FACULTY OF TECHNICAL SCIENCES
INSTITUTE FOR POWER ENGINEERING, PROCESS ENGINEERING AND ENVIRONMENT PROTECTION
NOVI SAD

POSSIBILITIES FOR UTILIZATION OF ENERGY POTENTIALS OF GEOTHERMAL WATERS IN VOJVODINA

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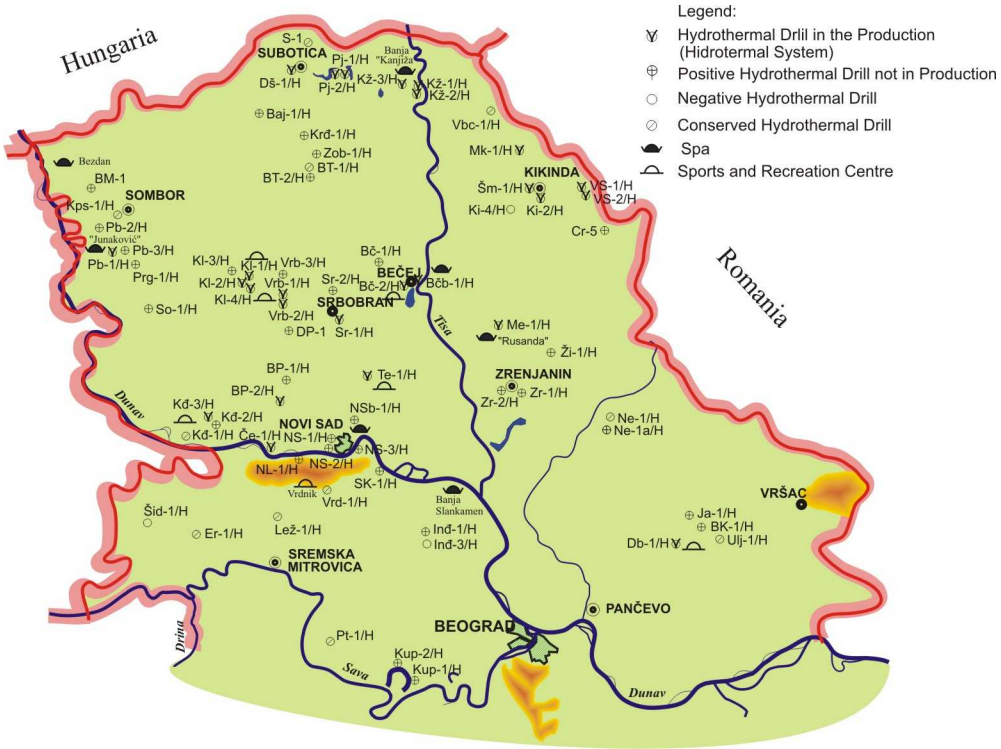
Introduction

Mineral and thermal waters of the Panonian Plain have been known for centuries. Records indicate that they were used by Ancient Romans and later by the Turks. The first drilling of Artesian Wells in the more recent history started in Banat. The drilling of Artesian Wells in Pavliš near Vršac is mentioned as early as 1848. The debths of first wells were as much as 400 m, and some of them have been used ever since. These are in: Bezdan, Temerin, Zmajevo, Bečej, Senta, Ada, Iodine Spa in Novi Sad and the like. At the beginning of the 20th century, there was a temporary halt in drilling in order to intensify again in the period from 1910 to 1914. The full prosperity occurred between the two World Wars. In that period almost 600 wells were drilled of which 384 are in Banat, 153 in Bačka and 54 in Srem. The basic purpose of these wells is to supply with drinking water although they are used for balneal purposes.

Geothermal Potentials of Vojvodina

More complete knowledge about geothermal potentials of drills has started to accumulate since 1949. In the period from 1969 to 1996, 73 hydrothermal drills were bored with the overall depth of 62,678.60 m. Drilling was financed and carried out by the Company "Naftagas". The most intensive researches were implemented in the 80s of the last century when 45 drills were bored with the total depth of 34,840 m or approximately 56% of all drills.



