

THE UTILIZATION STRUCTURE OF THERMAL WATER WELLS AND ITS UNEXPLOITED CAPACITIES IN HUNGARY

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Abstract

In order to mitigate Hungary's vulnerability in energy supply and accomplish the renewable energy production targets, it is essential to discover exploitable alternative opportunities for energy production and step up the utilization of the available capacities. The purpose of this publication is to map up the utilization structure of the existing Hungarian thermal water wells, describe its changes over the past 16 years, reveal the associated reasons and define the unutilized well capacities that may contribute to increasing the exploitation of geothermal heat by municipalities.

The studies have been conducted in view of the Cadaster of Thermal Water Wells of Hungary compiled in 1994, the well cadasters kept by the regional water management directorates, as well as the data of the digital thermal water cadaster of 2010. The calculations performed for the evaluation of data have been based on the ratios and respective utilization areas of the existing wells.

In the past 150 years, nearly 1500 thermal water wells have been drilled for use by a broad range of economic operations. The principal goals of constructing thermal water wells encompass the use of water in balneology, water and heat supply to the agriculture, hydrocarbon research and the satisfaction of municipal water demands. In 1994, 26% of the facilities was operated as baths, 21% was used by agriculture, while 13% and 12% served communal and waterworks supply, respectively. Then in 2010, 31% of thermal water wells was continued to be used for the water supply of bathing establishments, followed by 20% for agricultural use, 19% for utilization by waterworks, 11% for observation purposes and 10% for communal use.

During the 16 years between 1994 and 2010, the priorities of utilization often changed, new demands emerged in addition to the former utilization goals of thermal water wells. The economic landscape and changes in consumer habits have transformed the group of consumers, which is the reason why most of the resources have remained untapped. In 2010, 13% of all the thermal water wells were closed in, but could potentially be utilized; these capacities could be deployed for the satisfaction of the heat demands of municipal public institutions.

Keywords: geothermal energy, renewable energy, thermal water utilization, geothermal heat utilization

1. Introduction

Hungary's liberalized market and her shortage in traditional energy carriers (Perczel, 2003) pose a threat on the safety of supply, and make consumers vulnerable. The problem is further aggravated by her dependence on the politically instable supply sources and the monopolistic position of certain suppliers. The increasing concern for

the state of the environment (Buday, 2012), and the aspirations to accomplish the related objectives call for heightened attention to the exploitation of renewable energy potentials and decentralized networks. The narrowing resources, the sometimes hectically changing, but mostly steadily increasing energy prices (KSH, 2010) and cost-efficiency urge the exploitation of local energy sources both

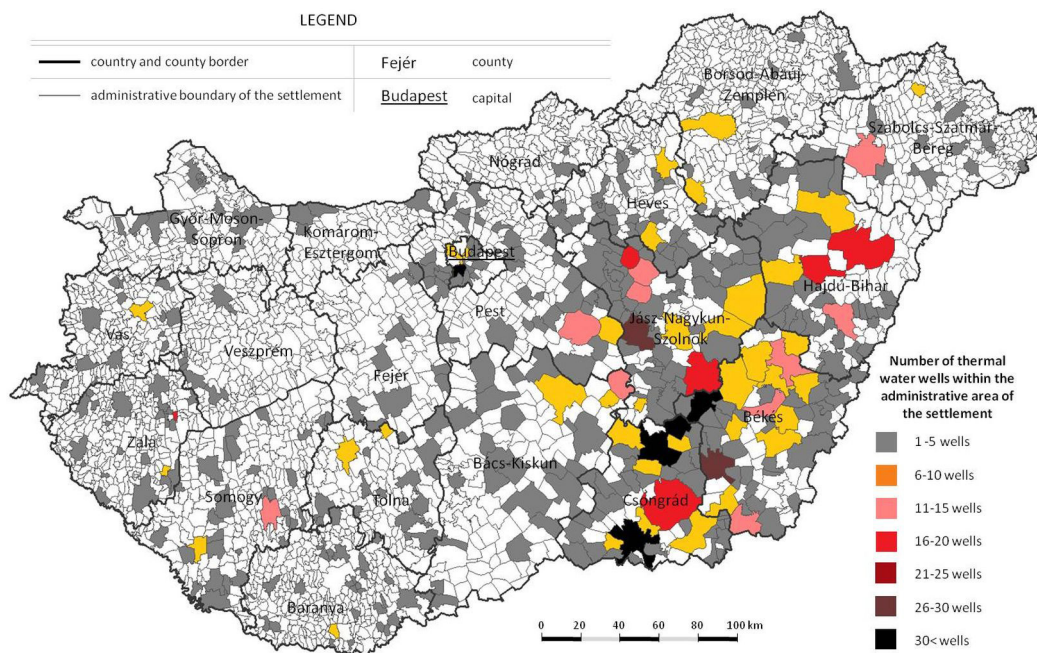


Fig. 1. Geographic location of thermal water wells in Hungary, 2010 (Source: the author on the basis of the data from the National Inspectorate for Water Management (OVF), Cadaster of Thermal Water Wells of Hungary, 2010)

in the private and the public sector. One of the exploitable sources of energy is the groundwater of more than 30°C, which can be found in approximately 70% of Hungary's territory, and for whose utilization nearly 1500 wells have been drilled so far (Mádlné Szőnyi, 2008) (Fig. 1.). The goals of establishment and the current forms of utilization are quite often out of alignment with each other; the priorities of exploitation have been changed in several instances. The economic landscape has changed, and strongly transformed the group of consumers, which is the reason why most of the resources have remained untapped (Kulcsár, 2012). The majority of these capacities have been undiscovered, and therefore potential users are not aware of the local opportunities. The data collection and investigation during the past four years have resulted in drawing up the national utilization structure of thermal water wells and the exploration of the unutilized potentials. The underlying goal in the national renewable energy strategy is to support the process of planning geothermal

energy utilization projects and decision-making (National Energy Strategy 2030).

