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# POSSIBLE ENVIRONMENTAL ASPECTS OF THERMAL WATER UTILISATION IN NORTH EAST HUNGARY

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***Abstract***

*The reserves and exploitation of conventional, so-called fossil energy resources are limited, therefore the utilisation of renewable energy resources has been becoming more and more important.*

*Present study focuses on the thermal water utilisation possibilities i.e. energy content utilisation, balneological utilisation, irrigation, and the related environmental aspects in North East part of Hungary. Among the environmental effects the total dissolved solid concentration and the methane and carbon dioxide content are examined through the examples of 66 thermal water wells screened into pannonian sensu lato (s.l). succession.*

*Thermal water utilisation may have many various environmental aspects: chemical impacts, gas emission, thermal effects, water quality effects noise effects, landscape change, from which methane and solids dissolved in thermal water emitted by its extraction are highlighted.*

*Considering that the annual thermal water extraction from reservoirs located in the Northern part of the Great Hungarian Plain the annual Total dissolved solid concentration (TDS) and methane production can be estimated as 28,207 tones and 1,671,482 $m^3$, respectively.*

*It must be highlighted that by applying cascade systems, the efficiency of thermal water utilisation can be improved while environmental aspects do not increase considerably.*

**Key words:** geothermal energy utilisation, thermal water, environmental aspects, pannonian s.l., North East Hungary

## INTRODUCTION

Nowadays, global energy demand has been continuously increasing due to accelerated economic development. The reserves and exploitation of conventional, so-called fossil energy resources are limited, therefore the utilisation of renewable energy resources has been becoming more and more important. According to Lund, 2007, the geothermal energy reserves in the upper 10 km of the earth's crust are approximately $3.6 \times 10^{14}$ GWh. This extractable energy could theoretically supply the global energy use for approximately 2.17 million years considering the average global energy consumption rate (Lu, 2017).

Compared to other renewable energy resources, e.g. wind and solar energy, geothermal energy cannot be affected by changes in the weather and available for a long-term period without any harmful environmental effect (Hou et al., 2018).

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In this work authors reviewed the energy status of Hungary, including the amount of primer energy used in Hungary and the proportion of the consumer sectors, studied the fields which utilize or will utilize thermal water, and presented the possible environmental aspects of geothermal utilisation.

**Primer energy used in Hungary (2005-2016)**

In Hungary, the rate of energy dependence is really similar to the European Union's average rate, which represents 62.8 % in 2016 (Fig. 1). Domestic and imported primer energy used in Hungary in the period of 2005-2016 has average values of 473.6 PJ and 807.81 PJ, respectively.

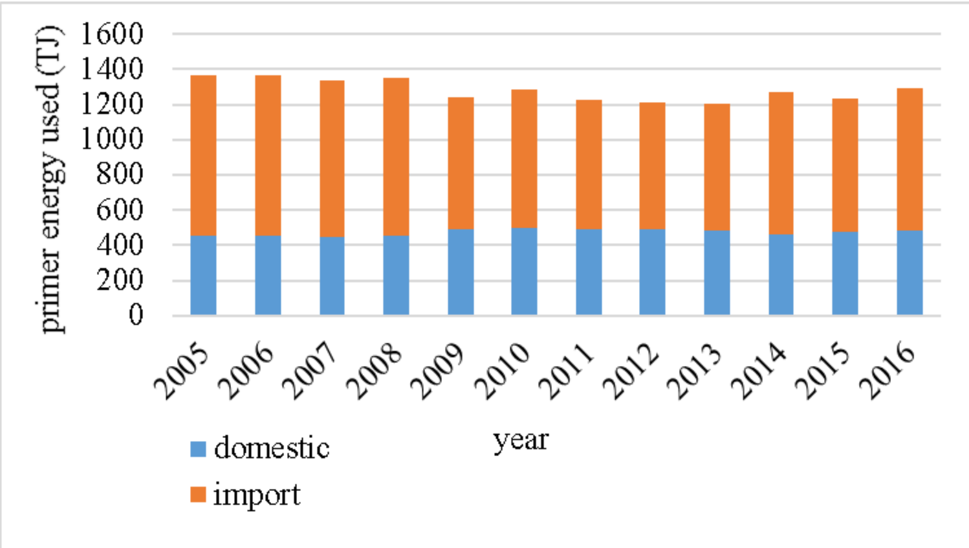


Fig. 1. Primer energy used in Hungary (based on data published by Hungarian Central Statistical Office)

Renewable energy resources give 3.9 % in total energy use, which has to be increased to 13 % by 2020. The distribution of the mentioned value among different types of renewable energy resources is the following:

- 88.2 % ignition of firewood and biomass,
- 8.0 % geothermal energy,
- 2.0 % electricity production from renewable energy resources,
- 0.5 % ignition of biomass and municipal solid waste,
- 0.2 % solar energy,
- 1.1 % other (e.g. wind energy).