Distribution of Hydrothermal Drills in Vojvodina

The territory of Vojvodina as a part of the Panonian Basin belongs to the large European Geothermal Zone which has favourable conditions for researches and utilization in the field of geothermal energy. For the time being, hydrothermal energy is investigated and utilized. This concerns thermal waters of natural springs and waters in rocky masses which can be accessed by drilling. In Vojvodina, four hydro geological systems are recognized and classified. Their basic characteristic are investigated and defined: lithological composition, stratigraphic references, type and quality of rock collectors, temperature and hydro dynamic features, physical and chemical features of thermal and thermo-mineral waters and accompanying released gases.

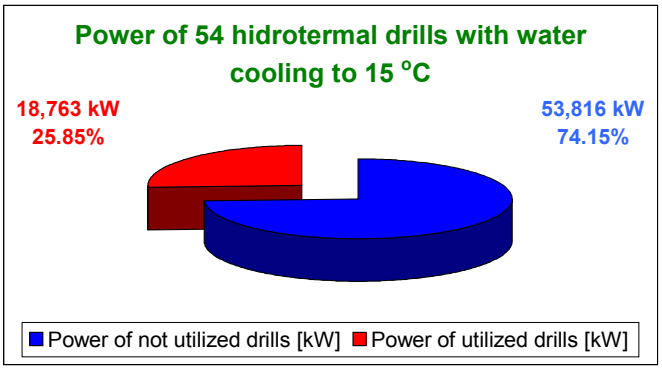
Generally speaking, geothermal waters suitable for use are accumulated in all systems. However, their temperature, profusion, collector properties, chemical composition, gaseous factor and other characteristics are decisive for determining future prospects and particular conditions for exploitation. This is the reason why each drill should be individually investigated in detail when making a decision concerning the choice of exploitation manner and the most suitable equipment.

General Picture of Important and Relevant Characteristics of Geothermal Waters in Vojvodina

Drills are mainly self-outflow operated and the most frequent water profusion is:	***(10-20) l/s***
Most frequent outflow temperature is	***(40-60) ° C***
Geothermal gradients are	***(4.5-7.5) °C/100 m***
Nearly all waters contain certain quantities of gasses	***mostly methane***
Waters contain dissolved minerals	***(0.42-13.94) g/l***
Mineral contents in drills bored for oil and gas is	***(0.40-40.18) g/l***

Drilled:	***73 hydrothermal drills***	**Positive:**	***65 drills***
Deepest:	***2,520 m***	***Vrbica, Banat***	***82° C at depth (1,749-1,854) m***
Shallowest:	***305.5 m***	***Novi Sad***	***25°C***

Overall heat energy of hydrothermal drills with water cooling to 15° C according to information from the year 1997 which included 65 drills was 85,605 kW, and according to information of the Company "NIS Naftagas" from the year 2005 for 54 hydrothermal drills it is 72,579 kW. Only 15 have been triggered for the production of heat energy.



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Potentials of Hydrothermal Drills according to Records of i NIS Naftagaa, May 2005

The Use of Geothermal Energy

The most important and regarding capacity the largest consumers of energy provided by hydrothermal drills are the spas:

- "Junaković", Apatin cca 150,000 m^3/a
- "Kanjiža", Knajiža cca 110,000 m^3/a

These are mainly consumers which use thermal waters during the whole year and in winter months for heating up of facilities. The group of consumers in Bečej are the second regarding importance:

- Youth Sports Centre OSC "Mladost",
- Health Centre "Predrag Hadnađev" and
- Hotel "Bela Lađa"

These consume totally cca 100,000 m^3 of thermal waters annually. However, the most significant consumption concerns seasonal heating up of facilities. The category of similar consumers also includes swimming pools in Temerin, Vrbas and Palić.

The group of exclusively seasonal consumers of the energy of hydrothermal waters is in the field of agricultural production. The most important concerns farms for pig breeding:

- Socially Owned Company "Kozara" from Banatsko Veliko Selo,
- Socially Owned Company "Mokrin" from Mokrin,
- "Jedinstvo" from Kikinda, (stopped using it a few years ago)

And the production of vegetables in the covered facilities

- Socially Owned Company “Elan" from Srbobran (for heating up plastic houses, ceased using it).

