	Object name	Name of the well or spring

No.	Parameter	Parameter description or sub-division
2	Local object name	If extra denominators are needed
3	National object ID	National identification code
4	Object settlement	Nearby town or village
5	Reservoir name	Characteristic for each country
6	Reservoir type*	Basin fill reservoir (BF) / Basement reservoir (BM)
7	Reservoir temperature interval**	30-50 °C / 50-75 °C / 75-100 °C / 100-125 °C / 125-150 °C / >150 °C
8	Country	Bosnia and Hercegovina / Croatia / Hungary / Romania / Serbia / Slovenia
9	User name (national language) and address	User of the borehole/well - named user in the database; can manage several user site
10	SITE name (national language) and address	A site where the wells are positioned: may be a sub-company/branch of the USER; the owner Co (USER) and the site Co (USER SITE) can be identical company
11	X, Y, Z in national coordinate system	
12	Vertical datum local system	Adriatic / Baltic / CRS - SI_TRIE/NOH / Black Sea
13	X and Y in ETRS89	
14	Well depth (m below surface)	Original total drilled depth in m below surface
15	Operational depth (m below surface)	This is the depth of the well at the moment of this investigation which might be different from the depth of the original borehole. It is typical to have a deeper borehole which later is transformed to a well with a shallower depth.
16	Year of completion	Year when the drilling was finalised
17	Top and bottom of screened interval (m below surface)	Depth below surface; in case of a production-reinjection well this are the water production screens
18	Number of screens	Number of open sections which can produce water; in case of a production-reinjection well these are the water production screens
19	Total length of screened sections within the screened interval (m)	Total length of open sections within the whole screened interval; in case of a production-reinjection well these are the water production screens
20	National WFD GW body No.	Number of the delineated groundwater body
21	National WFD GW body name	
22	National GW body determination	Declared / delineated but not declared / not delineated / declared but not properly categorised
23	Object type	Spring /well
24	Object purpose	Production / reinjection / production and reinjection / monitoring
25	Object activity	Continuously / occasional (randomly) / periodically (e.g. seasonally) / inactive / no information
26	Type of utilization	agriculture (unknown details) /agriculture general (other) / agriculture: heating of greenhouse / agriculture: other heating (e.g. barns, animal husbandry) / agriculture: fish-farming / agriculture: irrigation / heating (unknown details) / individual space heating (individual house, public building (library, school, hospital, spa building etc.) - everything which is NOT for agriculture purpose) / district heating / balneology-spa / drinking water / electricity production / industrial / monitoring of static conditions / water heating / sanitary water / snow melting / extraction of raw materials (e.g. salt or CO2) / bottling / unknown / reinjection / no use but has a permit / other
27	Date-range of average temperature calculation (from-to)	Reported for an individual temperature measurement or an average within a period of time for most recently available

No.	Parameter	Parameter description or sub-division
		data
28	Yield at which average outflow temperature occurs (l/s)	Report only one value - for current state or last available data
29	Average outflow temperature at wellhead (°C)	Report only one value - for current state or last available data
30	Date-range of reinjection temperature calculation (from-to)	Report only for current state or last available data
31	Average temperature of reinjected water (°C)	Report only one value - for current state or last available data
32	Place of measurement of reinjected water temperature	Place where this temperature is determined, e.g. at wellhead, before sand filters at the wellhead, 200 m below the wellhead in reinjection well, at the outlet of the user site which is 1 km from the reinjection well
33	Date-range of emitted waste water temperature calculation (from-to)	Report only for current state or last available data
34	Average temperature of emitted waste water	Report only one value - for current state or last available data
35	Water is heated prior to use	Yes / no / no information
36	Cold water mixed with thermal water	Yes / no / no information
37	Total annual production in 2015 (m3/year)	If not available, other year or an estimation was used
38	Total annual reinjection in 2015 (m3/year)	If not available, other year or an estimation was used
39	Maximum discharge (l/s)	Maximum discharge rate that the pump in the well can produce at maximum ever and was tested in any way
40	Maximum reinjection rate (l/s)	Maximum reinjection rate that can be applied and was tested in any way
41	Wellhead pressure at max. reinjection rate (bar)	
42	Geothermal doublet well pairs	name of the production wells from which the water is reinjected in this reinjection well
43	Is water reinjected in the same aquifer?	Yes / no / no information; based on the delineated reservoirs is the water reinjected in the same aquifer/reservoir so that it is hydraulically connected with the production zone and enables recovery of the aquifer
44	Type of water production	Natural outflow (artesian outflow) / activated outflow (airlift induces gas- and thermolift) / pumping / still outflowing but pumping is necessary for higher yields / reinjection / no information
45	Type of utilization permit	No permit / water right / geothermal right / mining right / no information
46	Licensed maximum annual production (m3/year)	Maximum annual amount of water production which is granted in the permit
47	Licensed maximum annual reinjection (m3/year)	Maximum annual amount of water reinjection which is granted in the permit
48	Licenced maximum momentary discharge (l/s)	Maximum momentary discharge which is granted in the permit; it is not necessarily connected to the power of the installed pump but is more often determined as the optimal discharge that does not cause damage to the well and its surroundings

* - As the reservoir delineation (Act 5.1) runs parallel to the current assessment (Act 5.2) the information is preliminary and will be available in details after completion of the Act 5.1. Category "Basin fill reservoir (BF)" stands for Lower and Upper Pannonian reservoirs with intergranular porosity while "Basement reservoir (BM)" stands for all fissured, fractured, karstified and dual porosity basement and Middle-Miocene reservoirs.

** - As the reservoir delineation (Act 5.1) runs parallel to the current assessment (Act 5.2) the information will be available after this report is submitted and added in the following months when the data will be prepared for transmission to the database.

Providing the answer to the question if used thermal water is reinjected in the same aquifer is not straightforward. There are no common definitions to determine if the pumped and reinjected layers are the same or not, especially if they have different chemistry. Therefore, the same aquifer layer was confirmed in the database if the two zones were hydraulically connected and enable recovery of the production zone. This indicator will be further developed in the benchmarking tool.

2.2. Data harvesting

The data were collected from various databases and, mostly, by contacting either the management authorities or the users themselves.

- in the Federation of Bosnia and Herzegovina (BA): Data were taken from Cadastre and GIS database of mineral, thermal and thermomineral waters of Federation of Bosnia and Herzegovina, which are performed and continuously updated by Federal Institute of Geology, than from Federal Ministry of Energy, Industry and Mining that verifies and monitors the reserves of these waters, from Sava River Watershed Agency Sarajevo as well as from users. All users in the project area were interviewed for the purpose of producing this report.

- in the Republic of Srpska (BA): The data reported for the Republic of Srpska are mostly based on the documents stored in the Central Geological Archive located in the Geological Survey of the Republic of Srpska. Data on current exploitation refer to the year 2015 except for the well GB-6 in Kula, where an estimation was made because the spa started producing thermal water again three months ago (in 2017) and has not yet provided new production data. Data on licensed maximum annual production is taken from the actual elaborates on the reserves that represent an obligatory document for concession permit.

- in Croatia: No unified database exists. The Ministry of Environment and Energy runs a concession base which is not available for public and is divided among two departments in two bases: concessions under the Mining Act (only if thermal waters are used for energy purpose) and water permits (until 2017 named concessions) under the Water Act (if thermal waters are used for balneology purpose plus some spas are using them for heating). A lot of e-mails were sent, phone calls made and some field trips done but only 70% of the users responded and even they often had only partial information as they do not systematically collect all the data we asked for. By law, it is obligatory only to monitor the amount of produced water and, periodically, waste water temperature.

- in Hungary: Data were taken from the central database of the Mining and Geological Survey of Hungary (MBFSZ), and additional data was provided by the regional Water Directorates (they haven't got all the required information) and by users. We tried to make connection with all the users of the 608 wells, but unfortunately, not all the users have answered, although a lot of energy was put into contacting them.

- in Romania: At first, public information was gathered for 13 wells from presentation FORADEX – geothermal heating : The potential of geothermal heating presentation, made by Liviu Meran in May 2015. These data was compared to data from Mr. Stefan Olah (S.C. Terra Technik S.R.L.) containing 25 wells. Comparing the two, only 3 wells coincided. Later at IGR request, the representative of the Romanian ASP, the National Agency for Mineral Resources, provided information on 55 wells from recent geothermal documentation. They were ready in autumn 2017 but it was not possible to obtain them for project needs due to bureaucratic obstruction of the NAMR chief of the structure of security of information. This problem was resolved in February 2018. Information on flow rate, licenced annual production and reinjection quantity and discharge are still confidential, and therefore were not provided.

- in Serbia: Collected data are taken from several available sources, since there is no one unified centralised database, including the personal contact with users. For the territory of Autonomus Province of Vojvodina, which covers almost the 90% of project area in Serbia, the Provincial Secretariat for Energy, Construction and Transport is running the geothermal database of exploitation and exploration licences. This database is partly publicly open. For the rest of the territory of Serbia, the Ministry for Mining and Energy is authorised. A similar database is run under this governmental body.

