POTENTIALS OF RENEWABLE ENERGY SOURCES IN THE REPUBLIC OF SERBIA WITH A DETAILED REVIEW OF THE EXPLOITATION OF GEOTHERMAL RESOURCES IN THE AUTONOMOUS PROVINCE OF VOJVODINA

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Abstract:
Energy supply is one of the basic issues in the contemporary world's sustainable development. By adopting the Kyoto Protocol and implementing its mechanisms, it is expected that the use of conventional energy sources shall stabilise and decrease on global level. The European Union's legal framework, through its appropriate directives, sets very clear objectives for the use of renewable energy sources for member states. Serbia is a country with significant potentials in renewable energy sources, which are, regretfully, underused. Renewable energy source potentials are featured by very favourable indicators in matters of both capacity and distribution. The status is especially favourable in the field of geothermal energy potentials in the Autonomous Province of Vojvodina, situated in the Pannonian Basin, where there are significant sources of this fuel. The paper presents the basic forms and characteristics of renewable energy sources in Serbia and provides an overview of the possibilities for their use.

Key words: *Renewable energy sources, potentials, capacities, resources, geothermal energy, Serbia, Vojvodina.*

1. INTRODUCTION

Solving global energy problems implies an interdisciplinary approach and considering the issues from different perspectives. Decreasing overall energy consumption, increasing energy efficiency, modernising the installation, using alternative energy sources and adopting and implementing a number of legal regulations and international covenants are the points of departure in solving this exceptionally complex issue. By ratifying specific international covenants, all signatory countries assume a number of commitments and limitations.

In the modern world, the use of renewable energy sources (RES) is an obligation and not merely one of the potential possibilities to satisfy the need for energy. The issue of providing stable energy offer is one of the paramount concerns in most countries.

The aim of this paper is to present those types of renewable energy sources which can be found in the Republic of Serbia likewise their territorial distribution and capacities. The presentation of the excerpts from strategic documents on renewable sources of energy indicates the need for including energy from renewable sources in the economic balance of the country, especially in relation to the EU's strategic documents. The paper's special part describes the present status in the use of geothermal energy on the territory of the Vojvodina Autonomous Province with regard to its position and the fact that the geothermal potentials of the Pannonian Basin in the neighbouring Hungary are exploited to a larger extent.

Based on energy development projections by 2020, energy demand will grow up to a highly significant 65% compared to 1995. Thereby carbon dioxide emission will increase for about 70%. The foreseen annual rate of energy demand growth will amount to 2%. Based on the indicated data, we may conclude, that the use of energy from renewable sources is of vital importance at global, worldwide level. The fact, that most countries, whether individually or through various organisations, assume qualitative and quantitative commitments to include to the possibly largest extent renewable energy source into their energy balance, goes in favour of this statement.

The EU's Directive 2011/77/EC, starting from the status in 1998, outlined that by 2010, the share of "green" energy in the total energy consumption would increase from 6% to 12%. This decision was of key importance for the boom in the use of all types of renewable sources.

EU's most recent energy development plans by 2020, based on the decision adopted by the heads of EU member states on their meeting in Brussels on December 9, 2008, are set out in the *Climate-energy legislative package* Directive on renewable energy sources. They are presented in Table 1. Apparently, there is a significant growth in the share of windmills with 14% in 2005 to 35% in 2020, likewise a rapid growth in solar power station capacity growth from a negligible 0,3% in 2005 to a notable 13,1% in 2020. This growth in the use of renewable energy sources in electricity production should increase the share of RES of 15,2% in 2005 to even 40% in 2020 [1, 2, 3, 4].

Table 1 The share of renewable energy sources in the consumption of electricity in the EU – projections by 2020 according to EU Renewable Energy Directive

Type of energy	2005 Eurostat TWh	2006 Eurostat TWh	2010 Projections TWh	2020 Targets TWh
Wind	70.5	82	176	477 (34.8%)
Hydro	346.9	357.2	360	384 (28%)
Photovoltaic	1.5	2.5	20	180 (13.1%)
Biomass	80	89.9	135	250 (18.3%)
Geothermal	5.4	5.6	10	31 (2.3%)
Solar thermal elect	-	-	2	43 (3.1%)
Ocean	-	-	1	5 (0.4%)
Total RES	504.3	537.2	704	1370
Total Gross Electricity Generation EU-27	3320.4	3361.5		
(Trends to 2030-baseline)			3568	4078
(Combined RES and EE)				3391
Share of RES	15.20%	16.00%	19.70%	33.6-40.4%

Table 1 clearly shows, that, in the EU countries, there is a stressed need for the continuous increase of the share of alternative energy sources in the gross national energy consumption. From a share of 15,20% for energy generated from alternative sources in the EU in 2005, the projections predict that this share will reach about 35% in 2020.