Particularly suitable are industrial consumers: for the time being these are textile Joint Stock Company "Kulski štofovi" and Leather Factory "Eterna" from Kula, as these are year round consumers for technological requirements. When we talk about consumers suitable for using geothermal waters energy it invariably concerns heat consumers requiring the lowest possible temperatures and, if possible, continuous application. Therefore, geothermal waters energy is traditionally utilized for: base heating in radiators or complete heating with the system of floor heating, i.e., heating of air, preparation of sanitary hot water and heating of pools or fish ponds. The existing consumers prove this and it seems that some significant changes are not expected to occur for the time being. In all mentioned combinations, the use of heat pump seems to fit in perfectly as it enables supplementary cooling of geothermal water and a more complete use of its energy potentials. Gas motor is suitable for the combustion of gases extracted from geothermal water with an additional use of natural gas. In any case, to meet peak demand it is necessary to provide for a peak boiler.

Current Prices of Drills and Energy

Current prices of energy from active geothermal drills in Vojvodina, based on water prices, depend on discharge water temperature and vary within the range:

- (0.1-0.24) €/m^3.

Based on known prices of existing drills, a current range of prices has been calculated relevant to the drill depth as follows:

- (220,000 -500,000) € for drill depths of (600-1,100) m.

For the purpose of comparative analyses in the study, current average prices of competitive energies in relation to the energy of geothermal waters in Vojvodina have also been determined. These are as follows:

- Natural gas price 2.0 c€/kWh,
- Electricity price of 3.5 c€/kWh and
- Thermal Power Plants price of heat energy 4.4 c€/kWh.

Modern Technologies for Utilizing Geothermal Energy

Considered opportunities for applying modern technologies in the exploitation of available resources of our geothermal waters (GTW) include conventional solutions, which are proved in practice, but also other available possible solutions. Implementation of technologies is considered within the context of resolving 4 global objectives:

i) Cogeneration of heat energy and electricity,
ii) Energy preparation for cooling of buildings,
iii) Energy preparation for heating of buildings, and
iv) Preparation of sanitary water and swimming pools water.

The choice has been made on the basis of three criteria:

- *Recommendations for utilization of GTW potentials (according to a so called* ***Lindal*** *Diagram),*
- *Review of the potentials of our GTWs and*
- *Review and analysis of potential users (consumers) of available resources.*

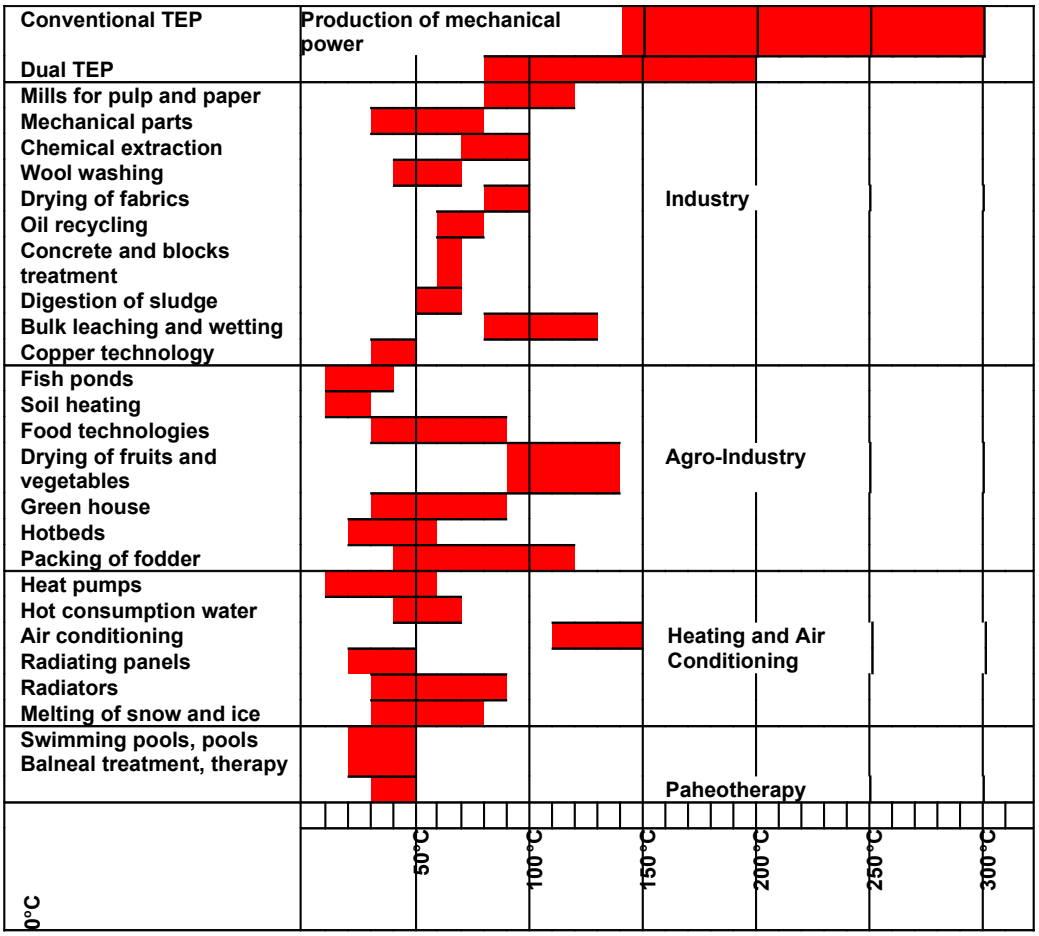
Energy potentials of our GTWs are predominantly with low temperatures. Conventional or dual (according to Lindal categorization) thermal energy plants with exclusive resources of our GTWs are not acceptable as investments and they are