- in Slovenia: We upgraded the public databases elaborated within the T-JAM and TRANSENERGY projects, used results from operational monitoring reports for year 2016, checked Decrees on concessions published in the Official Gazette of the Republic of Slovenia, and to minor extent performed field inspections and interviews with users.

2.3. Data processing

Data were interpreted using MS Office Excel, ArcGIS Map, and Photoshop.

Some modifications of the data gathered were needed before an interpretation was made. If the operational depth was unknown, the well depth was copied and both were assumed to be identical. Springs had a year of completion assigned as 0 to be differentiated within statistics, as well as the well depth and operational depth (if not stated differently for some captured springs). Croatia added Type of utilization permit as ‘’mining/water right in progress’’ which was accounted for as if the right is already granted. For the Federation of Bosnia and Herzegovina, "mining right" means the exploitation license obtained from the Federal Ministry of Energy, Mining and Industry based on the Law on Geological Investigation, and "water right" means a valid Concession Agreement. Badenian and Sarmatian limestone reservoirs were jointly interpreted as basement reservoir (BM) category due to their porosity type, while Pannonian delta slope reservoirs were joined to basin fill (BF) category. For Hungary, reservoirs were classified based on their delineation, porous as basin fill reservoir (BF) and of karstic and dual porosity as basement reservoir (BM).

Some reported wells were deleted because their water temperature was reported to be below 30 °C:

- BA: B-6 Gradačac (28.5 °C), PEB-4 had two lines (two users) – their names were joined in one line)
- RS: Db-1/H (25 °C)
- HU: Békés 3-225 (28 °C), Kaposvár 13-165 (18 °C).

Temperature of wells Derekegyház 5-238 (25 °C), Székkutas 5-243 (25 °C), Szentes 5-251 (25 °C) in Hungary has decreased from the 30-35 °C at the time of drilling to below 30 °C nowadays and therefore they are still kept in the database. The same stands for Db-1/H in Serbia which decreased from 32 °C to 25 °C.

3. Results

3.1. Data availability

Parameters which had 90% and more data available in total are assumed to provide a solid basis for the current utilization overview (ALL in Table 2). As Hungary has 79% of all objects included in the investigation, weighting had to be done to show more relevant availability of information. Three values of data availability were calculated, with different weighting approaches used (Table 2):

ALL_{wells} = number of wells with available data / number of all wells

$ALL_{welscontry}$ = sum of percentages of wells with available data per country*number of wells per a country / number of all wells

$ALL_{country}$ = sum of percentages of wells with available data per country / number of countries

If ''no information'' was reported, it counted as if no data was available. Where 75% and less data was available precautions had to be taken for interpretation and further use of this data as it might be strongly biased either by a country or some other issue.

Almost complete data on object names, locations, reservoir type (but not yet temperature), user name, depth, year of completion, type, purpose, outflow temperature and maximum discharge was available. However, information on objects' activity and related production and reinjection quantity, thermal water use (by cooling of mixing prior to use), and waste water temperature is rather sparse. What is surprising is that the information on licenced/granted amounts of thermal water is mostly not easily available, except for Slovenia where the quantities are published in the Official Gazette.

In the Federation of Bosnia and Herzegovina concessions (water rights) are issued by cantons (10 cantons in the Federation of B&H from which three are in the project area) and different ministries in the cantons; in some cases the Government of the Federation of B&H gives concessions, so it is difficult to know which institutions can give information about concessions. Decisions on concessions are public and they are published in Official Gazettes of cantons or the Federation of B&H. Official Gazettes of cantons are not available via the internet, so it is not easy to follow them, and we could not collect information about concessions for some wells.

In Croatia, the information on granted amounts of thermal water is not available for the public. The only public information is whether the user has a permit or not and if the answer is yes, the permit number, date of issuing and expiring date are available.

In Hungary, the licences on (thermal) wells are not open to the public, and neither is their data. The regional Water Directorates should have this information, but since the granting of water rights (except below 2500 m, which is subject of mining concession under the competence of the Mining and Geological Survey of Hungary) belongs to the regional Directorates for Disaster Management, these data are available by default there. Due to the high number of geothermal objects in Hungary and the timeframe available, it was not possible to collect data also from this source. A new data collection campaign, specifically oriented to collect data related to water rights (and not operation, current use) will be carried out for the pilot regions in the frame of benchmarking evaluation.

In Romania, coordinates of the geothermal exploration/exploitation parameter make part of the license and is published in the Official Monitor. On the website of the National Agency for Mineral Resources only the following are published: the substance, license owner, and its contact data (address and phone number). It might happen that exploitation licenses are not listed (excepting "waiting for approval"). That is why, at present, in Arad and Timis counties, that make part of DARLINGe project area, there are no exploitation licenses for geothermal water. However, a company can extract geothermal water once that the approval is obtained from the National Agency for Mineral Resources and have to provide every year a report on the extracted water. During this time the company is trying to obtain the other necessary approvals from: the Local Environmental Agency, Ministry of Culture, and Romanian Waters Authority. Only after these approvals are obtained, the license is published in the Official Monitor. The amount of produced geothermal water is not classified, and is not publicly available on the internet either. It must be obtained from the National Agency for Mineral Resources or directly from the well owner.

In Serbia, the licence on groundwater/geothermal use is publicly available through two web applications. Depending on the territorial jurisdiction, Provincial Secretariat for Energy, Construction and Transport, is running a database covering territory of Vojvodina, while the rest of Serbia is under the competence of Ministry of Mining and Energy. The databases are providing information on name of the user, type of mineral resource (groundwater/thermal water), location, number of licence and date of issuing. Data preview is organized both graphically and textually. Every licensed user have annual obligation to provide report on monitoring data (yield and temperature). Those data are not publicly available, nor the object characteristics, chemical composition and hydraulic data. Database updating goes periodically.

Table 2: Percentage of collected data per country and in total

No.	Parameter	BA	HR	HU	RO	RS	SI	ALL_{wells}	$ALL_{wells\ country}$	$ALL_{country}$
1	Object name	100	100	100	100	100	100	100	100	100
2	Local object name	100	100	100	0	100	100	87	93	83
3	National object ID	20	93	82	0	0	100	74	74	49
4	Object settlement	100	100	100	100	100	100	100	100	100
5	Reservoir name	100	100	100	100	95	100	100	100	99
6	Reservoir type	100	100	100	100	100	100	100	100	100
7	Reservoir temperature interval	100	100	1	95	100	100	21	21	83
8	Country	100	100	100	100	100	100	100	100	100
9	User name (national language) and address	100	100	94	98	100	100	96	95	99
11	Z in national coordinate system	100	52	100	91	89	100	97	97	89
13	X and Y in ETRS89	100	100	100	100	100	100	100	100	100
14	Well depth (m below surface)	100	89	100	98	92	100	99	99	97
15	Operational depth (m below surface)	100	89	100	65	92	100	97	97	91
16	Year of completion	100	81	100	45	92	100	95	95	86
17	Top and bottom of screened interval (m below surface)	100	44	100	96	89	98	97	97	88

No.	Parameter	BA	HR	HU	RO	RS	SI	ALLwells	ALLwells country	ALLcountry
18	Number of screens	100	44	100	16	89	98	90	92	75
19	Total length of screened sections within the screened interval (m)	100	44	100	14	89	84	90	91	72
20	National WFD GW body No.	0	0	100	0	0	100	92	85	33
21	National WFD GW body name	0	0	100	0	0	100	91	85	33
22	National GW body determination	0	100	100	0	100	100	93	92	67
23	Object type	100	100	100	100	100	100	100	100	100
24	Object purpose	100	100	100	93	100	100	99	99	99
25	Object activity	100	100	30	93	68	100	99	43	82
26	Type of utilization	100	100	86	2	100	98	82	82	81
27	Date-range of average temperature calculation (from-to)	100	33	100	65	0	91	91	91	65
28	Yield at which average outflow temperature occurs (l/s)	100	96	99	0	100	66	99	90	77
29	Average outflow temperature at wellhead (°C)	100	89	100	65	100	100	98	97	92
31	Average temperature of reinjected water (°C)	0	50	14	0	0	100	18	19	27
34	Average temperature of emitted waste water	30	56	1	0	100	77	11	11	44
38	Water is heated prior to use	90	30	100	0	68	100	89	89	65
39	Cold water mixed with thermal water	20	0	13	0	0	100	17	16	22
40	Total annual production in 2015 (m3/year)	30	19	54	29	100	100	62	55	55
41	Total annual	100	0	78	0	100	100	74	72	63

No.	Parameter	BA	HR	HU	RO	RS	SI	ALL_{wells}	$ALL_{wells\ country}$	$ALL_{country}$
	reinjection in 2015 (m3/year)									
42	Maximum discharge (l/s)	100	70	100	0	89	100	92	91	77
47	Type of water production	100	96	8	49	100	100	43	24	76
48	Type of utilization permit	70	100	82	58	58	100	84	81	78
49	Licensed maximum annual production (m3/year)	70	44	52	0	42	100	51	51	51
50	Licensed maximum annual reinjection (m3/year)	0	0	0	0	0	100	1	6	17
51	Licenced maximum momentary discharge (l/s)	60	0	18	0	0	100	22	21	30

3.2. Identified geothermal objects

According to set criteria 767 geothermal objects were identified in the six countries (Figure 1, Table 3) with an average density of their distribution as 7.7 objects per 1000 km^2. Their highest density is evident in Hungary with 26 objects per 1000 km^2, followed by Slovenia and Romania, while Serbia, Croatia and Bosnia and Hercegovina reach on average about one object per 1000 km^2.