2. THE BASIC CHARACTERISTICS AND CAPACITIES OF RENEWABLE ENERGY SOURCES IN SERBIA

In view of the current situation in Serbia, we must emphasise the lack of quantitative indicators for the planned fields of use for renewable energy sources, likewise the need for more articulated efforts in promoting their use. At present, in Serbia the share of energy from renewable source is about 6% (including large hydro-power plants) and the projections are that it will stay stable by 2015. The Energy Development Strategy by 2015 sets out that the share of new renewable sources (without large hydro-power plants) in the gross primary energy consumption should grow from 1,07 to 1,24% in 2015. (See: Table 2).

Table 2 The share of energy from renewable sources in the gross primary energy consumption

	2006.	2009.	2012.	2015.
Share of energy from renewable energy sources (without large hydro-power plants)	1.07 %	1.17 %	1.19 %	1.21 %

Source: Energy Development Strategy of the Republic of Serbia by 2015, dynamic economic growth scenario

In Serbia, the share of energy generated from renewable sources is minor, while from Table 2 it is apparent, that no increase in its share has been foreseen until the end of 2015. At present, only about 1% of the energy is generated from alternative sources in Serbia, which is negligibly small in view of the natural potentials and the Kyoto Protocol requirements.

In matters of establishing and increasing the share of renewable energy sources in the energy offer of the country, Serbia's example is not a positive one. In order to be able to consider the promotion of renewable energy sources, these sources should be at the disposal of the country. With a potential in renewable sources of 3,83 million toe (tonne of oil equivalent), Serbia more than fully satisfies this condition. However, there is an absence of an appropriate strategic plan for a more ambitious implementation of RES in the country's energy potentials [5, 6, 7].

2.1. Solar Energy

The average daily intensity of solar radiation on the territory of the Republic of Serbia ranges from 1,1 kWh/m2/day on the North to 1,7 kWh/m2/day on the South during January and from 5,9 to 6,6 kWh/m2/day during July.

On the annual level, the average value of solar power for the territory of the Republic of Serbia ranges from 1200 kWh/m2/year in the north-western part of Serbia, to 1550 kWh/m2/year in the south-eastern part of the country, while in its central part it amounts to about 1400 kWh/m2/year.

The largest potentials for the use of solar energy are in the cities located in the southern part of Serbia: Nis, Leskovac, Vranje (Figure 1).

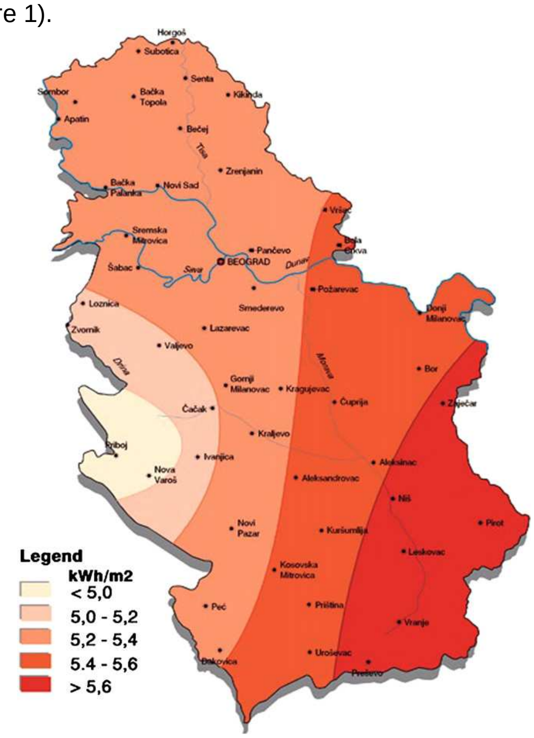

Figure 1 – Annual average of daily energy generated by global radiation on the horizontal plane [8]

Figure 1 clearly shows that Serbia, as a country has massive potentials in the quality and quantity of insolation during the whole year. Although the use of solar energy in Serbia is almost negligible at present, some projections indicate that there are potentials to satisfy about 50% of all energy needs from solar energy.

