GOSPODARKA SUROWCAMI MINERALNYMI – MINERAL RESOURCES MANAGEMENT

2020 Volume 36 Issue 1 Pages 123–134

DOI: 10.24425/gsm.2020.132555

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Rational management of geothermal waters after their energetic use – preliminary results of the project Geotermia Mazowiecka SA

Introduction

The geothermal waters from the Lower-Cretaceous sandstone intake from of well Mszczonów IG-1 have been exploited since 2000 by joint-stock company Geotermia Mazowiecka SA. This is one of six geothermal heating plants operating in Poland that generate heat for network customers (Fig. 1). In Mszczonów the approved amount of geothermal water resources is 60 m^3/h, at 25 m depression and 40.5°C wellhead temperature. The level of the static water level is 50 m below ground level. The reservoir water is therefore producted to the surface using a submersible pump. A specific feature of the intake is the fact that geothermal waters from a depth of about 1600–1700 m below the surface, have coutaining about 0.5 g/L of TDS, which allows them to be operated in a single well without injection

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Fig. 1. Location of Polish geothermal heating plants. The Mszczonów, Uniejów and Poddębice exploit waters from the Lower Cretaceous, Pyrzyce and Stargard – from the Lower Jurassic, in Bańska-Biały Dunajec – from mainly Triasic sediments

Rys. 1. Lokalizacja zakładów geotermalnych w Polsce. Mszczonów, Uniejów i Poddębice – wydobycie ze zbiornika dolnej kredy, Pyrzyce i Stargard – ze zbiornika dolnej jury, w Bańskiej-Białym Dunajcu – z głównego kolektora triasowego

into the level of source, while creating the possibility of using them for municipal purposes in drinking water installations and recreation centre (Bujakowski 2000, 2001; Bujakowski et al. 2000).

The main purpose of the geothermal heating plant is to generate thermal energy for the city of Mszczonów. It is implemented in two independent heating systems with technological parameters 80/60°C and 70/50°C. The first system uses an 2.7 MW absorption heat pump to cool the reservoir water (temp. 40.5°C) to approx. 20–30°C and generates heat for the higher temperature installation, the so-called "high circulation". The second is based on a compressor heat pump with a capacity of 1 MW, which further cools the aquifer water to about 17°C and produces heat for a lower temperature consumer network, the so-called "small circulation" (Bujakowski et al. 2017). As a result, an exceptionally wide interval of reception and rational management of geothermal heat was obtained, which was based on the relatively very low entry temperature of reservoir waters. Parallel to these activities related to maximizing energy production, work was undertaken on the use of water only.

These activities, dictated by environmental considerations, has resulted in a partial management of the producted water at the Water Treatment Plant (WTP) for consumption and at the "Termy Mszczonów" (recreation centre). Despite these solutions, a certain amount of water, necessary for the energy production process, had to be discharged into a surface watercourse in accordance with the regulations. The management of these waters was the subject of research work carried out as part of the project of the Regional Operational Program of the Masovian Voivodship for 2014–2020 (Priority Axis: Research and development activities of enterprises). This project entitled: "The development of a method for injecting after energy-used geothermal waters into selected geological structures" was implemented by a team of three institutions, i.e. joint-stock company Geotermia Mazowiecka SA (project leader), the Mineral and Energy Economy Research Institute of the Polish Academy of Sciences from Krakow and Warsaw University of Technology. The aim of the project was to optimize the process of using excess water through the use of innovative technology for their injection into a quaternary aquifer (relatively shallow), with the possibility of their later use for drinking and for social and living needs.

1. Utilization of reservoir waters at the Geothermal Plant in Mszczonów

The geothermal water is producted from the well Mszczonów IG-1 using a multi-stage submersible pump. Operational parameters were documented and approved during the reconstruction of the well (Balcer 2015; Kurek 2015). Aquifer tests, as well as research and analysis of water have allowed the determination of safe for stable operation of the horizon and water quality of the mentioned earlier parameters (Barbacki et al. 2000; Bujakowski 2000, 2001).