not profitable from the standpoint of commercial production of mechanical (that is, electric) energy. This is the reason for possible acceptance of GTWs only as:

> Possible alternative to the exploitation of other (conventional) recourses, that is, as their potential substituent.

The strategy of analysis of possible utilization of GTW potentials has been structured in such a manner to find answers for questions related to:

- *Theoretical possibilities for exploitation,*
- *Practical implementation of possible solutions at the level of conventional technologies,*
- *Consequences of the concrete choice, theoretical and practical possibilities within environmental surroundings, and*
- *Technical and economic aspects of the given choice adequacy in the sense of achieving the largest possible profit within the given limitations.*



Lindal Diagram

In relation to the integration of GTW potentials in plants for cogeneration of productive mechanical (electric) and heat energy (SPETE), the choice which imposes itself is that of a gas internal combustion motor. Namely, assuming that there are consumers of heat energy with a relatively low level, that an acceptable repayment period (without interest) of a plant is the one of 6-8 years, it will be justifiable to install the gas motor of up to max 5 MW of mechanical power. Installation is profitable after repayment and practical reasons relevant to procurement, mounting, exploitation and maintenance justify such a choice in relation to other available possibilities.
It is important to point out that only cases of cooling facilities above 0^{o} C have been taken into consideration here with two vitally different cooling solutions. First, if the use of GTW potentials is an imperative request, it can be acceptably resolved only by the use of absorption refrigeration machines (ARM). Second, if the use of other resources is allowed, then the application of compression refrigeration machines (KRM) with the electric current drive from the commercial grid is in all respects superior solution in relation to other possibilities. Then, however, GTW potentials are completely excluded from preparations of cooling energy. At the same time, both solutions are even more acceptable for the case when there are consumers of heat from the condenser of refrigeration machine.

In relation to the preparation of energy for heating facilities by using GTW resources, standard solutions have been considered here. These include complete exploitation of GTW heat potentials for required, however achievable, level through heat exchangers with the installation of "peak supplementary heaters" in order to meet possible energy shortage. Common solutions imply installations with gas boilers as peak supplementary heaters, which is the cheapest yet thermodynamically worst solution. As opposed to that, we have suggested here that the function of peak heaters should be executed by plant coolers of the corresponding level, for example, cogeneration plants for the production of heat and mechanical energy, then condensers of refrigeration machines, or condensers of heat pumps. An argument for such an attitude can be found in possibilities for the sale of "waste" heat (within the heating context – utilization of this heat for heating purposes), which significantly improves their technical and economical performances. It is, of course, clear that the final measure of acceptability of each solution concerns technical and economical indicators. However, as an option, the worst thermo-dynamical solution cannot be avoided – which refers to peak supplementary heating by fuel combustion – gas boilers.

Undoubtedly, all above stated facts indicate that the best solution is to install combined or multipurpose plants. In addition to those mentioned above, there is another reason in favour of the combined schemes proposal. Namely, it is necessary to take into consideration the fact that heating demand is to a certain extent complementary with cooling demand of the same buildings: heating and cooling seasons are different in a calendar and do not coincide. Therefore, from the standpoint of complete exploitation of GTW potentials, depending on the state of surroundings (ambience) once it can be totally acceptable to install a heat pump and under different circumstances completely the opposite – installation of the refrigeration machine.