2.2. Geothermal Energy

In Serbia, geothermal energy is underused, although our country belongs to the group of states with rich geothermal potentials. The presence of mineral and thermo-mineral waters in the Pannonian Plain has been well-known since ancient times. Written documents indicate that they were used by ancient Romans and later by the Turks. In the most recent history, the drilling of first artesian wells started in Banat. The drilling of an artesian well in Pavlisa near Vrsac was mentioned in 1848. The depth of the first wells was up to 400 m and some of them are used even today. A more comprehensive knowledge about the geothermal potential was acquired after 1949. In the period between 1969 and 1996, 73 hydro-

thermal drills were drilled with a total depth of 62.678,60 m. The most intensive researches were made in the 1980s, when 45 drill holes were made with a total depth of 34.840 m, which makes about 56% of all drills. The territory of Vojvodina, as part of the Pannonian Basin, belongs to a large European geothermal zone, having favourable conditions for the research and use of geothermal energy.
Serbia is a country with traditionally known, but underused geothermal resources. Most of the geothermal sources, based on Figure 6, are concentrated in Vojvodina and Central Serbia, yet most of these hot water springs are not used or are only used for sport and recreational purposes in spa and tourist centres, without any special exploitation and transformation of the hot water into some other forms of energy.
Geothermal heat-flow density is the main parameter for the estimation of geothermal potential of an area. It is the quantity of geothermal heat flowing from the inner parts of the Earth to the surface each second through an area of 1 m^2. Geothermal heat-flow density on most part of Serbia's territory is larger than its average value for the continental part of Europe and amounts to about 60 mW/m^2. The largest values exceeding 100 mW/m^2, are measured in the Pannonian Basin, in the central part of southern and in central Serbia.
On the territory of Serbia not belonging to the Pannonian Basin, there are 160 natural springs of geothermal waters with temperature higher than 15℃. The highest water temperatures are in Vranjska Banja (96℃), then in Jošani čka Banja (78℃), Sijerinska Banja (72℃) etc. The t otal flow of all natural geothermal springs is about 4.000 litres/second. The total quantity of heat accumulated in geothermal water localities in Serbia up to 3000 meters of depth is about twice as much as the equivalent heat energy which could be generated by the combustion of all types of coal from all coal localities in Serbia. The flow from 62 geothermal drill holes on the territory of Vojvodina is about 550 litres/second with about 50 MW thermal energy and 108 MW from 48 drill holes in other parts of Serbia. On the territory of Serbia, aside of the favourable opportunities for the exploitation of thermal energy and other geothermal resources from hot springs, there are also favourable opportunities for exploiting the geothermal energy of hot dry rocks, i.e. rocks not containing free underground water /9,10/.
Geothermal sources on the territory of Serbia and the geological map of the terrain indicating the localities of these springs are shown in Figure 2.

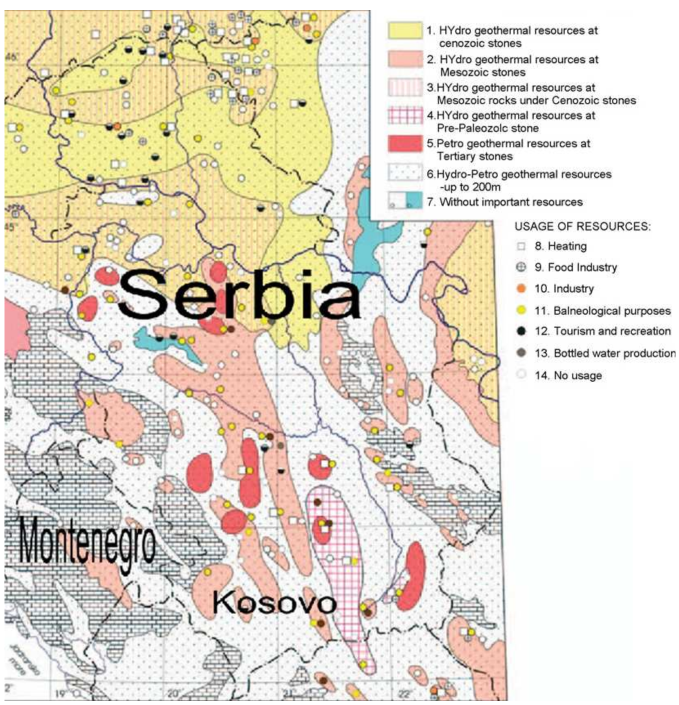

Figure 2 The map of geothermal potentials in Serbia [8]

2.3. Biomass Energy

Serbia, and especially Vojvodina, has at disposal a relatively large potential in biomass generated as an "surplus" in primary agricultural production. The total production in biomass from annuals agricultural plants in Serbia is over 12,5 million tonnes a year.

The potentials of biomass quantities, their lower thermal power and saving possibilities are shown in Table 3.

Table 3 Biomass potentials in Serbia

Table 3 clearly shows that the largest biomass potentials in Serbia are in straw and corn stover, which was to be expected with regard to the traditional character of growing these plants on the territory of Serbia. The largest opportunity for total savings in relation to light fuel oil was registered in the case of corn stover.

Most part of it is not used rationally. The energy which could be generated from biomass in Serbia is estimated to amount to 2,68 million tonnes of oil equivalent. Thereof 1,66 million tonnes of oil equivalent refer to agriculture and about one million tonnes to forest biomass. The total annual energy potential of biomass in Serbia is 40% of the energy value of cola annually produced in our mines.