The exploitation of geothermal waters in Mszczonów has been conducted since 2000. Total production from the Mszczonów IG-1 well was over three hundred and several dozen thousand m^3 annually. About 1/3 of this value is directed directly from the well to the "Termy Mszczonów". The main stream of water (about 2/3 mass) is fed to the geothermal heating plant. The use of water in "Termy Mszczonów" is recreational and balneotherapeutic in nature and has been implemented since 2008 as an additional way of making the management of local water resources more attractive. The main stream directed to the geothermal heating plant is aimed at implementing the basic task of the installation, i.e. generating energy for heating the city. Geothermal water is used as an energy carrier that powers the lower sources of the absorption and compressor pumps. Figure 2 present charts for the volume of water production and management in the last 8 years (2012–2019).

The exploitation of geothermal water from the well is determined by the energy needs of heat recipients. Over the nearly 20 years of operation of the geothermal heating plant in Mszczonów, the number and energetic characteristics of recipients have changed, which was related to the systematic expansion of the system and thermomodernization of facilities.

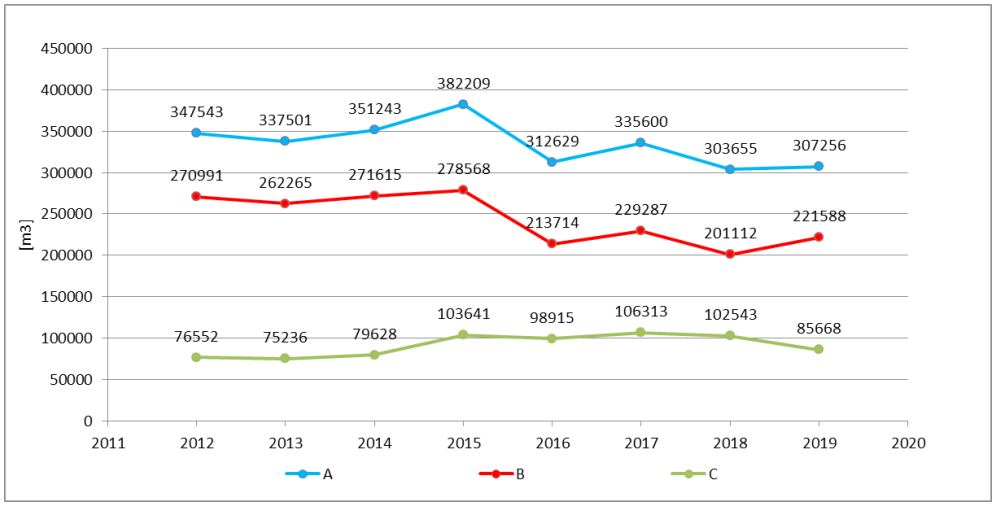

Fig. 2. A – Geothermal water production in the Mszczonów IG-1 well,
B – The use of geothermal waters in the geothermal plant for heating purposes,
C – The use of geothermal water in the recreation centre Termy Mszczonów

Rys. 2. A – Wydobycie wody geotermalnej otworem Mszczonów IG-1,
B – Wykorzystanie wód geotermalnych w Zakładzie Geotermalnym do celów ciepłowniczych,
C – Wykorzystanie wody geotermalnej w ośrodku rekreacyjnym Termy Mszczonów

Figure 3 presents a graph of changes in energy sales throughout the entire period of operation of the geothermal heating plant. It is worth recalling here a comparison of net heat prices in heating plants operated by the joint-stock company Geotermia Mazowiecka SA and using different fuels, i.e. (price for GJ in 2016): in Sochaczew (coal heating plant) – 11.83 €/GJ, in Błonie (gas heating plant) – 16.85 €/GJ and in Mszczonów (geothermal heating plant) – 14.6 €/GJ. Energy generated in the geothermal heating plant in 2016 was more expensive than energy from a coal-fired heating plant and cheaper than heat from a gas-fired heating plant (Bujakowski et al. 2017; Pająk and Bujakowski 2018).