In Fig. 2, the main energy consumers in the period of 2005-2016 can be seen: population, transportation, agriculture and commercial and public institutes.

Total annual energy consumption of the sectors, where geothermal energy can possibly come up as an energy resource, i.e. industry (137 PJ), population (262 PJ) commercial and public places (113.8 PJ), agriculture, forestry and fishery (all together 22 PJ) is approximated as 535 PJ, based on calculating the average annual energy consumption values of the sectors in Hungary within the period between of 2005 and 2016.

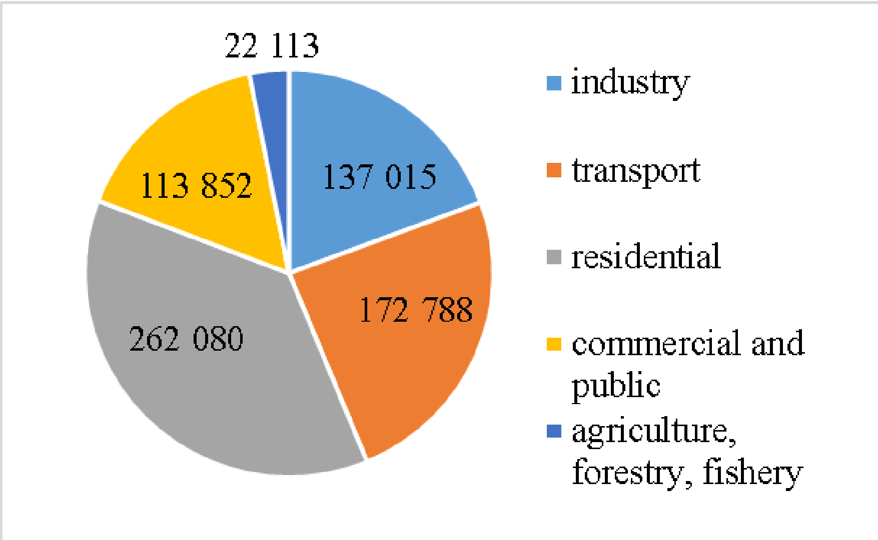


Fig. 2. Average annual energy consumption (TJ) by sectors in Hungary (2005-2016) (based on data published by Hungarian Central Statistical Office)

According to the study of Zilahi-Sebess et al., 2012, the annual geothermal energy potential originating from porous media is 60 PJ while from crystallized basement 130 PJ in Hungary.

Comparing these data, it can be stated that geothermal energy can provide significant proportion of energy need of the above presented sectors of energy consumers. Accordingly, energy need of agriculture, forestry, fishery and commercial and public places, all together or a significant part of the energy need of the population, can be provided by geothermal energy.

By involving geothermal energy into the energy system of Hungary, its energy dependence can be reduced, the absolute value and proportion of the renewable energy can be increased and other added values can be generated such as job creation, developing industry, ensuring sustainability (Sabău, 2015).

**Utilisation types**

Geothermal energy utilisation generally involves a wider group than thermal water utilisation, since it also includes the shallow geothermal and deep geothermal utilisation, as well. This study focuses on the thermal water and its energy content utilisation possibilities and the already existing capacities and the related environmental aspects in North East part of Hungary.

Based in data published in River Basin Management Plan 2 of Hungary the annual thermal water production rate in Hungary within the period of 2008-2013 extracted from porous reservoirs and karst thermal water was 72587 million $m^3$ from which the proportions are 69 % and 31 %, respectively (HAS, 2017). Its utilisation structure is presented by Fig. 3.