In the Republic of Serbia, there are conditions for the production of biofuel-bioethanol and biodiesel.

The production of bioethanol in the republic of Serbia is, at present, based on molasses and cereal crops. The available molasses quantities do not meet current production demand: The total capacities in the current sugar factories generate about 200,000 tonnes of molasses a year, whereof 50.000 tonnes are used, while the rest of about 150.000 tonnes can be considered for utilisation for other purposes and bioethanol production. The quantities of molasses lacking for the production of bioethanol could be imported and it presents a significant problem under high price fluctuations and available quantities on the world market.

With regard to the more developed agricultural production and the fact, that the produced quantities of cereals fully satisfy, even exceed, domestic demand for human food and animal fodder, it is necessary to consider the opportunity of producing bioethanol from cereals. For the production of 100.000 tonnes of bioethanol about 330.000 tonnes of cereals are needed and it is one third of surplus of cereals on the market or only about 2-4% of the total production of cereals.

In the Republic of Serbia oilseed crops, i.e. sunflower, soya and rapeseed and used cooking oil can be used for biodiesel production. The total area of land under rapeseed is estimated to amount 668.800 ha, whereof 350.000 ha could be used for rapeseed for the production of biodiesel. The average production of biodiesel from oilseed crops, which can be cultivated in the Republic of Serbia are shown in Table 4.

Table 4 The production of biodiesel from oilseed crops

Oilseed crop	**Average yield of the seed (t/ha)**	**Oil content of the seed (%)**	**Biodiesel production**	
			(kg/ha)	**(l/ha)**
Sunflower	1,79	40	716	816
Soya	2,25	18	405	460
Rapeseed	1,69	36	608	690

Table 6 points out individual biodiesel quantities which can be produced from oilseed crops, more specifically sunflower, soya and rapeseed, as the most appropriate for this purpose. The largest potential yield per hectare is registered in the case of soya, but the largest potential quantity of biodiesel can be produced from sunflower with regard to the fact, that sunflower seed contains the largest average percentage of oil in the seed. Yet, from the aspect of yield and the seed's oil content, rapeseed is traditionally considered a crop most favourable for biodiesel production.

For the biodiesel production crop mixtures are especially interesting, more specifically, combining crops in order to obtain optimum yield and optimum quantities of oil in the seed, which is shown in Table 5.

Table 5 The structure of crop sowing as a parameter of possible biodiesel production

Crop sowing structure	Possible biodiesel production (t)
100 % rapeseed	212.800
70 % rapeseed + 30% sunflower	224.140
50 % rapeseed + 50% sunflower	231.700
30 % rapeseed + 70% sunflower	239.260
100 % sunflower	250.600
100% soya	141.750

Biodiesel production may be considered the most acceptable form of combined sowing of crops (Table 5). The largest potential biodiesel quantities can be produced from sunflower only or by sowing rapeseed and sunflower in certain combination. Sowing soya only for biodiesel production purposes is considered the most unacceptable.

2.4. Wind Energy

Preliminary researches show that in the Republic of Serbia there are appropriate locations for the building of wind turbines on which, on a longer run, about 1,300 MW wind turbine production capacities could be installed providing an annual production of about 2.300 GWh electricity.
The best locations for exploiting the energy of the wind are:

- the Pannonian Plain, north of the rivers Danube and Sava. This area covers about 2000 km² and is favourable for the building of wind turbines, because there is built traffic infrastructure, power supply network and the large electricity consumption centres are in the vicinity, etc.
- the eastern parts of Serbia: Stara Planina, Vlasina, Ozren, Rtanj, Deli Jovan, Crn Vrh etc. This area covers about 2000 km² and, in perspective, significant wind turbine installed powers could be developed there, while
- Zlatibor, Kopaonik and Divcibare are mountainous regions, where micro-locations favourable for wind turbine building could be established by measurements. It is expected that larger capacities of wind turbines could also be installed in these regions.

The energy potential estimates were made relying on the data by the Republic Hydro-Meteorological Institute collected by measurements on up to 10 m high meteorological posts. The accurate assessment of the feasibility of building a wind power plant (wind farm) on a given location requires detailed wind speed and direction measurements. The Energy Efficiency Agency of the Republic of Serbia accomplished a measurements of wind parameters at a height of 50 meters in Negotin, Veliko Gradiste and Titel and their results are shown in Table 6.