2. Data processing and Methods

While studying the utilization structure of thermal water wells, first the goals of utilization foreseen at the time of the establishment of the wells were determined. The utilization structure drawn up with respect to the goals of utilization for the 1453 thermal water wells established in Hungary until 2008 (Figure 1) comprised the data and information provided in the Cadaster of Thermal Water Wells of Hungary (Blue Papers) that had been put together by the former Environmental Protection and Water Management Research Institute Nonprofit Ltd (VITUKI) in 1994 (VITUKI, Magyarország hévízkút katasztere, 1994), as well as the records of well cadasters kept by the 12 regional water management directorates. To describe the utilization structure of thermal water wells back in 1994 data from the Cadaster of Thermal Water Wells of Hungary

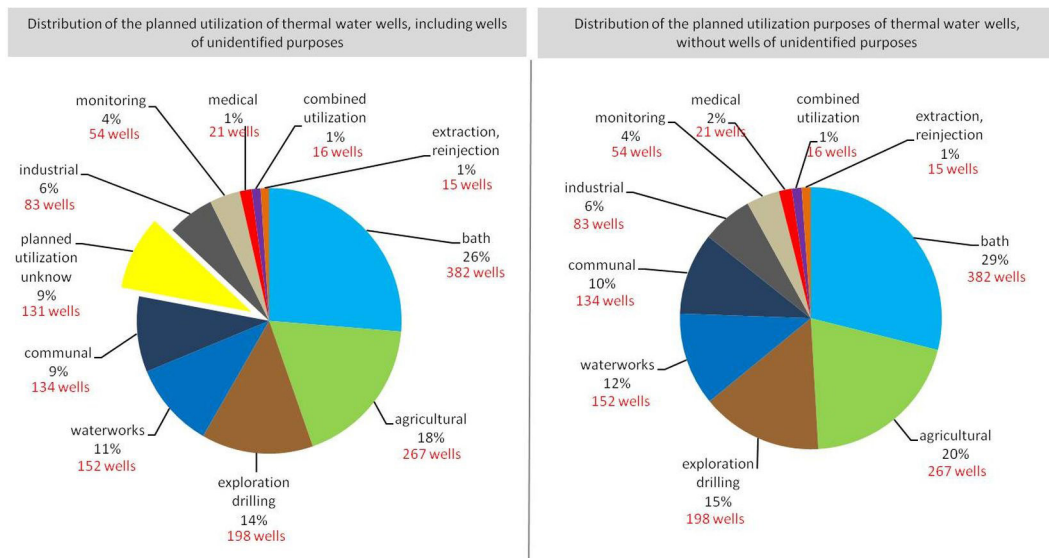


Fig. 2. The planned utilization structure of the thermal water wells of Hungary (Source: VITUKI's Cadaster of Thermal Water Wells of Hungary, 1994; the author on the basis of the regional well cadasters of Hungary)

(VITUKI, Magyarország hévízkút katasztere, 1994) were used, whereas the structure in 2010 reflected the data of the digital cadaster closed in 2010 by the National Water Management Directorate (OVF) (OVF, Magyarország hévízkút katasztere, 2010). The calculations performed for the evaluation of data have been based on the ratios and respective utilization areas of the existing wells. In the course of the investigations, the utilization structures planned at the time of the establishment of the wells were defined, but as the thermal water wells were continuously constructed for over a century, and thus the structure of the wells cannot be compared to the structure in 1994 or 2010, but it serves only information purposes. The only suitable years for the comparison of the utilization structures were the two assessment years (1994, 2010), as a results of which it was necessary to consider the varying quantities of samples. From conditions in 1994 and 2010, the data for thermal water wells of unidentified utilization purposes, as well as the stopped-up or closed-in thermal water wells were screened and ignored, and thus only functioning wells with known utilization structures were included in the comparison.

In these studies, wells of multipurpose utilization form a combined utilization category. The underlying intention was to avoid the inclusion of the same thermal water well in several different utilization categories in the course of the assessment, while the most modern, effective and economical form of the utilization of thermal water wells and the exploited thermal water is shared utilization in the light of the existing water and heat demands, which therefore calls for a separate utilization category. Similarly to a number of other wells, thermal water wells utilized for production, reinjection are used for direct heat utilization in geothermal heating systems, and therefore these facilities serve communal purposes together with the two wells of therapeutic use operated by the hospital of Makó. As a result, with respect to the utilization objectives, these facilities have been classified into the communal utilization category.

The planned utilization structure of the thermal water wells of Hungary

During the examination of planned utilization purposes for the 1453 groundwater wells having effluent temperatures over 30 °C

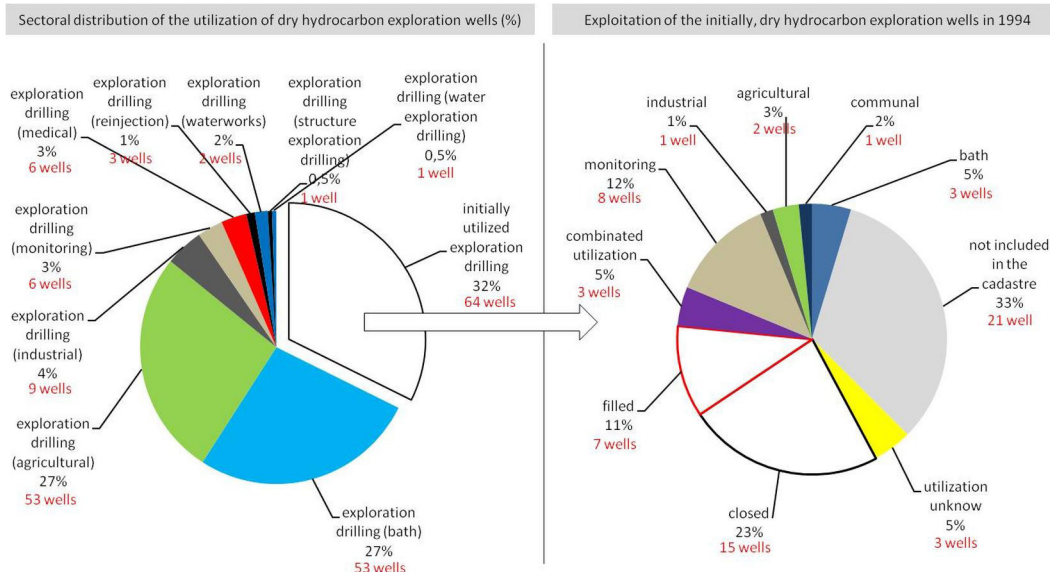


Fig. 3. Distribution of the utilization of thermal water wells constructed from exploratory hydrocarbon drilling in Hungary, and the goals of the utilization of initially unused exploration drillings in 1994 (Source: the author on the basis of VITUKI's Cadaster of Thermal Water Wells of Hungary, 1994; OVf's Cadaster of Thermal Water Wells of Hungary, 2010)

and constructed until 2008 in Hungary, in the case of 131 units of the 1453 wells included in the database the planned utilization purposes could not be identified (not indicated in any of the databases, or tracked back, either).