The energy needs of customers are covered by the geothermal heating plant using geothermal heat pumps supported by gas boilers. This hybrid energy source solution is typical for geothermal heating plants, being safe and economically effective. In the Mszczonów installation, geothermal water is the very important energy carrier, however, due to the low temperature in the final energy balance, the share of geothermal energy is estimated at about 40%, the remaining part of heat comes from gas. In other Polish plants, these shares are different, e.g. in Geotermia Podhalańska SA more than 90% of the energy produced comes from geothermal energy, which is the result of obtaining reservoir water at a temperature of over 85°C (Tomaszewska ed. 2018).

The geothermal water stream directed to the geothermal plant in Mszczonów, after being used for energy purposes in heat pumps, is directed to an automated water treatment plant (WTP) located near the heating plant. There, in mineral filters, it is mixed with quaternary

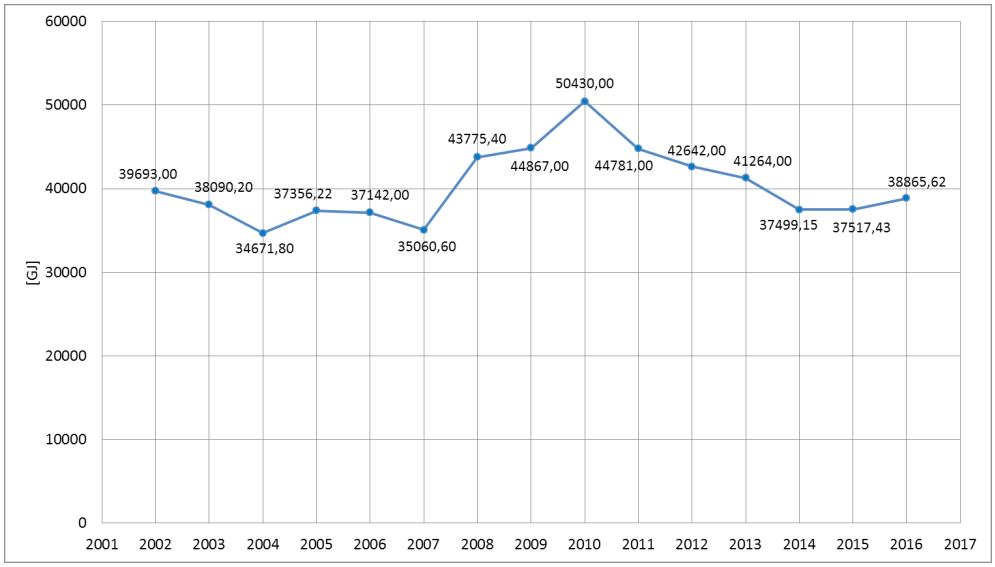

Fig. 3. Sale of heat energy by the geothermal heating plant in Mszczonów (Bujakowski et al. 2017)