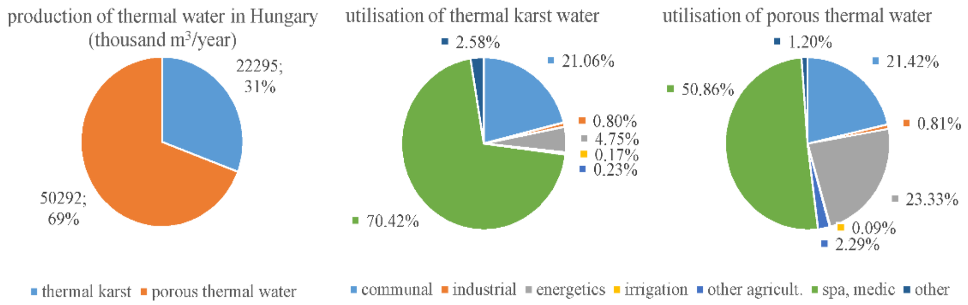


Fig. 3. Average annual amount of thermal water extracted in Hungary between 2008 and 2013, and the proportions of utilisation fields both from thermal karst and porous thermal reservoirs

According to this data, it can be stated that 69 % of the extracted thermal water was stored in porous thermal water reservoirs, half of which was utilised by spas and medical institutes, almost a quarter of it was utilised for energy production and almost another quarter of it for communal reasons. In comparison, thermal water extracted from thermal karst was utilised by spas and medical institutes in greater proportion while for energetic purposes with a lesser proportion and the other utilisation fields show similar rates.

The use of thermal water mainly depends on its temperature, secondly on its chemical composition. Utilisation field of thermal water in function of its temperature is presented by the well established Lindal-diagram. In general, it can be stated that water with tempreature above 60 °C can be used for heating, domestic hot water production and industrial processes (Iancu et al., 2011), while water with temperature below 60 °C can be utilized for agricultural utilisation and balneological utilisation.

It is to be noted that water at temperatures higher than 60 °C can also be utilized in the latter two utilisation fields after cooling to the right temperature. Water with high dissolved solid content has a very good physiological effect hence favourable in balneological utilisation and this utilisation form of it is quite popular in NE Hungary. There is some greater spas for instance Hajdúszoboszló and Debrecen two of which had an extraction amount of 2.6 million $m^3$ in 2008 (Bódi et al., 2015), and some smaller spas for instance Hajdúböszörmény, Hajdúnánás, Hajdúdorog. The latter three spas extracted approx. 0.37 million $m^3$ thermal water in 2008. Their wells extracting from the pannonian porous thermal water reservoirs.

**Effects of thermal water utilization on environment**

Thermal water utilisation may have many various environmental aspects: chemical impacts, gas emission, thermal effects, water quality effects (both for underground and surface water), noise effects, landscape change, from which methane and solids dissolved in thermal water emitted by its extraction are highlighted (Maochang, 2001).

Methane is a greenhouse gas, therefore its emission results in unfavorable environmental effects. From the solids dissolved in the extracted thermal water the natrium, cloride and hydrogene carbonate concentrations are highlighted since thermal water in the focus area are known as sodium chloride water from deeper reservoirs and sodium chloride and carbonated water from shallower reservoirs. These dissolved salts may be deposits within the system (e.g. pipes) or the environment causing serious damages. Their treatment is needed but also costly (Ghergheleş et al., 2011).

Estimation of the above mention effects is crucial from the aspect of sustainable and environment friendly utilisation (Sameer et al., 2013).

## MATERIAL AND METHOD

Hydrogeological documentation containing measurement results (e.g. dissolved solid concentration, methane, carbon dioxide, oxygen) of 66 thermal water wells located in NE part of the Great Hungarian Plain were overviewed. The following properties and values were collected: well head temperature (°C), depth of the deepest screening (m), value of natrium ion (mg/l), chloride ion (mg/l) and hydrogen carbonate ion (mg/l), total dissolved solid value (mg/l) and methane-water ratio ($l/m^3$).

Since well head temperature defines the utilisation fields, as it is presented in Lindal diagram, wells were grouped into 5 categories based on the well head temperatures. These categories are: 30 °C-40 °C, 40 °C-50 °C, 50 °C-60 °C, 60 °C-70 °C, 70 °C-80 °C. It is assumed that the parameters depend on the depth of the reservoir we extract thermal water from, main statistical parameters of the above listed properties for each groups of the wells are calculated.