Table 6 Wind speed measurement results from selected locations in Serbia

Location	Average wind speed at 50 m height (m/s)		Extrapolated average wind speed at 80 m height (m/s)		Availability of data	
	6	12	6	12	6	12
Veliko gradiste	3,61	3,50	3,82	3,71	99,7%	99,0%
Negotin.	5,24	5,77	5,55	6,10	86,4%	92,4%
Negotin	4,68	4,72	4,95	4,99	97,8%	98,1%

The largest average annual wind speed was registered by measurements on the territory of the Negotin Municipality, while slightly smaller values were registered in the municipalities of Titel and Veliko Gradiste.
Measurements made by the Energy Efficiency Agency on the whole territory of Serbia are given in Figure 3, in which three separate belts could clearly be detected.

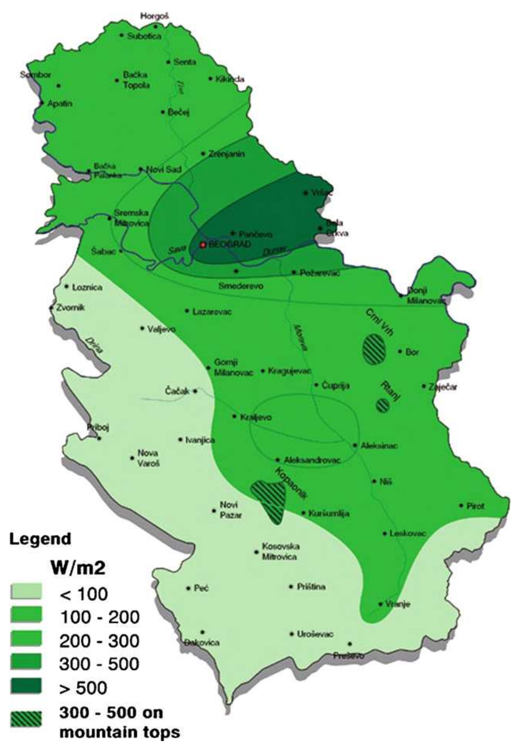

Figure 3 The map of average daily wind energy measured at 100 m height in Serbia[8]

The largest wind energy (over 500 W) was registered in that part of Serbia, which is in the vicinity of the state border with Romania, on the territory of the Vrsac Municipality and it stretches in the direction towards Belgrade. Slightly lower values, ranging from 100 to 500 W, were registered in most parts of Serbia, while the lowest wind energy values, i.e. below 100 W, which cannot be considered acceptable from wind turbine building view, were registered on the territory of South and West Serbia [I].

2.5. Hydroenergy – Small Hydropower Plants

It is estimated that Serbia's total hydro-potential is about 31 TWh a year. Most of this potential (about 62%) has already been exploited, because the building of larger production capacities is economically justified. The rest of the hydro-potential can be exploited by the building of smaller and more expensive facilities.

The potential of small water flows on which small hydropower plants may be built is about 0,4 million ten or 3% of the total renewable sources potential in Serbia. The energy potentials of water flows and the locations for the building of small hydropower plants are defined by the “Register of small hydropower plants on the territory of the Republic of Serbia outside the Socialist Autonomous Province” document from 1987, which made by the Energoprojekt- Hidroinzenjering Company and the Jaroslav Cerni Institute for the needs of the Associated Electricity Distribution Public Company and the register of small hydropower plants in the Autonomous Province of

Vojvodina, which treated 13 hydropower plants (Hidroinvest DTD, 1989). Some 900 potential locations were identified on which small hydropower plants could be built with output power ranging between 100 kW and 10 MW. The gross power which can be produced by the building of small hydropower plants on all locations is estimated to amount to approximately 500 MW. The fact is, that most of the locations, about 90% of them, has a capacity smaller than 1 MW. About 5,6% of the locations has a capacity between 1 and 2 MW, and 3,5% of them has a capacity of 2 and 5 MW, while only about 1% of the locations has a capacity between 5 and 10 MW. For the needs of making an overview of Serbia’s hydro-potentials, it is necessary to make a detailed overview of the distribution of river flows on the territory of Serbia, which is shown in Figure 4.

Serbia is a country rich in hydro-potential. Figure 4 apparently shows, that Serbia’s hydro-potential is almost equally distributed on the country’s whole territory and that there is an adequate canal network in Vojvodina. There are large, medium-sized and small capacity hydropower plants on the numerous watercourses in Serbia and all of them can be considered a potential for energy production of special interest.

With regard to the modest capacity of small hydropower plants, their use is justified for systems with smaller energy demand or through their inclusion into larger distribution systems [6, 10].