Table 3: Geothermal objects by countries

Country	No. of objects	Project area (km^2)	No. of objects per km^2	No. of objects per 1000 km^2
BA	10 wells	11,590	0.0009	0.9
HR	6 springs and 21 wells	27,690	0.0010	1
HU	606 wells	23,150	0.0262	26.2
RO	55 wells	8,033	0.0068	6.8
RS	1 spring and 24 wells	24,010	0.0010	1
SI	44 wells	4,874	0.0090	9
Project area	***767***	***99,347***	***0.0077***	***7.7***

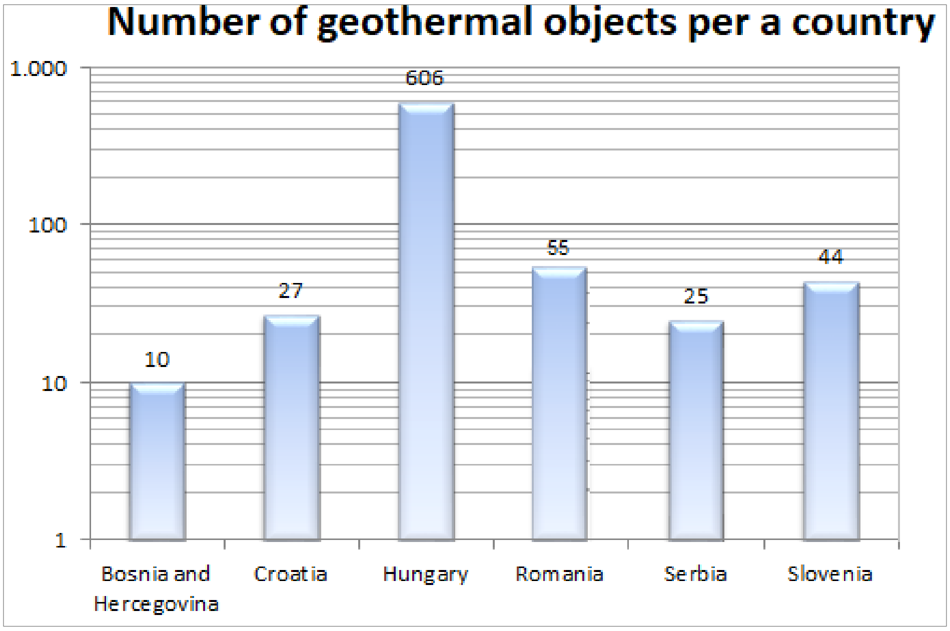

Figure 1: Number of geothermal objects by countries taken into account in this assessment

Objects were classified as producing from two reservoir types: a porous basin fill reservoir, in the interpretation of the current utilization also including the entire Pannonian sedimentary sequence (BF), and a fissured/karstified/double porosity basement reservoirs (BM), in the interpretation of the current utilization also including the Badenian or Sarmatian reservoirs in sedimentary basins (Figure 2, Figure 3). Porous basin fill reservoirs significantly predominate over the fissured ones as almost 6-times more objects produce thermal water from them.

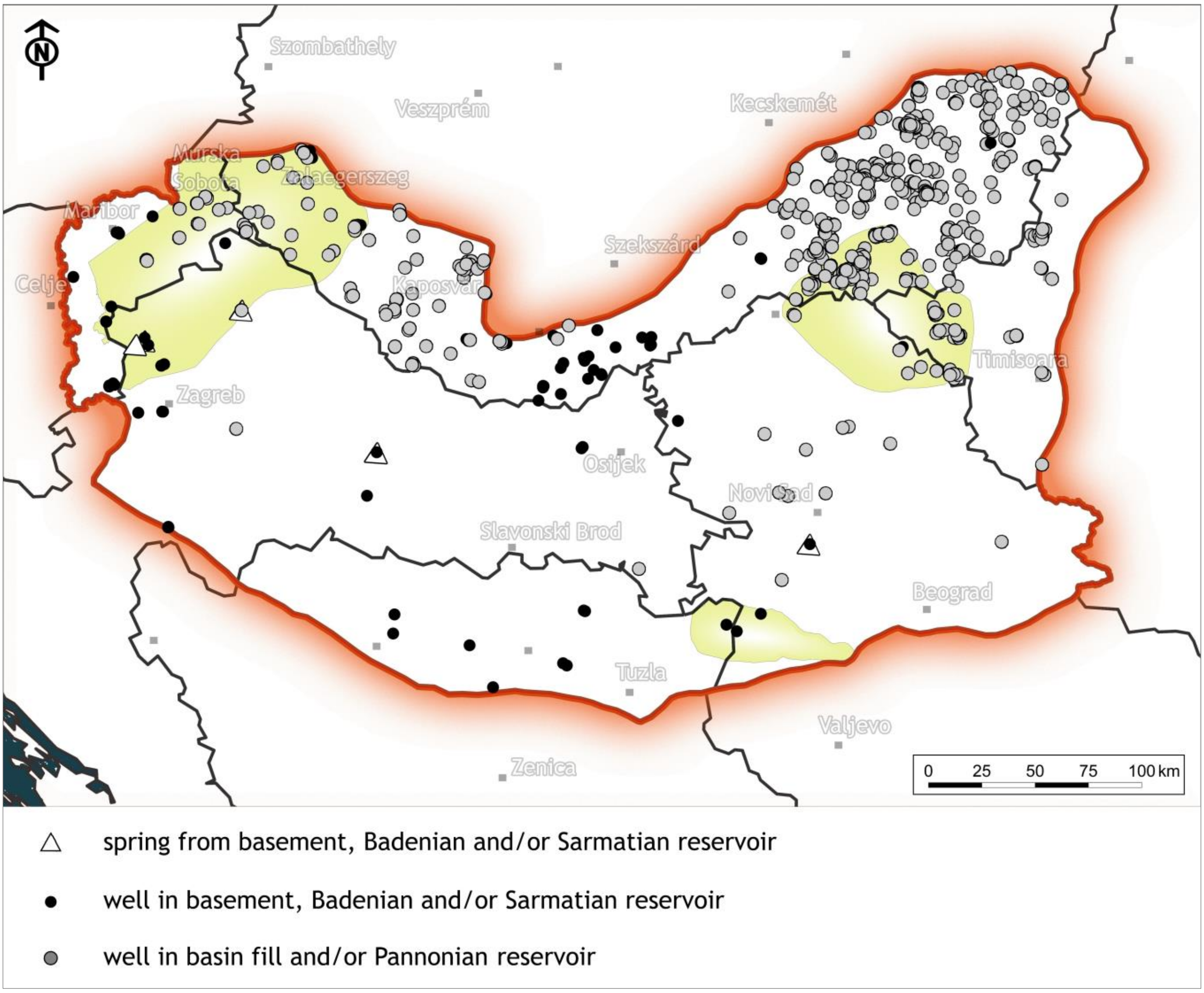

Figure 2: Object and reservoir types of 767 objects

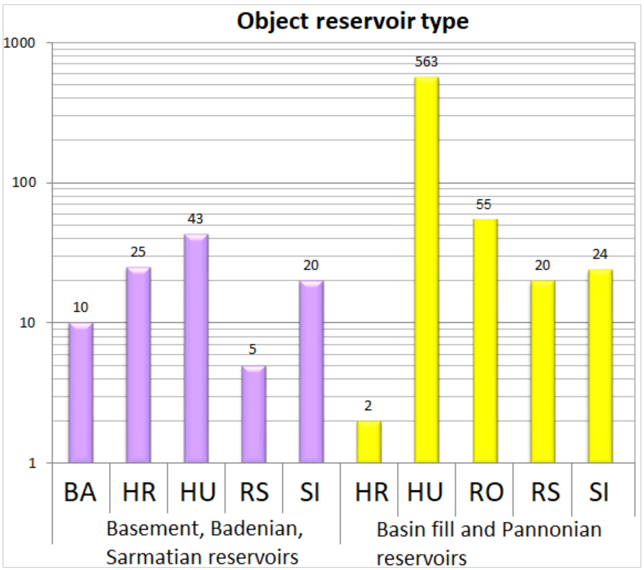

Figure 3: Identified reservoir types for 767 objects with the numbers of object in each type

Based on the reported operational depths of 744 objects, we can conclude that the average depth is approximately 1145 m while the maximum 3436 m (Figure 4). Comparing the average operational depths between the countries, it is obvious that the depth decreases from 1.8 km in Romania to 1.2 km in Hungary, 1.0 km in Slovenia, 0.9 km in Serbia, and 0.5 km in Croatia and Bosnia and Hercegovina. This is partially geology-dependent. We plan to compare these numbers to the depth parameter of the Pannonian Basin when the reservoir delineation is finished.