The aim is to give an estimation for ordering of magnitude of both the methane and total dissolved solids extracted by thermal water annually in Hungary based on the presented data sets. It is important to note, that to give more accurate estimations, measured extraction parameters is need for each producing thermal wells.

## RESULTS AND DISCUSSION

The total dissolved solids concentration (TDS) values of studied thermal wells in wide range: min.: 1,107.4 mg/l (Tiszacsege K108), max.: 13,304.5 mg/l (Hortobágy K11). In the case of water with lower TDS concentration both the amount and the rate of chloride ion significantly lower than in water with higher TDS concentration (Fig. 4 and Fig. 5).

It is explained by the fact that higher chloride concentration originated from marine paleoenvironment. From such reservoir higher sodium ion concentration is expected, as well. In the case of spas the typical TDS concentration value ranges between 3000 mg/l and 5000 mg/l.

According to the TDS values calculated for all groups it can be stated that water with higher temperature is likely to contain a higher amount of dissolved solids, however, over 60 °C TDS mean values are around 4,100-4,600 mg/l (Fig. 6).

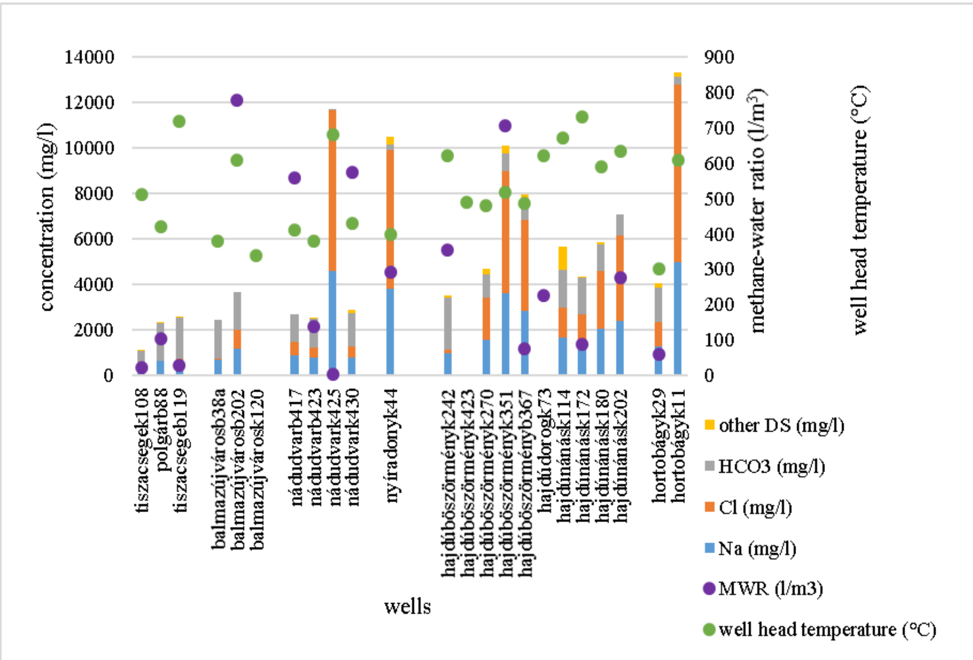


Fig. 4. TDS concentration (mg/l), methane-water ratio (MWR) ($l/m^3$) and well head temperatures (°C) (1)