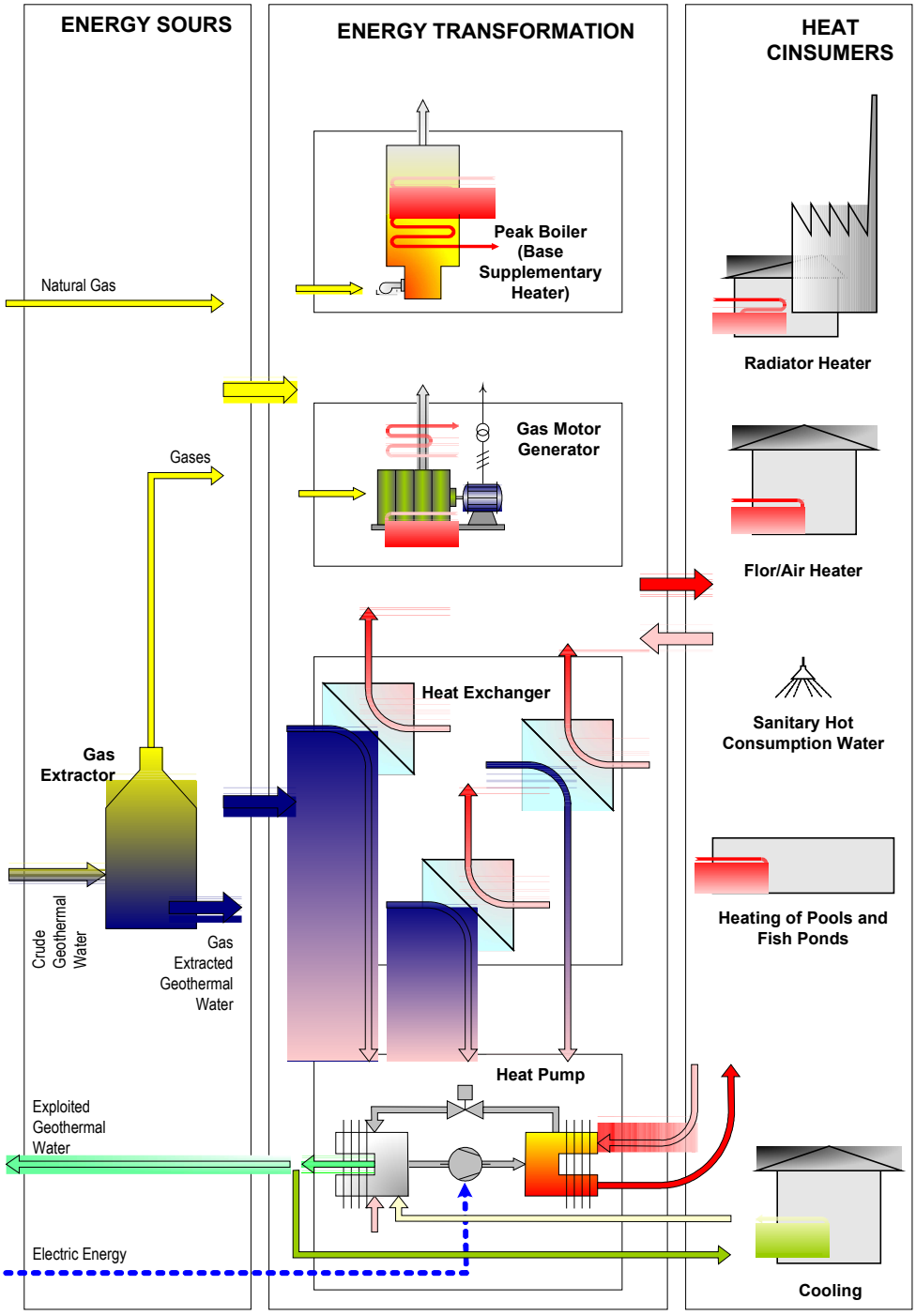


Chart of Systems for Preparation, Transformation and Utilization of Thermal Waters Energy