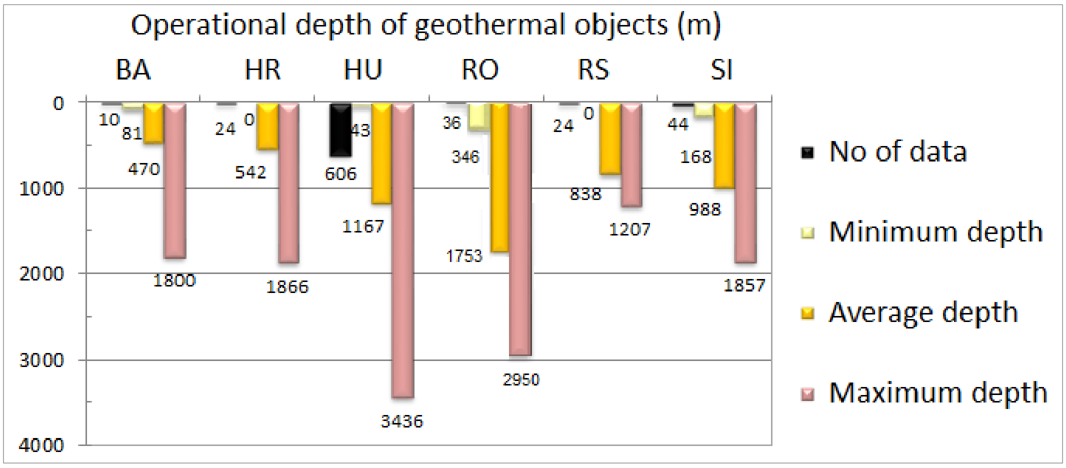

Figure 4: Operational depth of objects by countries

The year of completion was reported for 735 objects (Figure 5, Figure 6). Regarding the individual countries, the range of years is 1957-2013 for Bosnia and Hercegovina, 1960-2010 for Croatia, 1901-2016 for Hungary, 1900-2008 for Romania, 1974-2015 for Serbia and 1949-2011 for Slovenia. Percentages show that 13% of wells are younger than 10 years, 8% have 10-20 years, 9% 20-30 years, 22% 30-40 years, 22% 40-50 years, 20% 50-60 years and 6% are older than 60 years.

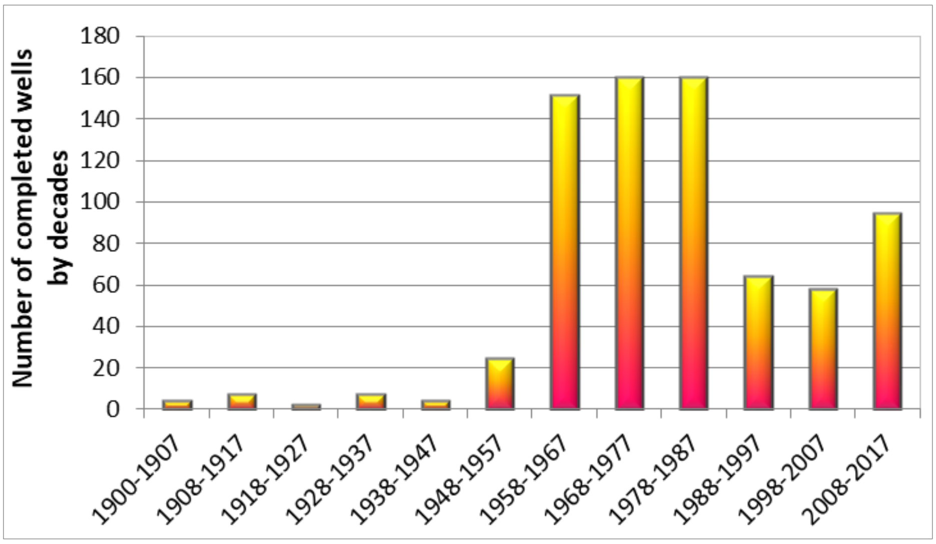

Figure 5: Number of completed wells by decades in the whole project area

The lifespan of geothermal wells is usually about 30 years and only about 29% of wells are younger than this. This might indicate several things. On one hand a positive point is that the objects obviously have very long life period and the large capital investment needed to drill them and make them operational is acceptable, on the other hand at least some of the wells may be approaching their final stages of operation due to a questionable status of the iron casing, weak cementation and plugs, and similar effects resulting from poor maintenance. The number of new wells put in operation has been decreasing in the region since 2008, which alarms for new support to investors and maintenance of the existing ones. These facts indicate that it will be necessary to promote new investments into geothermal wells in order to retain total capacity in the region in long-term.

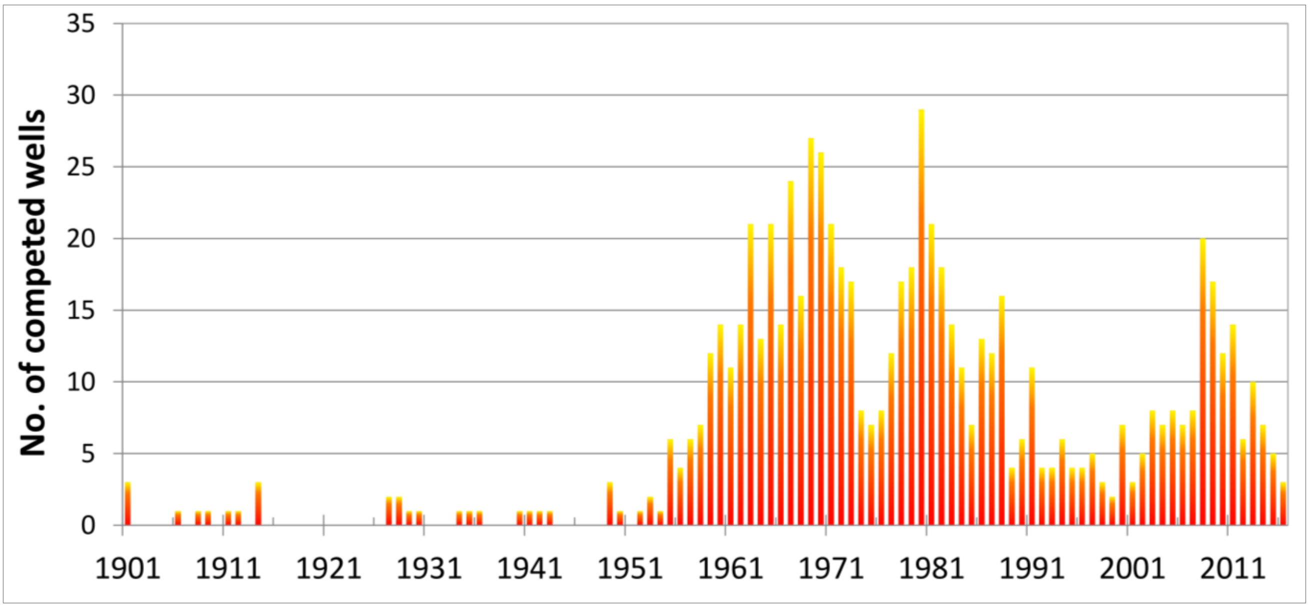

Figure 6: Number of completed wells by years in the whole project area

3.3. Thermal water temperature

Average outflow temperature shows that 36% of objects have temperatures below 40 °C while 50% below 50 °C (Figure 7, Figure 8). This means that half of the listed objects are more than favourable for geothermal heat production. The temperature range is 30-75 °C in Bosnia and Hercegovina, 32-97 °C in Croatia, 25 °C (originally 30 °C)-101 °C in Hungary, 29-85 °C in Romania, 25 °C (originally 31 °C) -72 °C in Serbia, and 30-75 °C in Slovenia. The highest temperatures of above 80 °C are mostly identified in Hungary, and to a lesser extent in Croatia and Romania.