Rys. 3. Sprzedaż energii cieplnej przez Zakład Geotermalny w Mszczonowie

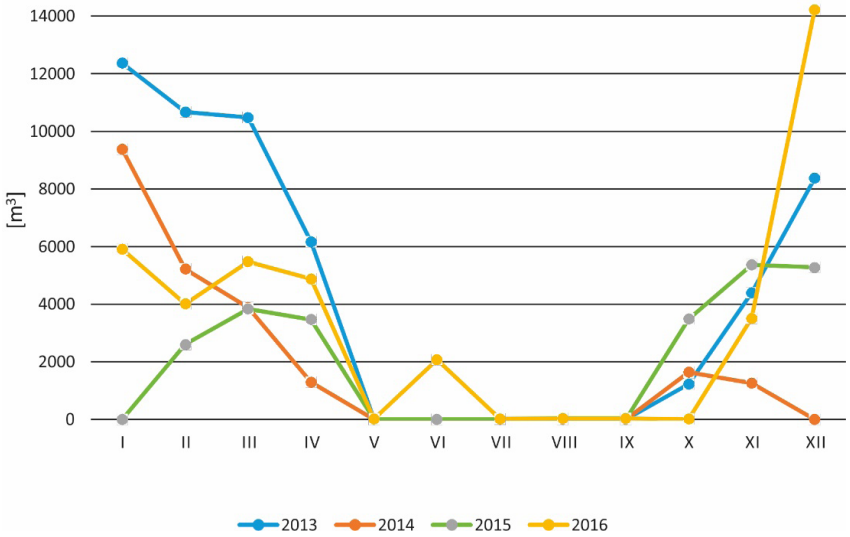

Fig. 4. The use of water from the geothermal heating plant in the municipal water supply system via WTP (Bujakowski et al. 2017)

Rys. 4. Wykorzystanie wody z Zakładu Geotermalnego w miejskiej sieci wodociągowej poprzez SUW

water, treated to drinking water parameters and pumped to the municipal water supply system and goes to the residents of Mszczonów (Balcer 2015; Bujakowski et al. 2017). Geothermal waters has been the subject of numerous considerations as alternative water resources intended for consumption (Pająk et al. 2020; Tomaszewska et al. 2020; Tyszer and Tomaszewska 2019). Water from the Mszczonów IG-1 well possess chemical composition permitted it to be used as drinking water. Only iron and ammonia show slight exceedances. The iron content is about 0.9 mg/L (permissible level up to 0.2 mg/L) and ammonia > 0.5 mg/L (permissible level up to 0.5 mg/L). Mainly for these reasons, geothermal waters require treatment at the WTP station before being used as drinking water.

Graphs of monthly water use in the water supply network for selected years presented in Figure 4 show that water use is not stable in particular periods of the year. In the period outside the heating season, from May to September, geothermal water is minimally producted from the well due to very low heat production and consumption. In the winter season, when the largest amounts of energy are produced, also the largest amounts of cooled water are directed to the WTP.

2. The structure of the use of geothermal water after commissioning of the installation for injecting cooled waters into shallow hydrogeological formations

The analyses presented above show that significant amounts of water necessary for the energy production process are undeveloped despite their inclusion in the drinking water supply system and use in the "Termy Mszczonów". These waters were directed, according to permits, to the storm water drainage system and, as a result, went to surface watercourses. It is estimated that in 2015–2017 over 50% of the water was utilized in this way.

Being guided by environmental considerations related to the improvement of drinking water retention (Tomaszewska 2015) but also by far-sighted objectives related to the economic efficiency of the entire geothermal system, the Management Board of Geotermia Mazowiecka SA undertook the implementation of an innovative above-mentioned project.

As a result of research and development, done the well to allow the injection of water to quaternary sandy deposits located at a depth of about 100 m below ground level (Bujakowski et al. 2018b; Gawlik et al. 2017). Conducted research and tests gave material for the preparation of necessary documents and obtaining a water injection legal permit for a period of 20 years. This decision concerns the injection of cooled geothermal waters to groundwater using the B-1 well in Mszczonów and for the periodic uptake of the mixture of injected water with water of the Quaternary layer for the target use in the water supply network. The permit allows the discharge of cooled geothermal water up to a maximum of 197 100 m^3/year, 0.00833 m^3/s, daily average 540 m^3/d. It also allows the intake of mixed stored water in the amount of 87 600 m^3/year, average daily 240 m^3/d and maximum of 0.00833 m^3/s (Bujakowski et al. 2018a).

The structure of water consumption in the geothermal installation in Mszczonów is presented in diagrams A, B and C in Figure 5.