For information purposes, these facilities are also indicated in the left chart of Fig. 2, but they were ignored in the planned utilization structure as instances for unidentified utilization purposes (right chart). Consequently, a total set of 1322 wells is included in the planned utilization structure.

The results showed that at the time of their establishment the primary field of utilization was use for bathing purposes, with 382 wells constructed for this purpose (29%). This was followed by agricultural utilization with 267 drillings (Fig. 2.). A significant number of drilled wells that had proved to be dry and useless for hydrocarbon (CH) production had revealed thermal water reservoirs, and therefore could be later transformed to serve various water supply purposes (15%). Considering the number of wells, the second- and the third-ranking designed utilization purposes were for waterworks (152 wells)

and communal services (134 wells), which cover 10–12% of the total number of wells. 83 wells were established for industrial use, making up 6% of the wells drilled until 2008. A significant number of wells were established for monitoring the water level, karstic water level and groundwater contamination, which make up 4% of the total number of wells. It is important to specifically mention wells for medicinal use, as well as wells designed for multipurpose utilization, and particularly constructed for production–reinjection purposes, though just a few actual examples can be found.

Two-third of the above-mentioned exploratory drillings were transformed during the upcoming few years after their construction, as reflected in the purposes described in Fig. 3. The predominant forms of utilization were again bathing and agricultural use – representing equal proportions –, and the realization of either options of application was mostly determined by the geographic locations of the drillings, i.e. their lying in the outer or inner areas of settlements. The number of wells transformed to serve industrial,

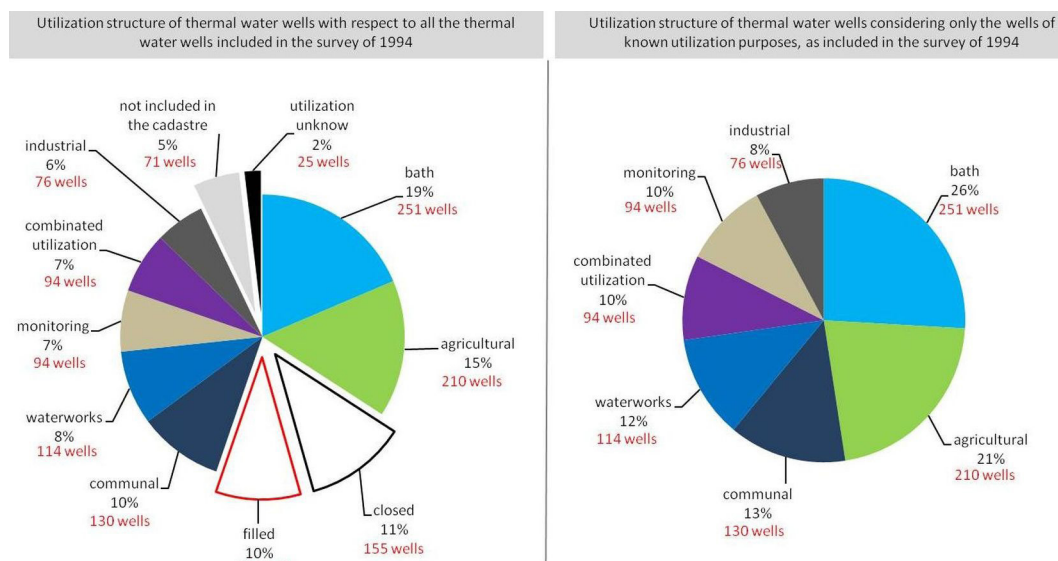


Fig. 4. Sectoral distribution of Hungary's thermal water wells and the ratio of closed-in wells representing unexploited potential with respect to all the wells assessed in 1994 (Source: the author on the basis of VITUKI's Cadaster of Thermal Water Wells of Hungary, 1994).

monitoring and medicinal purposes are also worth mentioning. In one-third of the dry exploratory drillings, the revealed thermal water was utilized just years later (right chart of Fig. 3.).

Utilization structure of Hungary's thermal water wells at the time of the compilation of the thermal water well cadastre, 1994

The utilization structure of 1994 was compiled based on the Cadaster of Thermal Water Wells of Hungary (VITUKI, 1994), and it took 969 thermal water wells into account. At that time, 1350 facilities were registered in Hungary, yet the wells that had been stopped up, closed in or had unidentified purposes were considered – for the sake of completeness, these wells are indicated in Fig. 4 (left chart).

Furthermore, for unknown reasons, this cadaster did not list 71 wells that were subsequently included in the database of 2010, and are known to have existed in 1994 in view of the dates of their construction (Fig. 4., left chart).

26% of all the 969 wells, i.e. 251 facilities served the water demand of the bathing

establishments. The next category comprises the wells that satisfy water supply and heating demands for the agriculture with 210 wells, representing 21% of all the units. They are followed by thermal water wells for communal utilization (130 wells) and waterworks services (114 wells), making up 13% and 12%, respectively.

It is to be pointed out that the meaning of the expression communal is rather problematic, because the interpretation of the word is ambiguous in association with thermal water wells. The established meanings of the word 'communal' are "1. related to a small town, local; 2. pertaining to settlement communities, towns or cities, i.e. things under their control; 3. something used for satisfying the social, healthcare, cultural etc. demands of a community" – therefore the expression primarily refers to use by households. If water supply or wastewater management is concerned in general, then as based on the expressions of industrial water supply, agricultural water supply and communal water supply, the word communal is unambiguously associated with the water supply related to the community. In addition to the word 'communal' the expression waterworks is also in used

Table 1. Types and volumes of combined or multipurpose thermal water well utilization (number of wells) at the time of planning in 1994 and 2010 (Source: VITUKI's Cadaster of Thermal Water Wells of Hungary, 1994; OVF's Cadaster of Thermal Water Wells of Hungary, 2010)

Types of multipurpose utilization	planned utilization	1994	2010
bath + thermal plant			4
bath + industrial	6	12	13
bath + industrial + agricultural		1	2
bath + communal	3	14	19
bath + communal + industrial		3	2
bath + communal + agricultural		4	4
bath + communal + agricultural + industrial		3	2
bath + agricultural	3	27	27
bath + agricultural heating		2	
bath + mineral water bottling			1
bath + reinjection			1
bath + waterworks		9	8
industrial + piped water supply	1	1	2
industrial + communal		3	2
industrial + communal – multipurpose			1
industrial + communal waterworks		1	
(piped water supply)			
industrial + agricultural		2	3
industrial + agricultural + communal heating	1	1	
industrial + social (piped water supply)			1
communal heating + domestic hot water	1		1
communal + medical + bath		1	
communal + agricultural (heating)	1	1	
agricultural + bath + mineral water bottling		1	
agricultural + waterworks		3	3
reinjection + communal			1
waterworks + industrial		2	1
waterworks + communal		2	2