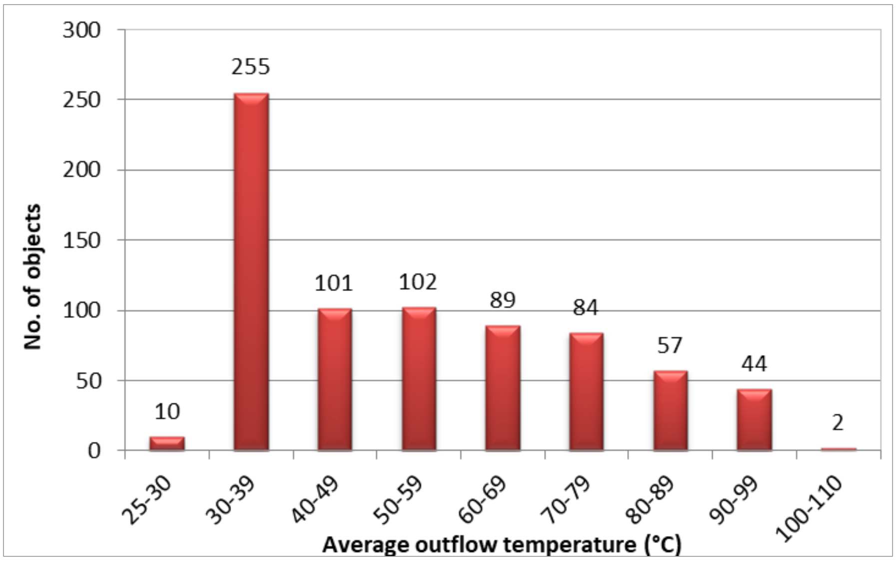

Figure 7: Distribution of average outflow temperatures of thermal waters of 744 objects

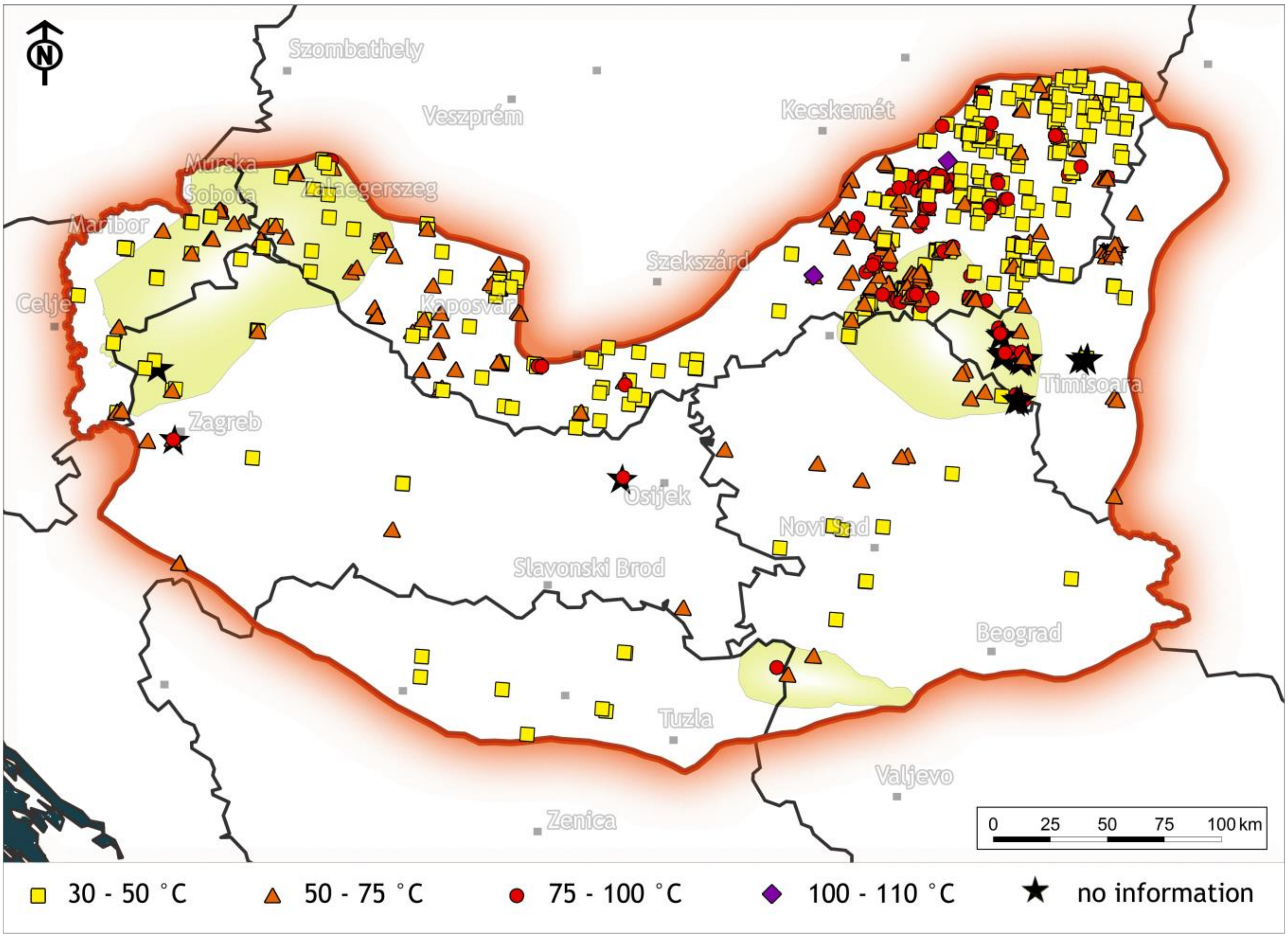

Figure 8: Distribution of average outflow temperatures at wellheads of 767 objects. Wells of which outflow temperature has decreased below 30 °C are still shown in the category 30-50 °C.

3.4. Drilling purposes and utilization types

Objects' drilling purposes are well known while information on their activity (Figure 10) is much poorer. Monitoring wells were reported only in Croatia (1) and Hungary (12). Production wells and springs are 714 in total (Figure 9), of which 128 have a continuous production, 76 with periodical (mostly seasonal) and 5 with occasional (random) production; no information was available for 403, whilst 102 are known to be inactive. A single production-reinjection well is reported in Croatia (reinjection well Mla-2 of 911 m cased in carbonates) and one 2.2 km deep in Hódmezővásárhely in Hungary. The reinjection part of the Hungarian well was in operation only for a short time, and at present only the production part operates. Well Mla-2 in Croatia was drilled in 1985 because the Mla-1 did not produce water with sufficient temperature. It was planned to be a production well and because of good testing results an additional well Mla-3 was drilled 2 m away from Mla-2. In Mla-2, lithothamnium limestones of Prečec Formation is tapped at 883-911 m and producing water with 63-65 °C. Static pressure at the wellhead is 7.8 bar. Optimal yield is 25 l/s with 63 °C. Nowadays, Mla-2 is used as a reinjection well because it has lower temperature and static/dynamic pressure than the Mla-3 with water of 78-80 °C. In a case of higher water demand, Mla-2 can be used as production well and Mla-1 would probably become a reinjection well.

As many as 39 wells are listed to be drilled for reinjection, 5 of them are constantly, 4 periodically and 14 at least occasionally active while no information on frequency of activity is available for the rest 16. In more details, one well is active in Bizovac and the other in Zagreb in Croatia, the third one in Lendava in Slovenia, while the one in Moravske Toplice is now used for production instead of reinjection, and at least 18 active reinjection wells exist in Hungary, while no information on current activity was available for the others. So good practice on reinjection should be able to be described for porous and carbonate aquifers. There is one well in Hungary which produces water and reinjected into fractured crystalline formation near a tectonic zone (Szentlőrinc), the rest is operating in porous and karstic aquifers. No reinjection occurs in the Romanian, Bosnian and Serbian project area.

Utilization was reported with varied precision per country (Table 2, Figure 11). Unknown use was reported for 130 objects in Hungary, Romania and Slovenia. To give a reasonable overview, some categories were joined for interpretation:

- 24% (183) have balneological use, out of these 28 are also used for heating (which includes 14 sanitary water heatings and 21 individual space heating),
- 17% (130) have drinking water utilization, however some of these might be used also for other purposes,
- 16% (122) have different types of heating (neglecting agriculture), out of these 13 use the water for district heating and 3 for individual space heating,
- 9% (70) have agricultural use, dominantly heating which usually means greenhouse heating
- 8% (58) other unlisted uses,
- 5% (39) are reinjection wells,
- 5% (36) are industrial wells, and
- 2% (11 objects) operate as monitoring wells.

No thermal wells are used for irrigation in BA, HR, HU, RO and SI project area, and probably in Serbia.