On Figure 5 graph A shows the average water consumption in the years (2015–2017) preceding the implementation of the project by Geotermia Mazowiecka SA Therefore, it is the reference state for the next stages of implementing water injection technology. The discharge of water into the rainwater drainage system is more than 50% of the total extraction. Chart B presents effects obtained during the project implementation (2018). Compared to the reference image (A), a segment appears (QA) covering 15% of the mass of water directed to the Quaternary sandy layer. The amount of water directed to discharge into the rainwater drainage system (RSS) clearly decreased. This effect would be much larger if the amount of water directed to WTP were at an earlier level, however, the waterworks plant did not receive

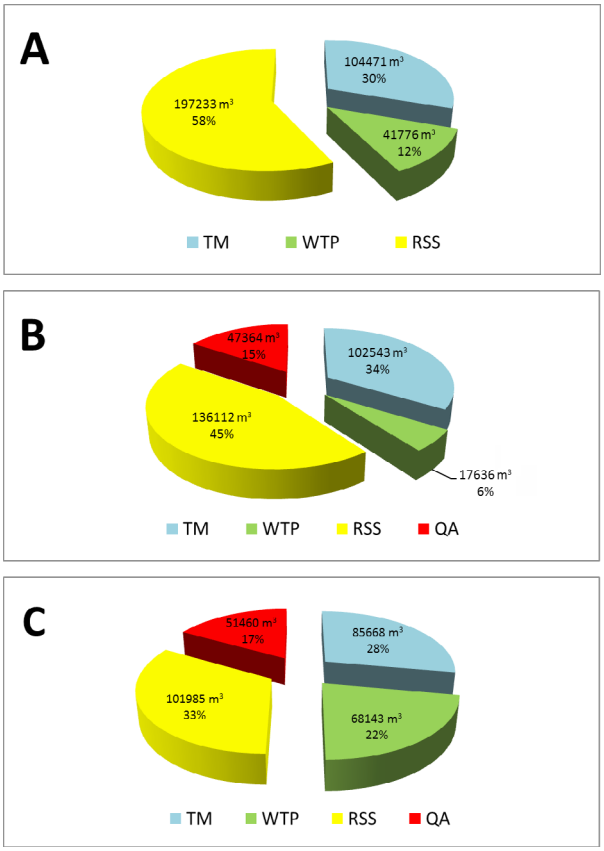

Fig. 5. Structure of geothermal water consumption: A – average from 2015–2017, B – in 2018, C – in 2019. TM – Termy Mszczonów, WTP – Water Treatment Plant, RSS – Rainwater Sewage System, QA – Quaternary Aquifer

Rys. 5. Struktura zużycia wód geotermalnych: A – średnia z lat 2015–2017, B – rok 2018, C – rok 2019. TM – Termy Mszczonów, WTP – Stacja Uzdatniania Wód (SUW), RSS – kanalizacja deszczowa, QA – czwartorzędowa warstwa wodonośna

potentially possible water management due to the project work. A more complete picture is presented in the C chart, which concerns the structure of water consumption in the first year of project results (2019). The main purpose of research, which is to reduce the discharge of water into surface watercourses (RSS), has been achieved very clearly. From the original 58% of the mass of water producted , this value was reduced to 33%. This image applies, as noted, the first year after commissioning of the water injection installation, therefore, has the value of movement test documentation. Figure 6 presents the structure of changes in water use in this first year (2019) on a monthly basis. This graph shows the various stages of the absorbent installation. In the first period, water injection into the aquifer (QA) was generally with a capacity of about 10 m^3/h. at head pressure up to 0.2 MPa. Unfortunately, after these few months, the injection was stopped due to the finding of water outflow to the surface. After testing for possible unsealing of the pipe column in the absorbent well and after its modernization, consisting in the introduction of an additional column of borehole pipes, injection was started. In November 2019, the injection rate was reduced again due to surface water leakage. After analysis, gravitational injection was started with a capacity of 2–3 m^3/h. The next year, decisions will be made regarding further corrective actions related to the absorbent installation.