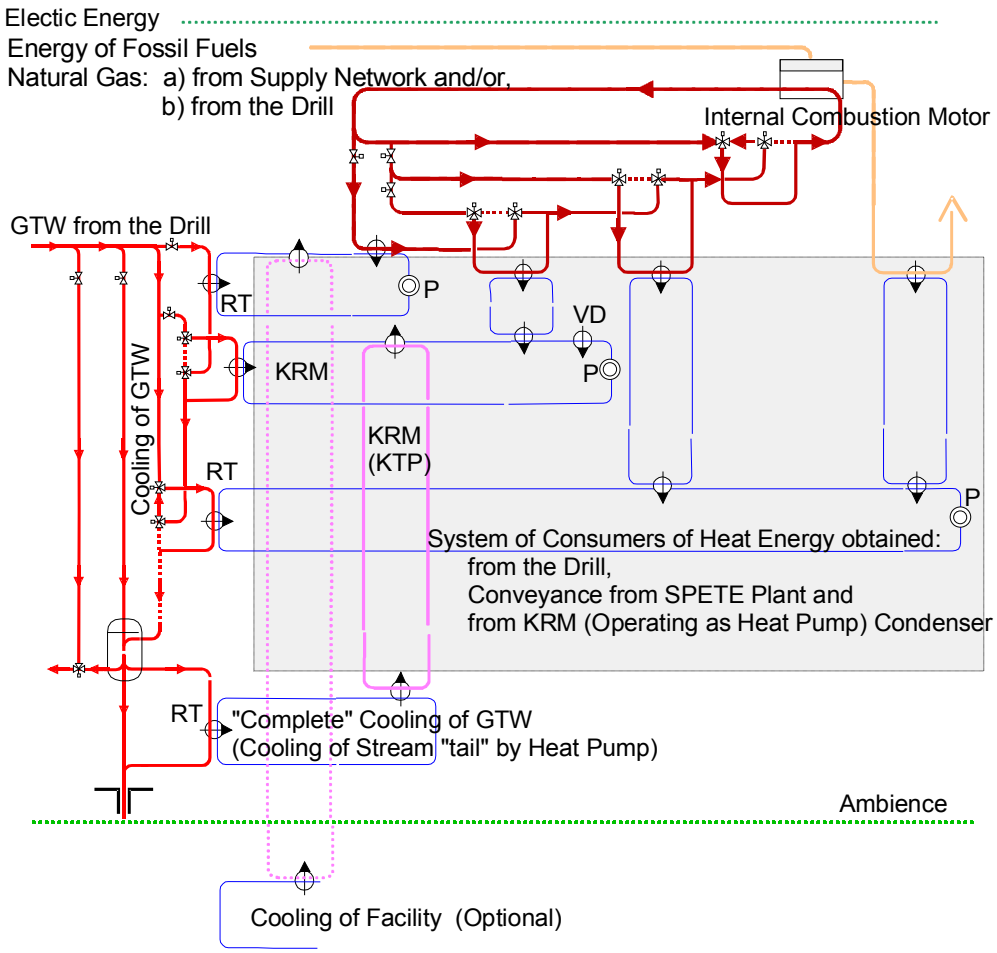


Diagram of Integrated Exploitation of GTW Potentials
RT – Heat Exchanger, KRM (KTP) – Compressor Cooling Device (Compressor Heat Pump),
P - Consumer (User) of Heat, VD – Peak Supplement Heater

The problems related to the exploitation of our GTW resources in the sense of sanitary water preparation and swimming pool water are outlined only broadly for the following reasons. First, when in GTW applications mixing is not allowed, or chemical and technological preparation of GTW is *a priori* excluded, then available GTW is only energy (heat) resource and the preparation of sanitary water and swimming pool water is reduced to the problem of heating the facilities Second, depending on the chemical composition of GTW it is possible to directly use it (substantial resources), but more often, special preparations of GTW are needed. Technologies for preparation vary significantly from case to case to such an extent that it is almost impossible to analytically follow a typical "common" feature. This is the reason why the exploitation of these “substantial” resources of GTW is not considered here. Also, our GTWs are not categorised from the aspect of this application a special study would be undoubtedly needed with an aim to prepare guidelines for the utilization of substantial potentials of our GTWs).