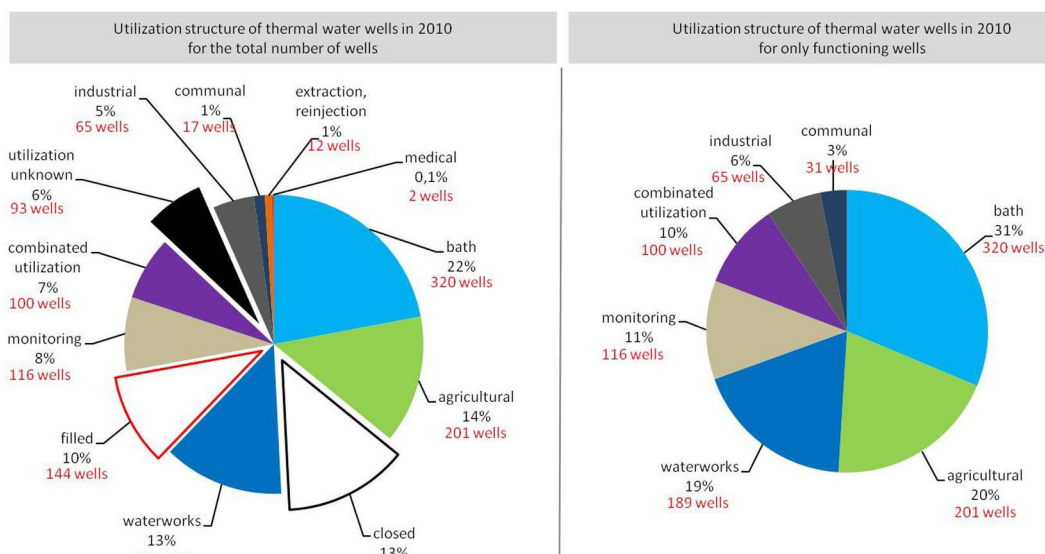


Fig. 5. Sectoral distribution of Hungary's thermal water wells and the ratio of the closed-in wells indicating unutilized potentials, for all the wells in 1994 (Source: the author on the basis of OVf's Cadaster of Thermal Water Wells of Hungary, 2010)

as a specific purpose of utilization. The expression 'communal' used in the context of thermal water wells incorporates a broad range of utilization purposes, but refers to utilization primarily satisfying the demands of households. In the case of the 1994 cadaster, the favoured expressions are the communal waterworks (106 wells) in addition to waterworks (114 wells) (Fig. 4). Furthermore, the following expressions can be found: communal, communal (medicinal), communal (sanitary hot water), communal heating, as well as the communal heating (production) and communal heating (reinjection) versions of this latter term.

While combined, i.e. multipurpose utilization were planned only in 1% of the thermal water wells at the time of their establishment, this ratio increased to 10% in the cadaster of 1994, therefore further utilization purposes were added to the functions of certain thermal water wells. In the case of certain wells, it involves two or three sectors, e.g. at that time the forms of utilization for Well III of Harkány and Well III of Győr were bathing + agricultural + industrial + communal. Within the category

of multipurpose utilization, 22 different combinations can be found, or when the priority order is also taken into consideration the variations count 31. For instance, if for a well used for bathing + communal + agricultural purposes the above order was defined, the primarily utilization purpose was bathing, followed by the satisfaction of communal and agricultural needs. If the order was agricultural + bath + communal, then the priorities were set accordingly (Table 1). Further categories include 94 facilities for monitoring purposes, and 76 wells – thus representing the smallest group – for industrial use, making up 10% and 8% of all the wells, respectively. In the industrial sector, the major users of thermal water wells are the light industry and food processing in following subsectors, such as hemp production, leather, canning and meat industry, sugar production and the mineral water industry. Significant users are the petrochemistry (Algyő hydrocarbon field) and chemical industry, as well as the establishments operated by the Hungarian State Railways (MÁV).

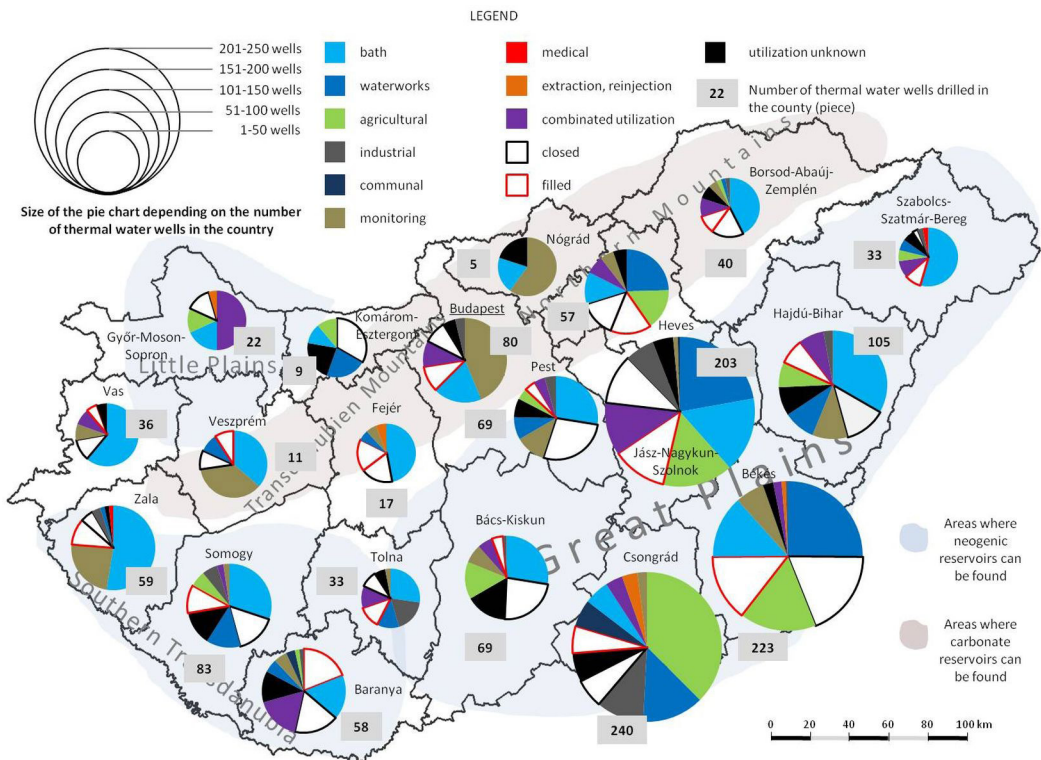


Fig. 6. Number and distribution of thermal water wells in view of their utilization purposes, in the individual counties of Hungary, in 2010 (Source: the author on the basis of the data from the National Inspectorate for Water Management (OVF), Cadaster of Thermal Water Wells of Hungary, 2010)