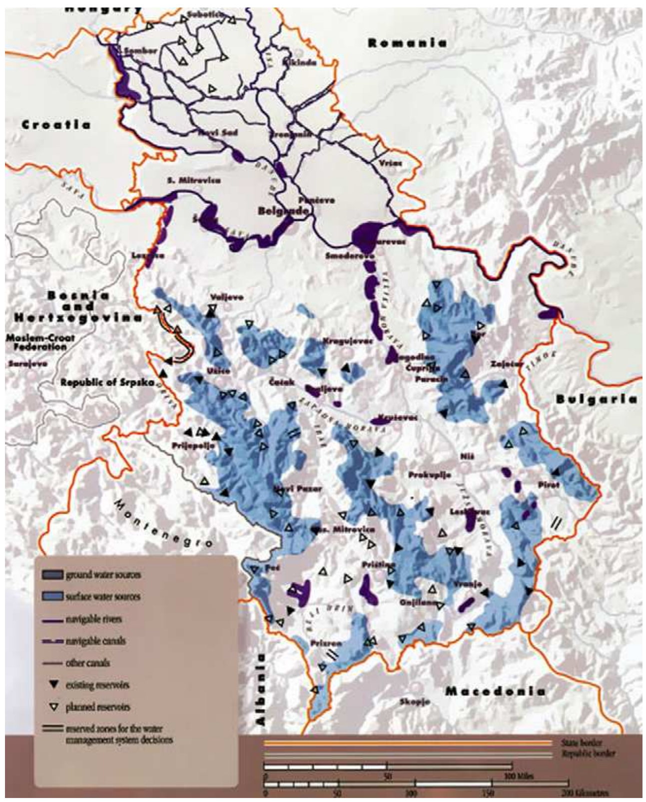

Figure 4 Map of Serbia’s hydro-potentials [8]

3. DETAILED OVERVIEW OF THE EXPLOITATION OF GEOTHERMAL SOURCES IN THE AUTONOMOUS PROVINCE OF VOJVODINA [11], [12], [13], [14]

3.1. Introductory Remarks

Our country is an area with energy deficit, hence, in the forthcoming period, significant efforts should be invested in finding new sources of energy. Beyond the efforts in providing the required quantities of conventional fuel (crude oil, gas and coal) and also in the intensive energy savings through rationalising the energy consumption of current installations, it is necessary to enable the use of available alternative (renewable) and non-conventional sources of energy as well (i.e. the use of biomass, geothermal energy, solar energy, biogas etc.).

Non-conventional sources may contribute to the prolongation of usage time of the deficient conventional energy sources. It is estimated that on a world-wide scale non-conventional energy sources participate with up to 2% in the total energy consumption. From this perspective, it may be concluded, that their importance in solving the energy problems of the future are nothing special. However, bearing in mind their **renewability**, uneven distribution in space, environmental advantage in exploitation, the tendency of growth in gross energy consumption, increasing attention is being devoted to this type of energy. The development level of specific non-conventional energy sources is differing country by country.

The major barrier in exploiting alternative energy sources is not the lack of good technical solutions and technologies of exploitation, but the requirement that the energy from these sources is competitive to conventional energy. On top of that, the reasons for lagging behind in building and promotion of alternative energy sources are the following:

- insufficiently linked programmes of scientific, research and producing organisations and the lack of uniform policy for the development of installations to be used for these types of energy,
- insufficiently informed investors and competent state authorities about the state of technology development and possible effects of substitution and about the decrease exploitation energy costs by applying these energy sources,
- higher investments costs than for traditional systems and the absence of incentives in financial-crediting and tax policies for their use.

The largest number of installations using alternative energy sources was built on the territory of Vojvodina. The reason for that is, that the Province Energy and Resources Committee from 1983 through 1989, appropriated incentive funds from the incomes from the basic tax on crude oil derivatives trade for programmes for the use of alternative energy sources and this Committee was accompanied by the Naftagas Company, which also provided incentives appropriated under the Law on Extra Fees.

3.2. General Part – Geothermal Energy

Currently, geothermal energy is used in many countries of the world, mostly, in two fields: for the production of electricity from natural water steam and for heating. There are no conditions in Vojvodina for using natural water steam, yet there are good conditions for exploiting thermal waters.

The first systematic and organised researches of thermo-mineral waters and hydro-geothermal energy in Vojvodina have started in 1969. In the beginning, the researches advanced relatively quickly and efficiently owing to the abundant heritage in expert documents developed in the process of exploring crude oil and gas, likewise the financial and professional potentials of the Naftagas Company. Under those circumstances, regional, and subsequently detailed, explorations could be approached systematically and in a planned manner. The conditions of occurrence, geo-temperature regimes and the physical and chemical characteristics of the water were registered within a relatively short period of time and it enabled to start with the second phase, i.e. the exploitation of thermo-mineral waters and hydro-geothermal energy.

The production of thermo-mineral waters and geothermal energy in Vojvodina started in 1978, while sales started in 1986.