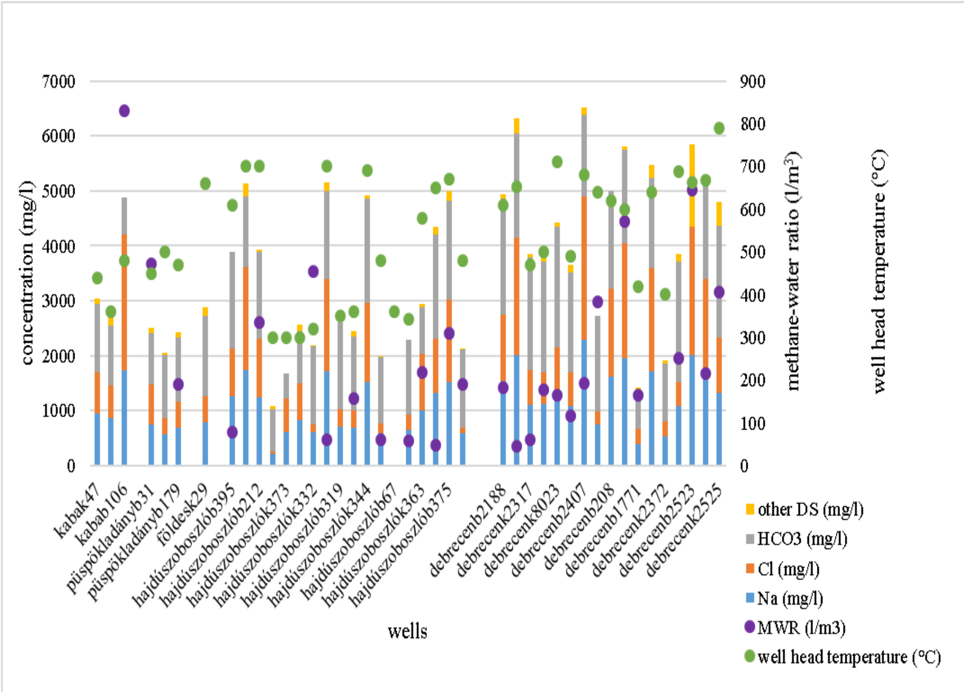


Fig. 5. TDS concentration (mg/l), methane-water ratio (MWR) (l/m$^3$) and well head temperatures (°C) (2)

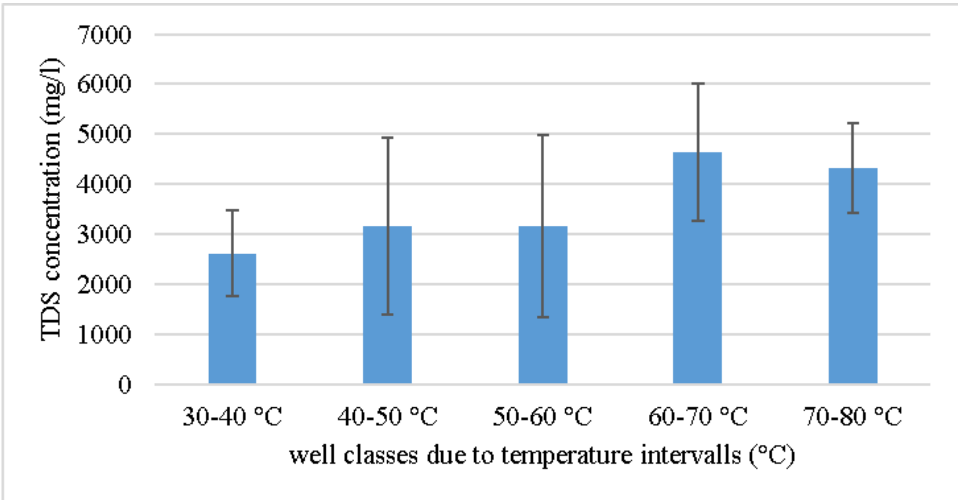


Fig. 6. Mean and standard deviation values of total dissolved solids (TDS) concentration (mg/l)

The standard deviation is significant in most groups. It can be explained by hydrogeological characteristics of the reservoirs. The arithmethic mean of the TDS concentration values for all wells is 4,339.6 mg/l.

If TDS values of thermal water are studied within one well but from different depths, that means different screening depths, a significant rise in concentration can be measured. Hajdúszoboszló I is an example for that (Table 1).

*Table 1*

TDS concentration in thermal well Hajdúszoboszló I.

| Screening depth intervalls (m) | Total dissolved solids TDS (mg/l) |
|---|---|
| 1,088 – 1,094 | 5,572 |
| 1,284 – 1,288 | 1,0695.48 |
| 1,366 – 1,369 | 1,6231.52 |
| 1,373 – 1,376 | 1,6303 |

The mean values of methane extracted with 1 $m^3$ thermal water show variety in a wider range, standard deviation is considerable (Fig. 7).

The lowest mean values occur in both the lowest temperature and the highest temperature group. Extremities occur in wells with well head temperature higher than 40 °C but lower than 70 °C. The arithmetic mean of the methane values for all wells is 257.2 l/$m^3$.