Utilization structure of Hungary's thermal water wells at the time of the compilation of the thermal water well cadastre, 2010

According to the database of the National Water Management Directorate (OVF) updated in 2010, 1453 thermal water wells were constructed in Hungary until 2008, 1022 of which are currently operational. 144 units of the 1453 wells have been stopped up, 93 feature unidentified utilization purposes (no records can be found in the cadaster), while 194 wells have been closed in, which make up 13% of the established wells. Since the above categories cannot be considered as utilization in the conventional sense of the word, these wells are not included in the utilization structure of 2010. Thus, the number of the utilized thermal water wells of Hungary in 2010 was 1022 (Fig. 5).

During the past 16 years, the ranking with

respect to the utilization structure has not changed substantially; the largest proportion is still represented by wells for bathing establishments with 320 wells, which make up 31% of all the functioning thermal water wells. They are followed by the agricultural facilities with 201 wells (20%), waterworks with 189 wells (19%), the monitoring establishments with 116 wells (11%) and 100 wells for multipurpose utilization (10%).

Regarding the order of exploitation, the only change can be found in the field of communal utilization where the number of wells used for this purpose decreased from 130 to 31, though the underlying reason has been the above-mentioned change in the terminology: using the expression waterworks instead of communal or communal waterworks. It is also supported by the fact that since 1994 only two wells with effluent water of temperatures over 30 °C have been drilled

for waterworks purposes, while reduced water consumption would not have justified the construction of more wells following the year of 1990 anyway. Furthermore, one was stopped up and five were closed in from among the wells that had previously been referred to as communal.

Only two thermal water wells have been constructed for multipurpose use after 1994, whereas in the case of the other wells representing increase in the given numbers the former single-purpose production was completed with other functions (Table 1.). The smallest proportions belong to industrial and communal utilization (Fig. 5.). In addition to users from the sectors recorded earlier, industrial users came to include primarily mineral water bottling companies and soft drink producers. The three wells having been constructed since 1994 have been established for these purposes, too.

The thermal water that can be explored in the territory of Hungary lies in neogenic reservoirs under the Great Plains, Little Plains and South Transdanubia (Tóth-Almási, 2001 Juhász, 1991, Horváth, 2007), whereas in the mountain zones and their close surroundings they can be brought to the surface from carbonate reservoirs (Lorberer, 2004). The regions of the country featuring the most favourable geothermal endowments are the eastern and southern sections of the Great Plains, in particular the highly thick Upper-Pannonian sediments of the Makó Ditch and Békés Depression. For this reason, the largest number of thermal water wells has been settled on this layer formation in the areas of Csongrád, Békés, Jász-Nagykun-Szolnok and Hajdú-Bihar County (Fig. 6.). Owing to the high temperature of effluent water, these wells are used for various purposes as depending on the temperature of thermal water and allowed by the broad temperature ranges (Lindal, 1967). In the southeastern part of the Great Plains having favourable agricultural endowments, a major proportion of thermal water is used in the agriculture, i.e. for heating greenhouses, dryers in Csongrád, Békés and Bács-Kiskun county, whereas in

Jász-Nagykun-Szolnok, Heves, Hajdú-Bihar, as well as Győr-Moson-Sopron and Komárom-Esztergom counties in the Little Plains rather stables are heated, thermal water and other agricultural water demands are satisfied. In the area of the other counties, agricultural use tends to be very scarce.

Across the country, a typical form of the utilization of thermal water is balneology, for which purpose the largest number of thermal water wells have been established in order to supply public baths, and more recently medicinal and adventure baths. This form of utilization is present in the largest proportion in Szabolcs-Szatmár-Bereg, Hajdú-Bihar, Vas and Zala counties. While earlier the water of wells constructed for bathing purposes was solely used to fill the pools, lately with the increase of the price of fossil energy sources the extraction of the heat of thermal waters for heating in the buildings of bathing complexes has been quickly spreading.

In Hungary, the utilization of thermal waters in waterworks and the higher proportion of this form of use in certain areas are determined by several factors. Thermal water is used by waterworks to a considerable extent in the Jászság region (Jász-Nagykun-Szolnok county), where there are no water-bearing layers with sufficient water yields near the surface. In the southern part of the Great Plains, i.e. Csongrád and Békés counties certain elements (e.g. arsenic) in the mineral composition of shallow-lying artesian springs are present in excess of the respective limit values, and therefore the necessary volume of water is made up from thermal water sources. On the other hand, in the areas of limestone mountains thermal water comes from carbonate reservoirs, thermal karst systems, and because of its good quality it can enter communal networks after just minor treatment (e.g. Heves, Komárom-Esztergom, Somogy counties).

There is gradual improvement in the multipurpose, combined utilization of the water of thermal water wells, which serves the betterment of efficiency and enhanced exploitation of capacities. In the field of

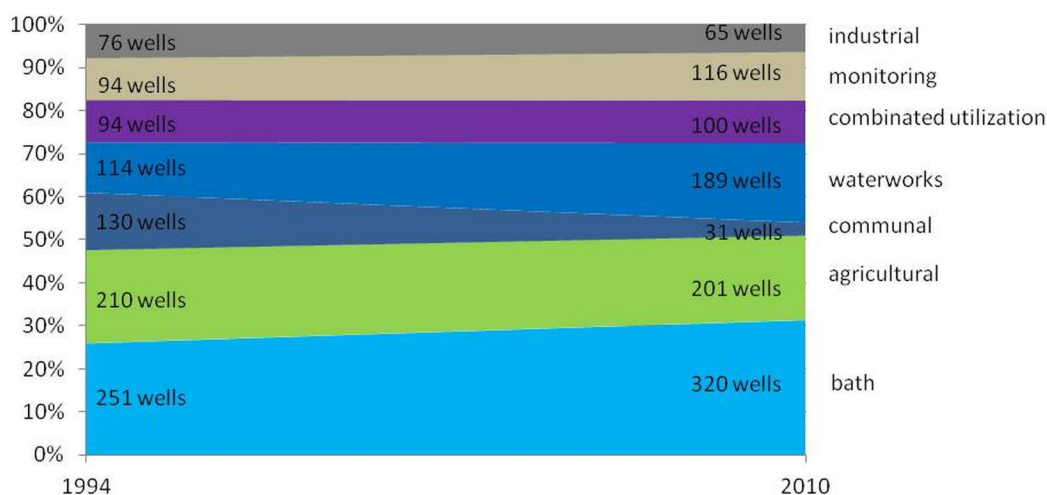


Fig. 7. Changes in the proportions of utilization purposes between 1994 and 2010 (Source: the author on the basis of VITUKI's Cadaster of Thermal Water Wells of Hungary, 1994; OVF's Cadaster of Thermal Water Wells of Hungary, 2010).

multipurpose utilization, the most typical combinations are bathing+agriculture, bathing+communal, bathing+industrial and bathing+waterworks that are mainly present in Győr-Moson-Sopron, Baranya and Jász-Nagykun-Szolnok counties.