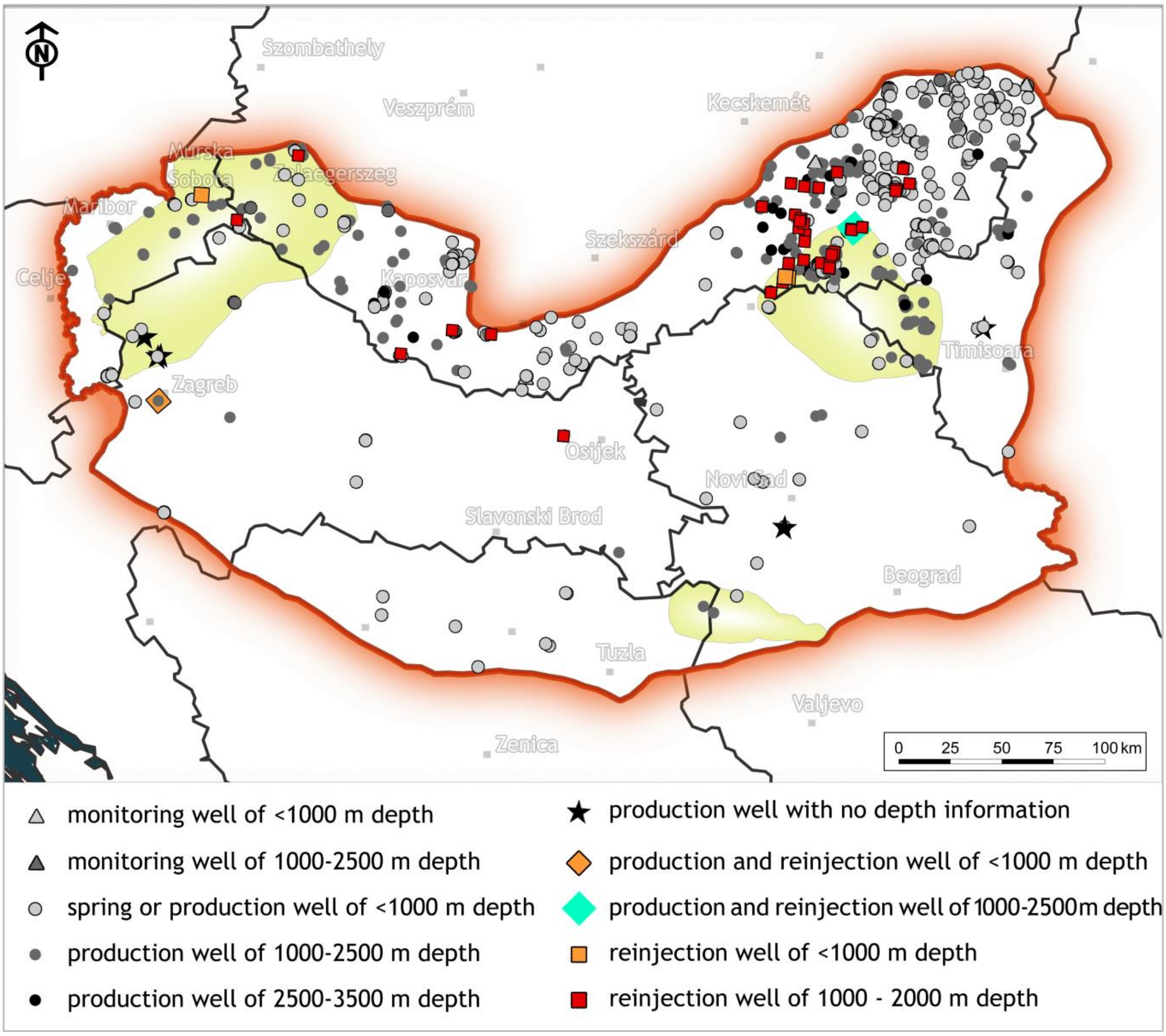

Figure 9: Objects' drilling purpose and operational depths for 767 objects

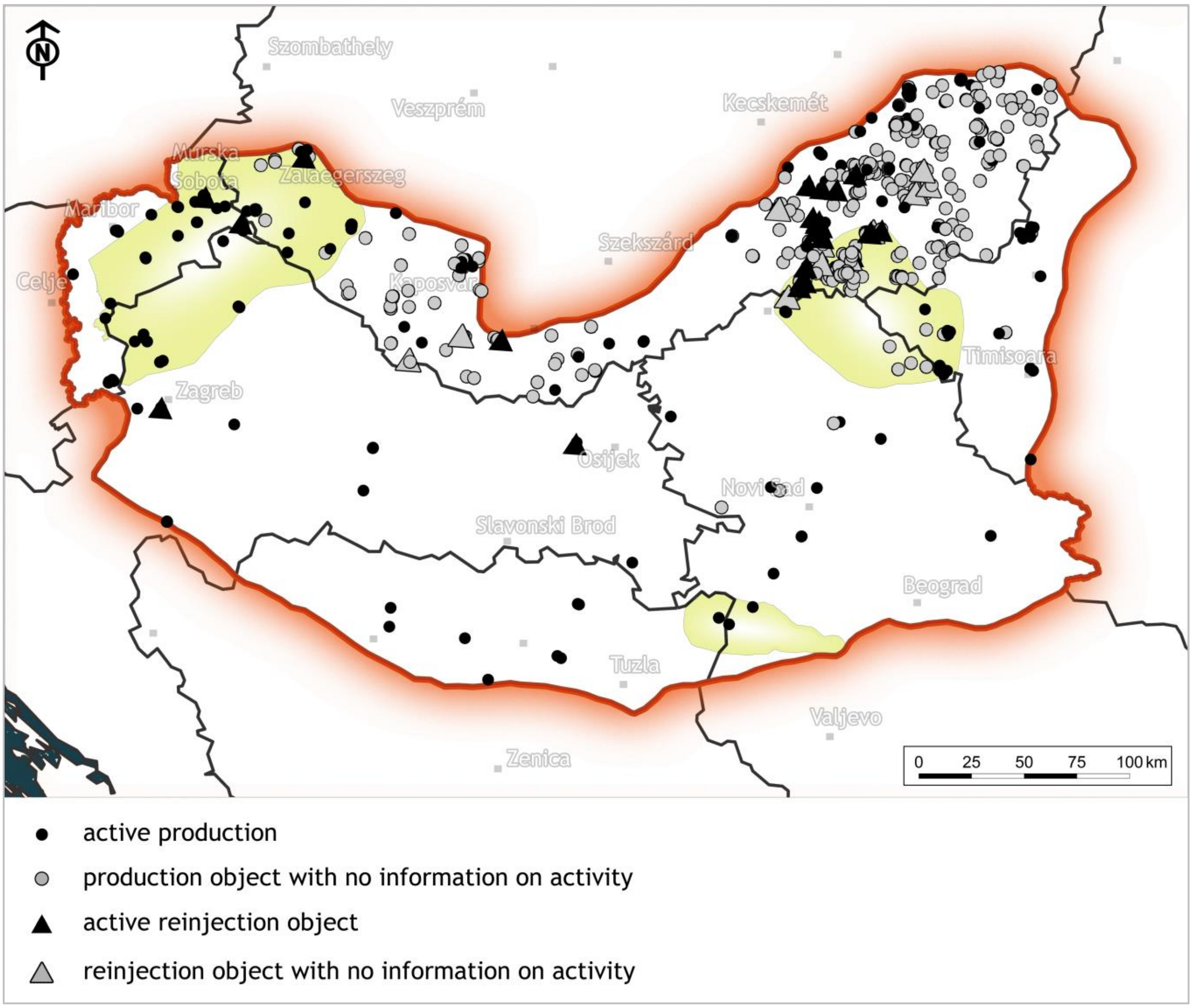

Figure 10: Activity of geothermal objects in shown for 652 objects which are either active or have no information on activity