The use of thermo-mineral healing waters in balneotherapy and prevention has always played an important role in the development of civilisation and it is still attractive for the contemporary society. The use of thermo-mineral waters for energy purposes started in the recent periods, while it has started to be used more extensively since the first energy crisis in the 1970s.

Based on experiences from the world and our country, it is estimated, that the Pannonian Basin's geothermal waters in Vojvodina, with regard to their physical-chemical and geothermal features, could be used in the following fields: in agriculture for heating greenhouses, in livestock and poultry breeding for heating farms, in the industry as a technological hot water, in balneotherapy and sport and tourist centres, for heating residential houses and other buildings, for providing sanitary water for households, in fishing etc.

In most cases, the indicated fields of use are practically exploited in our regions in the existing hydrothermal systems. Practically, the usage is most expressed in the non-energy sector and in spas and sport and recreational centres respectively. Yet, the basic aim of the use of geothermal waters is the area of energy targeted to substitute traditional fuels, which means, that the structure of use should be changed in favour of this latter area of consumption.

When the Naftagas Company, suggested by the Energy and Resources Committee, accepted to design and co-finance the project on the use of geothermal waters, 23 systems were built for the use of thermo-mineral waters, partly for energy and partly for balneotherapeutical and sport and recreational purposes (Table 1 and 2). The Energy and Resources Committee co-financed the implementation of the programme on the use of geothermal energy for energy purposes from the incomes from retail price of crude oil derivatives in the period from 1983 through 1989.

3.3. The Current Status in Using Geothermal Energy in Vojvodina

3.3.1. Operating Hydrothermal Drill Holes

In 2012, NIS –Gaspromnjeft exploited 15 hydrothermal drill holes with a total production of about 1.042.000 m^3 /year. The total optimum capacity of these drill holes is about 134 litres/second, i.e. about 2.700.000 m^3 annually and it means, that the available capacities were exploited about 38,6% in 2004. The basic data about operating hydrothermal drill holes are given in Table 7.

Tabel 7 : Operating hydrothermal drill holes

No	Locality - settlement	Used by	Started to use	Purpose	Gen. Flow (l/s)	Temp. (°C)	Possible substitution by heating oil (t/g)
1	Bečej	Mladost Youth Sport Club	1988	Space and pool heating	17,2	65	2.097
2	Srbobran	Elan Greenhouse	1984	Greenhousing heating	11,67	63	403
3 4 5	Kanjiža	Banja-Kanjiža Spa	1981 1986 1999	Heating of the spa and balneology	1,8 9,3 12,5	41 65 70	76 1.067 1.791
6	Prigrevica	Junaković Spa	1983	Heating of the spa and balneology	11,8	53	1.228
7	Palić	Elitte	1985	Outdoor pool for Sports and recreation	5,5	48	178
8	Palić	Hotel Jezero	1988	Heating space	6,3	48	241
9	Temerin	Komunala PC	1987	Outdoor pool for recreation	14,9	40	179
10	Alibunar	Tourist organisation (Devojacki bunar)	1986	Outdoor pool for recreation	7,4	24	...
11	Ban.Veliko Selo	Kozara Company	1987	Heating of pig farm	11,2	43	433

The possible heating oil substitution in facilities indicated in Table 7 amounts to approximately 7.700 tonnes a year. The use of these utilities at optimum level would enable annual savings in heating oil of up to 13.000 tonnes. Regretfully, only a part of the available energy is used in the current hydrothermal systems, partly because of the users' inadequate installation, partly because of the non-harmonised needs of users with the drill holes' capacities. At present, geothermal waters in Vojvodina are underused and we may say that it is symbolic.

3.3.2. Once Operating Hydrothermal Drills

Besides the above indicated 15 operating systems, aboveground hydrothermal systems were built on another eleven hydrothermal drill holes, yet, these are out of production currently because the system users stopped taking over thermal water. Table 8 shows hydrothermal drill holes with established hydrothermal systems not being exploited.