Country-wide, thermal water wells for monitoring purposes represent a considerable proportion; these wells can be found in the largest numbers in Zala and Veszprém counties, as well as in Budapest. For such purposes, mostly uneconomically operable waterworks wells of low water yields and unused wells are applied.

Industrial utilization is very rare with respect to the utilization forms of the thermal water wells of the individual counties. Still, outstanding proportions of such use have been achieved in Csongrád and Jász-Nagykun-Szolnok counties. In Csongrád, thermal water is used in the petroleum industry, and it also appears in the light and food industry, whereas in Jász-Nagykun-Szolnok County the key users are light and food industry operators, as well as the railway. The are other, rather scarce examples for the industrial utilization of thermal water wells in some other counties where the demands of the light and food industry are satisfied (Szabolcs-Szatmár-Bereg, Tolna and Somogy

County, Budapest).

In the cadasters, the large majority of the thermal water wells serving the ends of production and reinjection – generally well pairs – have been constructed recently with the principal goal of geothermal heat generation. They are present in the largest numbers in geothermal areas of outstanding endowments, i.e. in Csongrád and Békés counties (Fig. 6.).

3. Results

In the light of our study of changes between 1994 and 2010, it can be claimed that while 1350 thermal water wells had been established until 1994, this figure increased to 1453 by 2010, which means that 103 wells were constructed in 16 years, which brought about 7.5% increase in the number of wells. Within this category, the number of functioning wells – of known utilization purposes – increased to 1022 from 969 (1994), which represents only 5.5% increase involving 53 wells. During this period of time, 14 wells were stopped up, and 65 wells were closed in. In view of the utilization purposes, the most significant, 27.5% increase can be observed in the area of the wells constructed for bathing purposes, where the number of

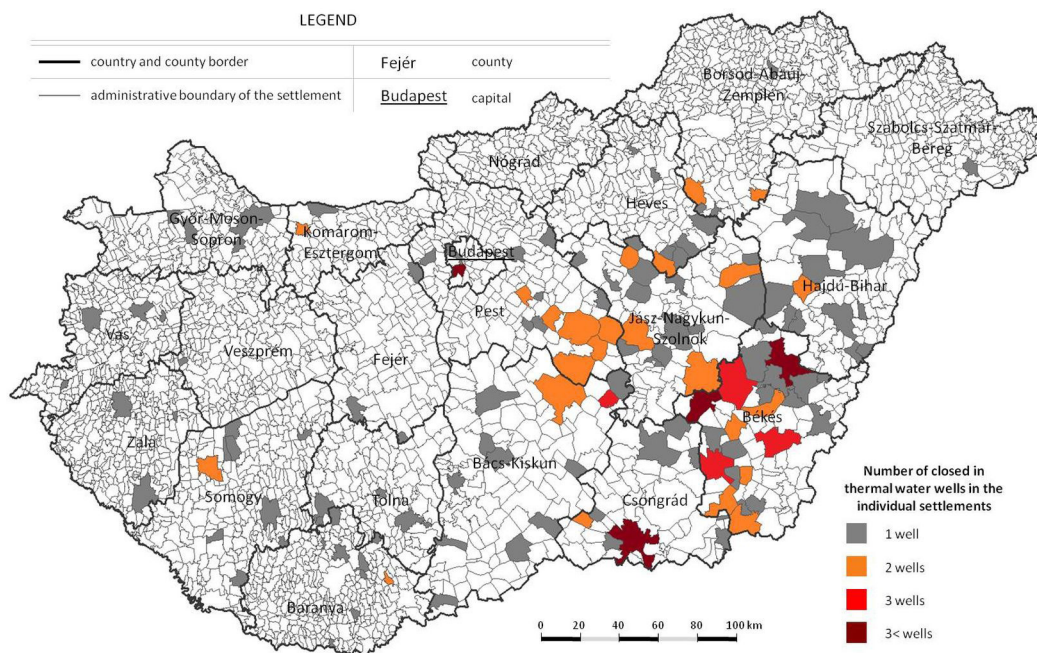


Fig. 8. Geographic location of closed-in thermal water wells in Hungary, 2010 (Source: the author on the basis of the data from the National Inspectorate for Water Management (OVF), Cadaster of Thermal Water Wells of Hungary, 2010)

facilities increased by 69 wells on the whole (Fig. 7.).

The number of monitoring wells increased from 94 to 116, i.e. by 23.5%, whereas the number of wells for combined use also rose from 94 to 100, i.e. by 64%. For 73% of thermal water wells of combined utilization, there have been no change in the multipurpose utilization structure of the given wells. For ten establishments, further utilization goals have been added to the earlier single form of use, while in the case of nine thermal water wells the scopes of exploitation have been narrowed. For two wells, multipurpose utilization has been terminated, whereas for two others it has been introduced. Since 1994, there have been three thermal water wells constructed specifically for combined utilization, another well that was closed in earlier has been re-commissioned for multipurpose use, and finally two engineering structures have been closed in (Table 1.). As it is apparent from Figure 7, the largest pace of increase in these proportions took place in

connection with the number of waterworks wells, but as it has been mentioned above the alteration in the associated terminology can be the underlying reason. The number of wells belonging to communal utilization decreased approximately at a pace similar to this increase. Basically both waterworks and communal wells are used to satisfy the water supply demands of households. Consequently, if these two categories are combined with each other, the number of wells belonging to these two groups decreased from 244 from to 220 wells in 16 years, which means a nearly 10% drop. Similarly, the number of wells for industrial and agricultural utilization purposes diminished. The number of industrial and agricultural wells shrank by 14.5% and 4.3%, respectively (Fig. 7.).