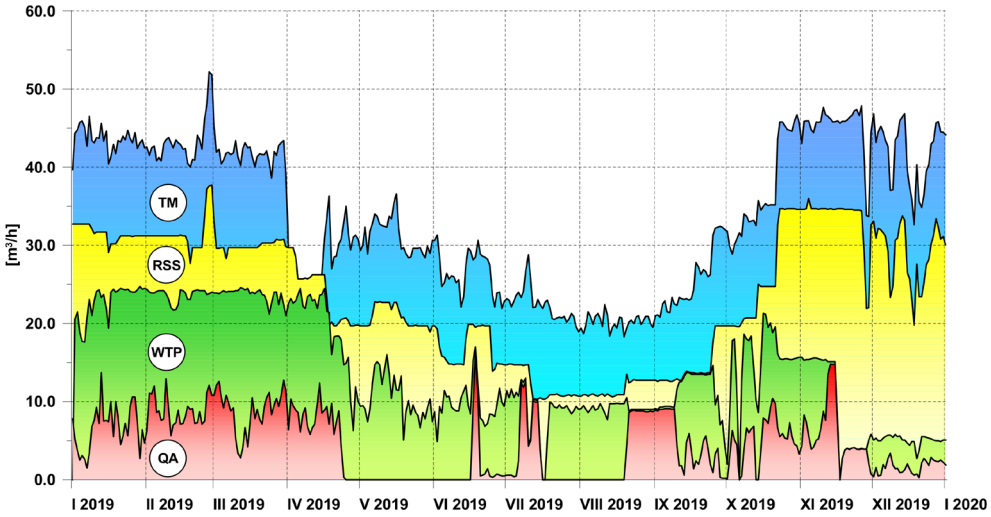

Fig. 6. Graph of changes in the directions of use of geothermal waters in the first year of operation of the injection cooled waters. Explanations as in Figure 5

Rys. 6. Wykres zmian kierunków wykorzystania wód geotermalnych w pierwszym roku funkcjonowania instalacji zatłaczania schłodzonych wód. Objaśnienia jak na rys. 5

Summary

The problem of drinking water deficit and replenishment of their natural resources is clearly growing in Poland. Also guided by these premises, the Management Board of Geotermia Mazowiecka SA decided that the possibilities of use of exploited waters than for energy purposes should be recognized. This was done by an innovative research project called "The development of a method for injecting after energy-used geothermal waters into selected geological structures" implemented as part of the Regional Operational Program of the Mazowieckie Voivodship for 2014–2020 (Priority Axis: Research and development activities of enterprises). This project resulted in the launch of the injection of the used water to the Quaternary sandy layer. In the first test year of the installation commissioning, a nearly 50% reduction of previously discharged to the surface watercourses was obtained. Based on the results of the project so far, it can be assumed that it is possible to achieve nearly 100% reduction of discharge and making full use of the exploited reservoir waters.

In addition to these results, studies and observations on parameters (pressure, chemistry and water temperature) have been and are still carried out in the Quaternary sands layer. The effects of these studies, during the project period, increased in formal approvals for the injection process. After the project, observations of these parameters will be continued and published systematically.

To sum up, it can be concluded that the geothermal energy in Mszczonów is a unique installation not only in Poland, but also internationally. The evidence for this is not only the scale of rational use of geothermal water for energy purposes (cooling from 40.5°C to about 17°C), but also their use in other areas: for recreation in Termy Mszczonów and for the production of drinking water using shallow aquifers.

Article was created as part of the project: "Development of a method for injection of geothermal waters used for energy purposes into selected geological structures". Co-financed by the European Regional Fund under Priority Axis: I – Use of research and development activities in the economy. Action: 1.2 – R&D activities of enterprises. Regional Operational Programme of Mazowieckie Voivodeship for 2014–2020.