Economic Overview

The concrete economic analysis, which respects the most recent guidelines concerning ecological requirements (the need to drill and equip a reversible drill), shows that the drills above 40° C and with strong discharge (around 60 m^3/h) are profitable assuming that the consumer is capable of employing the overall potential of the drill of over 6,000 h/a. The term "the overall potential" means that geothermal waters are cooled to around 15° C during exploitation. This is achieved only by building in of heat pump. Such a volume of exploitation of the drill can be employed only by a consumer which will in addition to a heating season for the purpose of heating the building use available capacities in transitional periods (spring and autumn), but also during night in the heating season. This significantly reduces the choice of real consumers and thus the application of geothermal waters for energy purposes.

A special and some sort of a "semi-economic" analysis is necessary for existing drills which are not used at all. Considerable amount of money was invested in them long time ago and nobody is repaying that (economically, their geothermal energy does not have any value at all). In order to launch their exploitation, it is necessary to make additional investments in the construction of a potential consumer of heat energy at that location. As the choice of these consumers is very small, the possibility of selling geothermal waters at very low prices (even free of charge) should not be excluded at least not in the initial period of business development and mastering of the market.

Conclusions

- In the previous period, geothermal waters at the territory of Vojvodina were investigated in detail by boring at 75 locations of which 65 were active. Also, a large number of drills, 27, is technically equipped with hydrothermal systems for exploitation, and only 15 springs were or are still used. Thus, this region ranks very high regarding the scope of investigations at the European continent and conclusions about its resources can be made with adequate reliability.

- Investigated resources are from the energetic point of view modest, particularly regarding temperatures of geothermal waters at the discharge. There are only few springs with the temperature over 60° C at the depth of around 1,000 m, and only 3 are between 70-82° C. It is not probable that further investigations and expensive drillings will produce higher temperature potentials. Therefore, overall potentials are below 90° C, which is the bottom limit at the generally accepted Lindal Diagram for utilization in the production of mechanical (electrical) energy by using still rare binary plants at temperatures below 150° C for utilization in standard thermal energy plants. In other words, there are only theoretical possibilities (explained in details in the Chapter 4 of this study) for transformation of Vojvodina's geothermal water potentials into mechanical, i.e., electric energy.

- For this type of geothermal waters the only existent possibility for utilization is transformation in heat energy for heating with a relatively low temperature

level (in majority cases below 60° C). This is another much more complicated part of utilizing geothermal energy. Namely, for quite some time, low temperature heat consumers have been sought unsuccessfully for various alternative sources of heat supply (solar energy, waste heat from industrial plants, and etc.). It is obvious beforehand, that this application will be profitable in a small number of industrial consumers which will operate 7,000 h/a under full capacity and satisfied with this temperature level. Unfortunately, these are only few.

- The largest number of consumers of this type of low temperature energy is in the field of technologies for heating of buildings which are of seasonal character. They are only used in winter periods and with typical breaks during the night. This provides exploitation of the constructed plant up to 3,200 h/a in a so called base heating power. Due to a small number of very cold winter days, the base power of low temperature heating is not sufficient and it is necessary to install an additional peak plant of a significantly larger power which will practically be out of operations all the time but incur maintenance costs.

- Based on the above stated, we conclude that before decision making regarding the construction, it is necessary to study in detail economic (and ecological) aspects of various alternatives of heat schemes for each given case. In doing so, possibilities for expanding the duration (season) of envisaged installation use should be carefully investigated which will have a decisive impact on economical operations. At the present moment, available options for extending the exploitation season of these geothermal springs are swimming pools, fish ponds, green houses and plastic houses in agriculture. These facilities do not require large investments; however, in the period of exploitation their energy cost will be very low. But, the main problem regarding these facilities is good organization and finding out safe and reliable markets.

- The final conclusion is that on the territory of Vojvodina there are geothermal potentials which are respectable from the standpoint of small and medium size consumers. These are not energy sources of great importance for the Province which could have considerable effects on overall energy supply. This does not mean that the Province should not be involved in their inclusion into regular exploitation. On the contrary, each envisaged project of this type should be supported by low interest rates the same as it is done in developed countries for all cases of utilizing a so called “green energy".

- However, for the time being it is not recommended to undertake new drillings except at individual requests of consumers which have considered their projects comprehensively. More investments should be made into heat consumers at locations of existing drills with larger energy potentials even if this is accompanied by intensely subsidised price of geothermal waters.