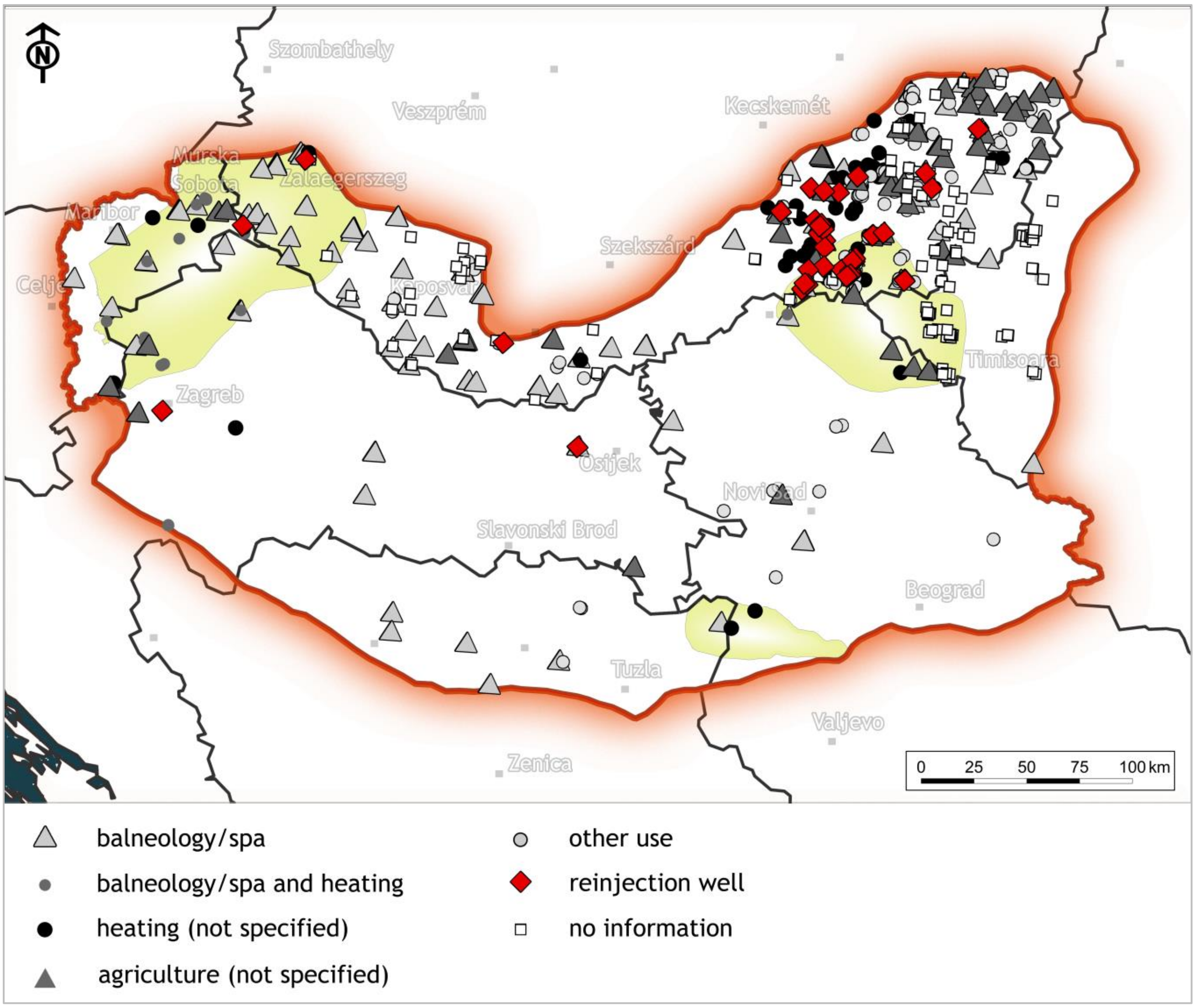

Figure 11: Generalised types of utilization for 668 active objects or which have no information on activity. Heating includes district heating, sanitary water heating and individual space heating. Agriculture includes different agricultural uses, also heating of greenhouses. Other use stands mostly for industrial use and monitoring wells.

3.5. Thermal water production, types of permits and licenced quantities

Only 62% objects had information on production. The total annual production summed to $5.5 \cdot 10^6$ m^3 in Serbia (100% data available; 76% from basin fill and Pannonian reservoirs), $28.7 \cdot 10^6$ m^3 in Hungary (54% data available; 91% from basin fill and Pannonian reservoir), $4.7 \cdot 10^6$ m^3 in Slovenia (100% data available; 70% from basin fill and Pannonian reservoirs), $0.39 \cdot 10^6$ m^3 in Croatia (19% data available; 55% from basement, Badenian and/or Sarmatian reservoirs), $0.28 \cdot 10^6$ m^3 in Bosnia and Hercegovina (30% data available, all from basement, Badenian and/or Sarmatian reservoirs), and $0.4 \cdot 10^6$ m^3 in Romania (29% data available; all from Pannonian reservoirs). In total, more than $40.0 \cdot 10^6$ m^3 was produced in 2015 (Figure 12), and 85% was produced from basin fill (Pannonian) reservoirs while the other thermal water from basement, Badenian and/or Sarmatian reservoirs.

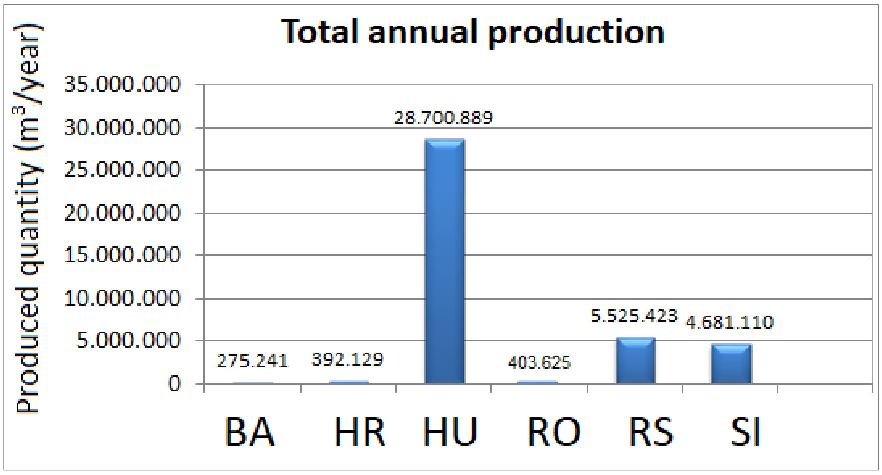

Figure 12: Annual production quantity per countries. Notice that 90% of the objects had production information in BA, 19% in HR, 55% in HU, 96% in RS, 29% in RO and all in SI.

Licensed maximum annual production sums to at least $62.3 \cdot 10^6$ m^3 per year (51% available data; Figure 13, Figure 14), to $3.6 \cdot 10^6$ m^3 per year in BA, $8.5 \cdot 10^6$ m^3 per year in HR, $38.1 \cdot 10^6$ m^3 per year in HU, $6.4 \cdot 10^6$ m^3 per year in Serbia and $5.7 \cdot 10^6$ m^3 per year in Slovenia while no data is available for Romania. If comparing reservoir types, $18.7 \cdot 10^6$ m^3 per year (30%) plans to be extracted from basement, Badenian and Sarmatian reservoirs while the other $43.7 \cdot 10^6$ m^3 per year (70%) from the porous basin fill (Pannonian) reservoirs. No precise data are available for licenced reinjection quantity except for a well in Slovenia with granted $1 \cdot 10^6$ m^3 per year for reinjection.