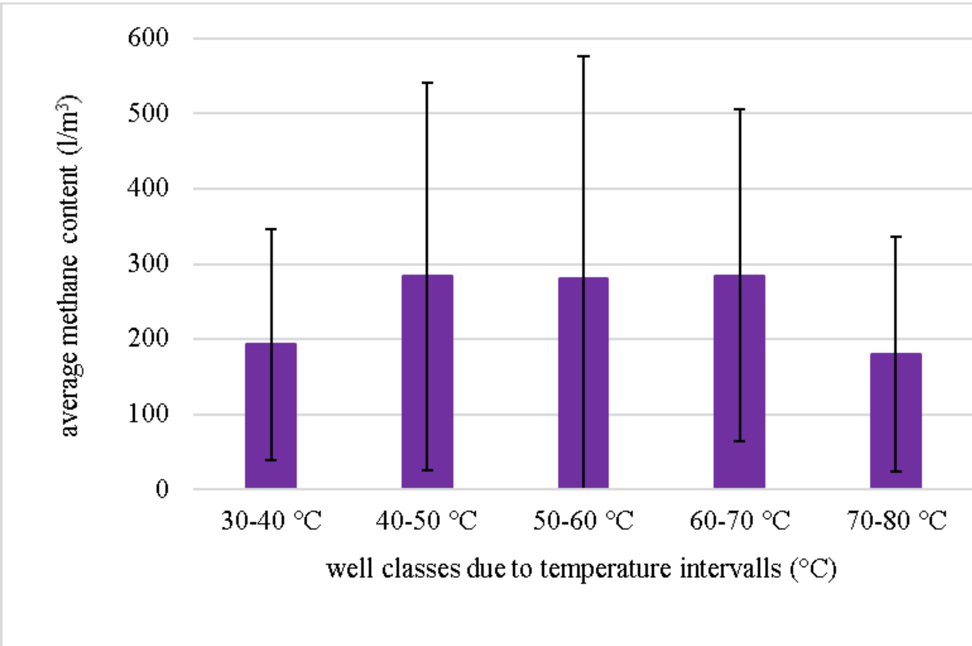


Fig. 7. Mean and standard deviation values of methane (l/$m^3$)

Considering that the annual thermal water extraction from reservoirs located in the Northern part of the Great Hungarian Plain based on 2008-2013 data series is 6,500,000 $m^3$/year and using the TDS mean and the average methane content the annual TDS and methane production can be estimated as 28,207 tones and 1,671,482 $m^3$, respectively.

**CONCLUSIONS**

High TDS content has a significant effect on the soil in case of irrigation and during water treatment processes. If salt content capture could be solved the deponisation of that amount of salts would mean a significant environmental burden and challenge, moreover, it is considered to be costly.

However, the decrease of the groundwater table of the forests of NE Hungary for instance the Great Forest in and nearby Debrecen, or the forest steppes on the sandy lands of the Nyírség is a well-stablished fact and from this aspect thermal water could mean an irrigation alternative if its salt content would not be so considerable. Irrigating with thermal water can affect very harmful both the biosphere and the soil, therefore it is certainly not advisable without any pre-treatment or a very firm argument.

It is important to note, that if a spa is not connected or only recently connected to the local water infrastructure system, its waste thermal water treatment practice is simply about relasing water to surface water bodies. It could have taken considerable size since balneological and recreational utilisation form of thermal water has had great importance and history in Hungary, especially in NE Hungary. Thermal water used in spas is non-rejectable it is treated with sewage and rain water and its effects on the environment strongly depend on the technology applied in the treatment plant. However, it can be clearly stated that by the intensification of this thermal water utilisation way the already occurred environmental effects will be intensified but new ones will not occur.

If thermal water is used for non-balenological purposes, therefore high TDS content is not a requirement, it is more suggested to extract from a reservoir water of which has lower salt content accepting the fact that its temperature may be lower that is around 50 °C hence the energy which can be produced from it lower as well. This is mainly regarding to the energy production utilisation ways. For irrigation purposes that water is considered to be high-temperatured but due to lower TDS content it can be prosperous.

Methane content is considered high in cases of several wells, relative to the extracted water. Its capturement and then its combustion by gas motor in order to produce electricity is favorable. By combustion other greenhouse gases such as water vapor and carbon dioxide are emitted which is unfavorable therefore this emission must be reduced, as well.

It must be highlighted that by applying cascade systems, the efficiency of thermal water utilisation can be improved while environmental aspects do not increase considerably.

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