Hungary's thermal water utilization structure does not include wells that have been stopped up, closed in or are of unidentified utilization purposes. Nevertheless, the importance of the closed-in wells not considered in the determination

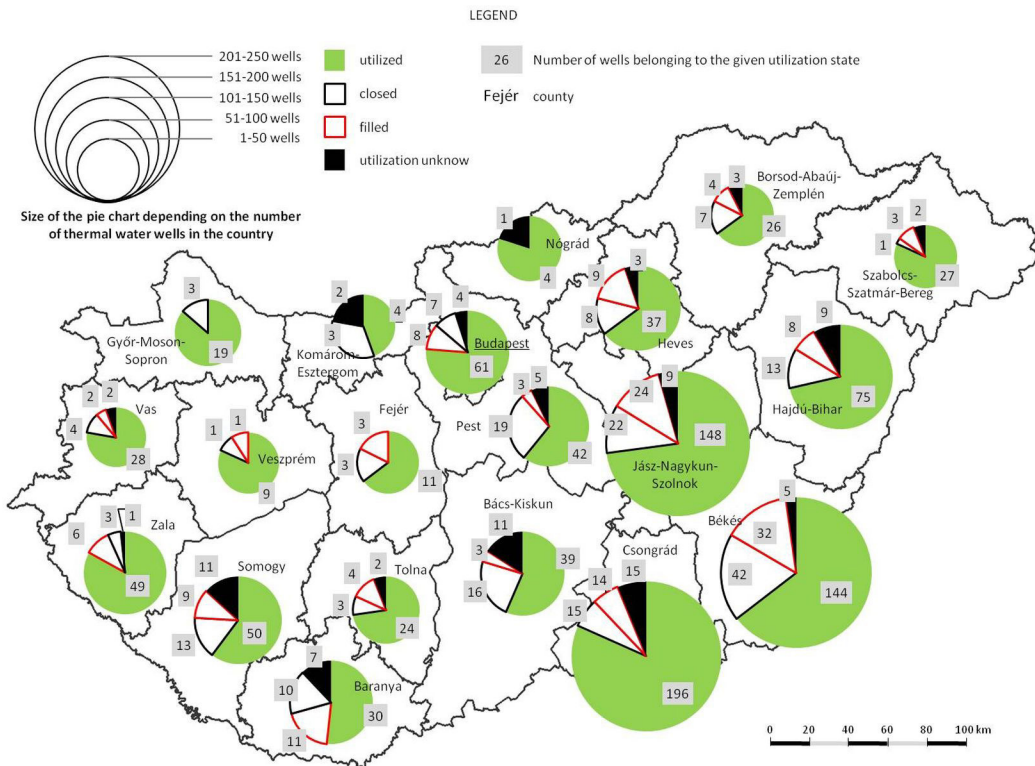


Fig. 9. Proportions of closed-in thermal water wells in the individual counties of Hungary, 2010 (Source: the author on the basis of the data from the National Inspectorate for Water Management (OVF), Cadaster of Thermal Water Wells of Hungary, 2010)

of the utilization structure is not negligible. In the database of 2010, 194 such wells were listed, which made up 13% of the total number of wells (Fig. 8.).

The closed-in facilities comprise a usable inventory of engineering structures; among other things, they are closed in, because the current ways of utilization are not manageable. The companies, cooperatives and other businesses formerly operating the closed-in wells have been dissolved, and in the light of the current demands the wells are unneeded, or are kept in reserve.

The exploitation of still untapped geothermal potentials, primarily for heating constructed structures, is becoming an increasingly favoured form of thermal water well utilization. It is primarily the state-owned public buildings that are regarded as suitable for the economical, efficient use of this source of heat energy.

It is our obligation imposed by the European Union and national interest to frame long-term building service engineering programs and elaborate energy strategies for long-term energy safety, efficiency and the realization of low-cost operation (2012/27/EC). To create the National Energy Strategy for the Building Sector, all those alternative energy production options have to be taken into consideration that serve the cost-efficient accomplishment of the above goals.

To satisfy the heat demands of public buildings in the individual settlements from geothermal sources, in most cases new thermal water wells are constructed, but it has substantial costs (in 2010, a 1000–1500 meter deep well could be constructed by expending HUF 100–150 million). It is therefore worth considering the number of the existing wells in the area or surroundings of the investment, as well as their usability

with respect to the prevailing conditions (e.g. utilization of existing closed-in wells after reconstruction during the development of the geothermal cascade system of the University of Debrecen).

In Hungary, the majority of the currently closed-in – i.e. operable, but not utilized – thermal water wells can be found in the central, eastern and southeastern parts of the Great Plains, meaning that they are located in regions with more wells owing to the most favourable geothermal endowments. An exception is Csongrád County, where in spite of the large number of wells there are just few unused and terminated thermal water wells, which indicates the appropriate design of these wells and continuous, prospering users (Fig. 8-9.). There is an outstandingly large number of unused capacities in Békés County, where the number of thermal water wells out of operation exceeds 40. The numbers of closed-in wells are significant – falling in the range of 10–22 wells – in Jász-Nagykun-Szolnok, Pest, Bács-Kiskun, Csongrád, Hajdú-Bihar, Somogy and Baranya counties. There are some fewer, but still not insignificant number of engineering structures (7–8 wells) waiting for utilization in Budapest, as well as Borsod-Abaúj-Zemplén and Heves counties. In the counties having the smallest numbers of thermal water wells, unutilized capacities are low, yet may represent large proportions in comparison with the total numbers of wells. In Pest County, for instance, 28% of thermal water wells are not used, and the corresponding proportion is 23% in Bács-Kiskun County, 17% in Baranya County, 2+% in Somogy County (Fig. 9.).

30% of the wells are located in the inner areas of settlements, whereas 70% can be found outside settlements. The geographic locations of closed-in establishments coincide with the regions where larger settlements are situated. These settlements have considerable inventories of buildings to use the heating capacities of these wells, while their economic powers are more suitable for financing costly geothermal investments, the obtainment of grant application funds (Fig.

8.).

The conditions of closed-in thermal water wells, however, make their utilization questionable, and therefore they are to be subjected to individual well tests. The results of the tests highlight the expenditures to be allocated to the reconstruction, and then economic analysis is performed to decide whether the given well can be used for the planned purpose, or it is financially more reasonable to construct a new establishment.