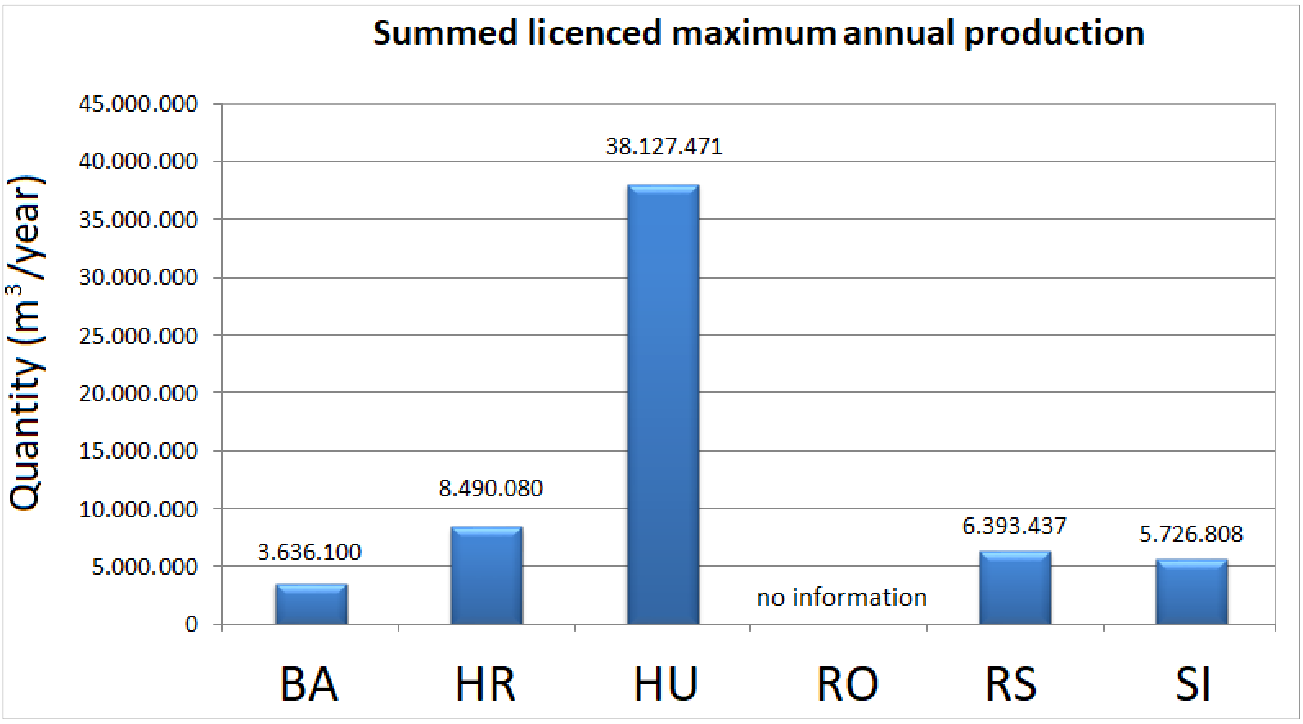

Figure 13: Granted annual production quantity per countries

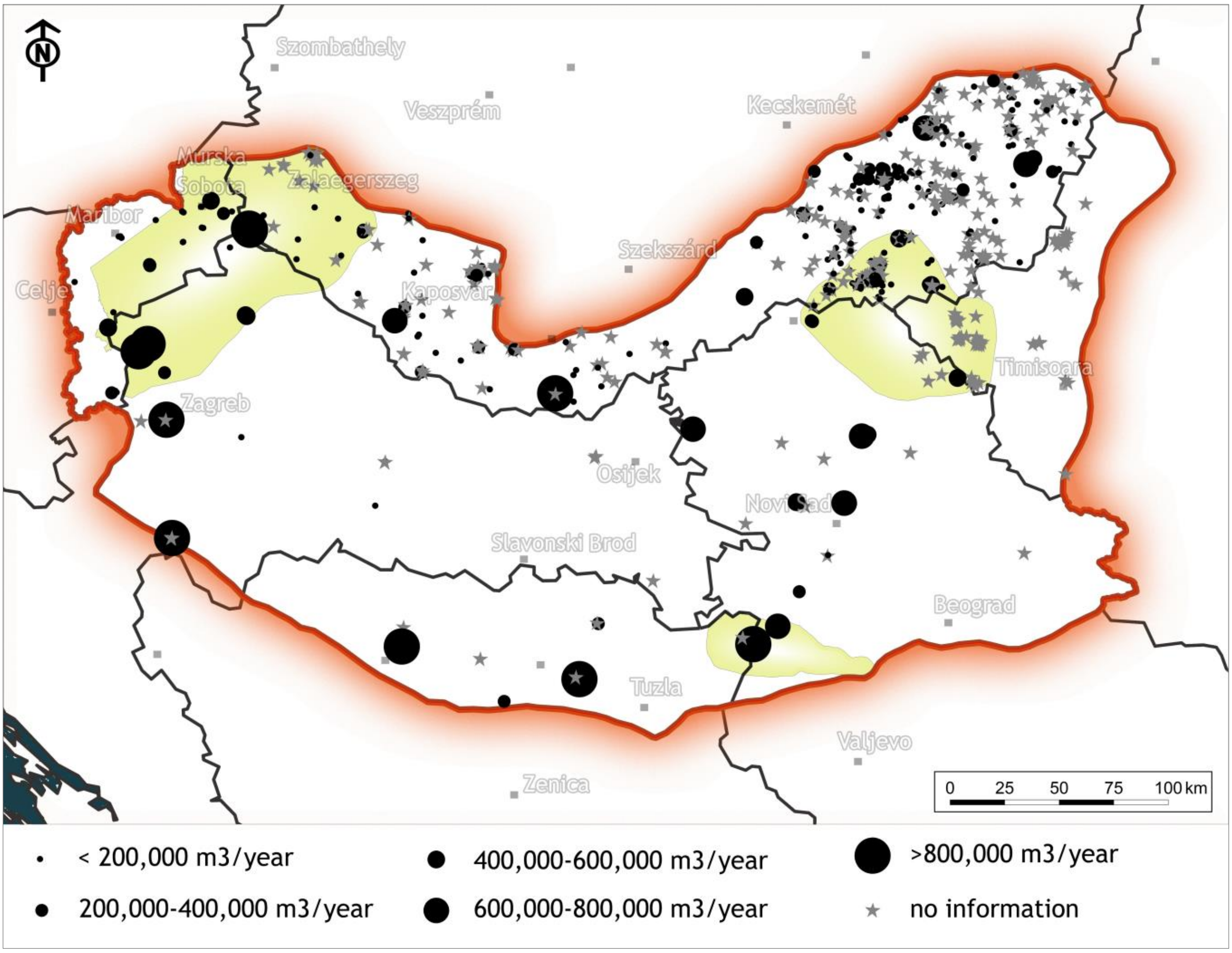

Figure 14: Licensed maximum annual production/reinjection from an object for 767 objects

Regarding the granted permits, water rights prevail in Croatia, Hungary, and Slovenia, geothermal rights in Serbia, and mining rights in Bosnia and Hercegovina and Romania. In total, 72% are water rights (Figure 15), 18% have no information on permits, 6% have mining rights, 2% geothermal rights, and 1% have no rights granted.

In Croatia, thermal water utilization is regulated by two different laws, depending on the purpose of utilization. If the purpose is to use water (bottling, swimming, balneology) then the Water law is amenable (Official gazette 153/09, 63/11, 130/11, 56/13, 14/14). On the other hand, the Mining law is amenable (Official gazette 56/13, 14/14), if the purpose is to use the energy (heating, electricity generation). Since swimming and balneology utilization prevail, in Croatia is more water permits than mining permits (concessions).

In Hungary, the type of utilization was reported only if an exact answer to the distributed questionnaire was received; however, all operating wells should have a licence. Water rights were assigned to those which have a licence confirmed in the questionnaire. A water right can be assumed for others with no information also, as it was compulsory to get the licence until now, so wells which report their water production to authorities or operate as monitoring wells most probably also have a licence.

In Romania, geothermal, mineral groundwater, as well as therapeutic water, is considered subsoil resources and they are administered by the National Agency for Mineral Resources. Surface waters and groundwater resources as well as the infrastructure for their exploitation are administered by the Romanian Waters Authority (Apele Romane).

In Slovenia, thermal water use without 100% reinjection is governed by the Water Law and concessions for spa/balneology, and spa/balneology and heating are granted as water permits. Only one mining concession is granted for a production-reinjection pair of wells in Lendava with demanded 100% reinjection.

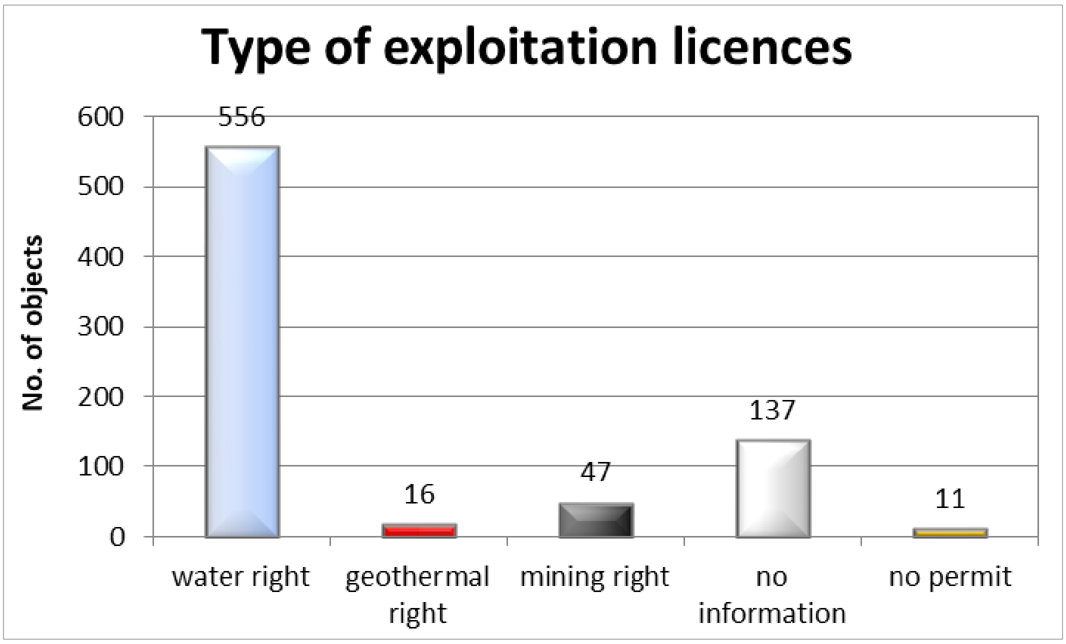

Figure 15: Types of granted utilization rights

4. Conclusions

The utilization is diverse, good (and bad) practices should not be hard to identify.

The current utilization overview identified 767 geothermal objects, resulting in an average density of their distribution of 7.7 objects per 1000 km². 93% of these are intended for thermal water production and of these at least 29% are exploiting thermal water, 14% are inactive and for 56% no information on activity was available. About 5% of objects are reinjection wells. The average well depth is approximately 1145 m. About 13% of wells are younger than 10 years, additional 17% below 30 years, while 26% are older than 50 years. Thermal water temperature exceeds 50 °C at 51% objects, while the highest measured temperature reached 101 °C in Hungary. This confirms a very favourable potential for geothermal heat production. Among reservoir types, the porous basin fill and Pannonian delta slope reservoirs significantly predominate over the fissured/karstified basement, Badenian and Sarmatian reservoirs, as almost 6-times more objects produce thermal water from it. It is important to mention that there are some wells in the Badenian, Sarmatian and Lower Pannonian too, which were attributed to both types and will be further classified and described within the pilot area study.

Bathing and balneological use is prevalent with 24% but only 15% of these also have heating systems applied. Different types of heating with 16% successfully follow, out of these 13 wells produce water for district heating and 3 for individual space heating. Additional 9% have agricultural use, dominantly (greenhouse) heating. The 5% appertains to reinjection wells. Mostly in Hungary, drinking water

(17%), industrial use (5%) and monitoring wells (2%) are also common. Only 62% objects have had production information provided which summed to (at least) $40 \cdot 10^6$ m^3 per year, wherefrom 85% was exploited from basin fill and Pannonian reservoirs. In total, 72% of objects have had granted water rights, 6% mining rights, 2% geothermal rights, 1% no rights, and the others no information on permits. Licensed maximum annual production gives even highest quantities – $62.3 \cdot 10^6$ m^3 in per year (55% available data), of which 70% may be produced from basin fill and Pannonian reservoirs. No precise data is available for licenced reinjection quantities except for a well in Slovenia with granted $1 \cdot 10^6$ m^3 per year for reinjection.

This overview confirms the large geothermal potential of the Pannonian basin region and points out that significant development can be achieved already by using existing geothermal objects.

Benchmarking tool for improved management will discuss also methodologies for the calculation of available thermal power, available and used geothermal energy which is non-uniform, and therefore was not included in this report.