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RATIONAL MANAGEMENT OF GEOTHERMAL WATERS AFTER THEIR ENERGETIC USE – PRELIMINARY RESULTS OF THE PROJECT GEOTERMIA MAZOWIECKA SA

Keywords

geothermal water, Mszczonów geothermal heating plant, waters intended for drinking

Abstract

Poland belongs to the countries with limited waters intended for drinking resources. To meet this problem, the Management Board of Geotermia Mazowiecka SA carries out activities to determine the possibilities of using exploited geothermal waters other than energy purposes.

In addition to energy, the geothermal water is used for recreation and balneotherapy in "Termy Mszczonów" and for the production of drinking water for the local water supply system. Some water needs to be discharged into surface watercourses due to a lack of coherence of heating and water supply needs. For recognizing this problem innovative research project entitled: "The development of a method for injecting after energy-used geothermal waters into selected geological structures" was prepared and implemented as part of the Regional Operational Program of the Mazowieckie Voivodship for 2014–2020 (Priority Axis: Research and development activities of enterprises).

This project has resulted in the launch of the installation pumping excess water to the quaternary sandy leyer. Based on the results from the first year of operation of the project, it can be assumed that it is possible to achieve nearly 100% reduction of water discharge and, consequently, the full use of producted geothermal waters. In summary, it can be stated that the geothermal plant in Mszczonów is a unique installation not only on the Polish but also international scale. The proof of this is not only the scale of rational use of water for energy purposes (cooling from 41°C to about 17°C), but also their development in other areas, for example in "Termy Mszczonów" and for the production of waters intended for drinking. The article presents the results of the first year (2019) of operation of the water injection system. During this period, in cooled water discharged into surface watercourse nearly 50% reduction was achieved.

RACJONALNA GOSPODARKA WODAMI GEOTERMALNYMI PO ICH ENERGETYCZNYM WYKORZYSTANIU – WSTĘPNE EFEKTY PROJEKTU GEOTERMII MAZOWIECKIEJ SA

Słowa kluczowe

wody geotermalne, ciepłownia geotermalna Mszczonów,
wody przeznaczone do spożycia

Streszczenie

Polska należy do krajów o ograniczonych zasobach wód pitnych. Wychodząc naprzeciw temu problemowi Zarząd Spółki Geotermia Mazowiecka SA prowadzi działania w kierunku określenia możliwości wykorzystania eksploatowanych wód geotermalnych innych niż cele energetyczne. Wody złożowe oprócz zagospodarowania do generacji ciepła wykorzystywane są do rekreacji i balneoterapii w Termach Mazowieckich oraz do celów wytwarzania wód pitnych w lokalnym systemie wodociągowym. Część wód musiała być odprowadzana do cieków powierzchniowych z powodu braku koherencji potrzeb ciepłowniczych i wodociągowych. Temu służył innowacyjny projekt badawczy pn.: „Opracowanie metody zatłaczania wykorzystanych energetycznie wód geotermalnych do wytypowanych struktur geologicznych" realizowany w ramach Regionalnego Programu Operacyjnego Województwa Mazowieckiego na lata 2014–2020. Projekt ten zaowocował uruchomieniem instalacji zatłaczania nadmiarowych energetycznie wód do czwartorzędowego poziomu piaszczystego. Na podstawie wyników z pierwszego roku funkcjonowania projektu można założyć, że możliwe jest osiągnięcie blisko 100% redukcji zrzutu wód i co się z tym wiąże pełne wykorzystanie eksploatowanych wód złożowych. Podsumowując można stwierdzić, że Zakład geotermalny funkcjonujący w Mszczonowie jest unikalną instalacją nie tylko w skali polskiej ale także międzynarodowej. Dowodem na to jest nie tylko skala racjonalnego wykorzystania wód do celów energetycznych (schłodzenie od 41°C do około 17°C), ale także zagospodarowanie ich w innych obszarach: w Termach Mszczonowskich i do produkcji wód pitnych z SUW i z płytkich zbiorników hydrogeologicznych. W artykule przestawiono wyniki pierwszego, 2019 roku, funkcjonowania systemu zatłaczania schłodzonych wód.