Certain conclusions can be drawn from the available data pertaining to the earlier utilization of closed-in wells, the duration of standby state, as well as the year of construction. In 2010, 48 of the closed-in wells – of which 29 wells had already been closed-in back in 1994 – were managed by the regional waterworks; in response to the decrease of water consumption after the change of the political regime, they had been placed in reserve, but they were regularly maintained by the waterworks, and therefore most of these facilities were in good conditions.

The largest number of thermal water wells that are currently out of operation are those having been constructed for agricultural purposes; in 2010 there were 53 such wells. Of this group, 36 wells had already been closed-in in 1994. Ten wells established for industrial purposes are not operated with three of them not producing water back in 1994, either. In the light of our experience earned in the case studies and onsite visits during the earlier research, the conditions of a large number of wells having left without users – and proper maintenance – upon the dissolution of agricultural cooperatives and industrial plants can be claimed to be bad. The re-utilization potentials of these thermal water wells are further deteriorated by the fact that their majority can be found in outer areas, and therefore they can potentially be used primarily in the field of agriculture.

The number of wells established for use in balneology, and then closed in is 34, of which 23 wells are fully unused. Half of these closed-in wells served the bathing

establishments of small settlements, but they could not be operated and sustained under the changed operating circumstances, and therefore the wells were closed in together with the bathing facilities. Closed-in bathing water wells in the towns are not operated as a result of the closure, integrations of several small bathing establishments formerly run by the settlements.

The year of establishment also carries information with respect to the usability of the well, the reconstruction options and expected costs. 24% of the wells being closed in in 2010 were constructed before 1960, 55% of them between 1960 and 1970, 21% just thereafter, and there are wells that were established in 2002. The operability and reconstructing potentials of establishments that are older than 50 years are doubtful, and in most cases reconstruction efforts would involve such expenditures that in most cases the construction of a more modern well is more reasonable. On the other hand, old wells may as well be operated reliably, for instance well no. 1 of Széchenyi Baths established back in 1878 is still used, which suggests that regularly maintained facilities can be kept serviceable even for 100–150 years. Finally, with the development of the technological means of the reconstruction of thermal water wells and well testing methods, they can be brought back to operation with gradually decreasing costs.

4. Conclusions

The remarkable growth that can be seen in the field of balneology utilization is based on the substantial economic development of settlements with medicinal and adventure baths. Offering broad ranges of services at high standards, these establishments with medicinal water qualifications and the related tourism infrastructure are major sources of revenues for the hosting local government and inhabitants (Csomós-Kulcsár, 2011). In the light of the results of studies on tourism and economic structure, it can be seen that after the turn of the millennium there have

been numerous settlements expending considerable European Union funds on medicinal and adventure tourism investment (KSH, 2013, *A gyógyturizmusban érintett települések Magyarországon* [Settlements concerned in medical tourism in Hungary]). To supply these facilities, mostly new thermal water wells have been established.

The decrease in the number of water facilities used in the agriculture and industry surfaced as a consequence of the economic fallback in the period between the two assessments, the dissolution of a number of business entities pursuing agricultural activities, processing companies (KSH, 2005, *Magyarország mezőgazdasága, gazdaságtipológia, 2000, 2003* [Agriculture in Hungary, Farm typology, 2000, 2003]; KSH, 2008, *Magyarország mezőgazdasága, gazdaságtipológia, 2007* [Agriculture in Hungary, Farm typology, 2007])(Fig. 7.).

The number of monitoring wells for the observation of the water level and contamination was primarily increased by the application of exploratory drillings in the 1960s for water monitoring purposes, but they were still not included in the thermal water well cadaster of 1994 due to the lack of their water management function. Apart from the foregoing, in 2010 there were one well for each of the balneology, agricultural, industrial and communal forms of utilization that also performed monitoring tasks.

The slow increase in the number of thermal water wells of combined utilization that is regarded to be the most efficient form of use clearly reflects that domestic investments for the utilization of renewable energies and energy efficiency progress at a rate of spread that is below the desirable pace.

The closed-in facilities are operational, but they are closed in, because the current ways of utilization are not manageable; the companies, cooperatives and other businesses formerly operating the closed-in wells have been dissolved, and therefore the wells are currently unneeded, or are kept in reserve.

From Hungary's 3154 towns and villages

(KSH, 2014), there are approximately 729 settlements with multiple disadvantages (Government Decree 240/2006 (Nov 30), 2014), which is due to complex reasons. They are all characterized by acute employment crisis, high unemployment rates, the lack of enterprises, poor infrastructure, large distances from central cities, difficult accessibility, which results in exterior and interior peripheral conditions. Because of the low level of incomes in these settlements, the general conditions are deteriorating, the obsolescence of facilities and the infrastructure is apparent, the maintenance costs are steadily increasing and therefore cause growing burdens for the settlements, consequently the operation of the local governments is increasingly rendered impossible without external assistance, which on the other hand poses weighty expenses on the state and society. Financing the maintenance of the local institutions tend to be an increasingly challenging responsibility not only in settlements with multiple disadvantages – , but even in finely prospering cities with larger number of inhabitants and incomes, since it withholds considerable funds from the regional development tasks.

A possible way out of this situation may be the satisfaction of local energy demands by utilizing the locally accessible renewable energy sources. The exploitation of still untapped energy potentials, primarily for heating constructed structures, is becoming an increasingly favoured form of thermal water well utilization (Pálné Schreiner, 2012., Benke-Pátzay, 2010). This source of heat energy is primarily suitable for economical and efficient use when utilized in the public buildings managed by the local governments (Kóbor et al., 2008; Szanyi-Kovács, 2010), while in places of favourable conditions it potentially allows the development of settlement-wide systems for the use of renewable energy sources, or as specific

component it can be incorporated into combined renewable energy systems.

5. Summary

During the 16 years having elapsed between the two surveys, there have not been substantial changes in the focal points of the utilization structures of the thermal water wells in Hungary. The dominant sectors of utilization are still bathing, agriculture and waterworks. Some changes can be observed in the areas of monitoring and multipurpose utilization, where the number of the monitoring wells increased at a larger rate than the wells of combined utilization purposes.

The proportion of closed-in wells is significant in the utilization structure of thermal water wells (13%) which should be taken into account in the planning of geothermal utilization projects. The renewal options of closed-in, but operational wells need to be assessed as based on individual well surveys and economic analysis.

In the cadasters and records of Hungary's thermal water wells, the information pertaining to the utilization purposes of wells defines excessively broad categories, they are rather inconsistent and the terminology (e.g. communal) is not unambiguously determined. It seems to be desirable to conduct a nationwide survey that would provide detailed information of thermal water wells, and shed light on the forms of the utilization of the wells in question.

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