Tabel 8 : Non-exploited hydrothermal drills

No	Settlement	Former user	Started to use	Purpose	Optimum Flow (l/s)	Temp. (°C)	Status
1	Subotica	Institute for Physical Culture	1984	Outdoor pool for sport and recreation	4,83	35	Not exploited since 2001
2	Čelarevo	Dunav TC	1996	Dunav Motel indoor pool	5,00	31	Already 8 years not exploited
3	Kula	Centre for Physical Culture	1981	Heating of the sport and recreation centre	9,50	50	Not exploited For several years
4	Kula	Eterna Leather Factory	1984	Industrial hot water	8,33	53	Not exploited, stand-by drill hole
5	Kula	FVT"Sloboda"	1985	Industrial hot water	8,50	51	Not exploited since long time
6	Melenci	Rusanda Spa	1985	Balneology	6,9	33	not exploited for year
7 8	Vrbas	Institute for Physical Culture	1986 1986	Indoor pool for recreation	3,50 4,33	39 51	Not exploited, the system is disassembled
9	Banatsko Veliko Selo	IPP"Banat"	1988	Heating of business premises	6,67	45	Never exploited
10	Kikinda	KRO"6.oktobar"	1984	Heating of business premises	6.17	50	Not exploited For several years
11	Kikinda	Jedinstvo Pig Farm	1985	Heating of the farm	10,1	51	Not exploited since 2002
12	Bački Petrovac	Institute for Hop	1987	Space heating And plant drying	6,5	46	Not exploited For several years
13	Mokrin	Mokrin Company	1984	Heating of pig farm	7,0	51	Not exploited For several years
14	Kula	Eterna Leather Factory	1984	Industrial hot water	5,6	53	Not exploited recently

As apparent from Table 8, 14 from the total number of established systems do not operate because of various reasons:
- The Institute for Physical Culture from Subotica used geothermal energy to heat the outdoor pool, but it has not been exploited since 2001.
- The Dunav Textile Factory from Celarevo used geothermal energy for the indoor pool in the Dunav Motel, but stopped using it for this purpose eight years ago, because the motel was closed.
- U Centru za fizičku kulturu u Kuli, sistem je predviđen za podno grejanje i napajanje rekreacionog bazena. Međutim, Centar već duže vreme ne radi i sistem korišćenja geotermalne energije nije u funkciji.
- In the Eterna Leather Factory in Kula the system used to satisfy the needs of the leather processing technology, but the factory was closed. Postojala je zainteresovanost za korišćenje geotermalne vode od strane Kompanije Rodić, koja se nalazi u neposrednoj blizini.
- In the Sloboda Factory of Wool Fabrics in Kula, the system was foreseen to heat hot consume water, but, since the factory is not operating, the drill hole is not used.
- In the Elan Factory in Srbobran, the system was foreseen to heat 0,5 ha of greenhouses but it is not in operation. Some technical repairs would enable to re-direct geothermal water for heating part of the existing greenhouses when the cooperative will start with operation. The greenhouses have not been used since 1992.
- In Vrbas geothermal energy was used for indoor recreational pool. The user unilaterally stopped to use geothermal water 10 years ago, justifying his decision by limescale incrustations on the pool's walls and in the meantime parts of the system's equipment were disassembled and used in other hydrothermal drill holes.

- In IPP Banat from Banatsko Veliko Selo, the system was foreseen to be used for heating business premises, but the users failed to accommodate their installations for using thermal water, so the system has not been used since the construction works stopped.
- The 6 oktobar Public Utility Organisation in Kikinda used the system for heating its commercial building during the transitional period, however, several years ago, the user unilaterally stopped using geothermal water and now uses gas.
- The Jedinstvo Pig Farm in Kikinda used geothermal energy to heat the farm. This system has been out of operation since 2002 because the user installed electric heaters for heating the farrowing barn.

In order to re-activate these hydrothermal systems, it is necessary, firstly, to implement a fault diagnosis of these installations, then to plan their possible reconstruction and repair, discuss it with the users, who assumed contractual obligations, but do not use geothermal water and thereafter to consider the possible schedule of including these system in production.

In cases where activating the production for existing users is not possible, the opportunity of finding new geothermal water users for a given system should be considered in cooperation with the municipal administration bodies.

3.3.3. Never Exploited Positive Hydrothermal Drill Holes

Besides the established hydrothermal systems, there is whole set of thermal drill holes which could be used in perspective both in energy and drinking water supply of users. The basic data about these drill holes are given in Table 9. The flow values of these drill holes are given there as a maximum flow used for hydro-dynamic measurements, yet in a smaller number of cases, where such measurements were not accomplished, the maximum flow was given based on the flow established during the start of drilling.

Table 9 : Hydrothermal drills with possible exploitation

No	Drill hole –Locality	Q_{max} (l/s)	Testing method	T_{iz} (^oC)	M (g/l)	S (g/l)	Remark:
1	2	3	4	5	6	7	8
1	Bč-1/H (Bečej)	10,65	Flowing	33	4,51	0,61	Within the Flora Factory. After testings, an eruption device was mounted on the drill. The drill hole has never been exploited.
2	BP-1/H (Bački Petrovac)	16,67	With pump	46	0,79	0,13	Located on property PPRO 15. oktobar, 200 m from the traffic road Novi Sad- Bački Petrovac
3	BT-2/H (Bačka Topola)	10,67	With pump	37	3,84	0,67	The drill should have replaced the existing exploitation utility for the supply of the sport and recreation centre. The drill's technical status is not known.
4	Cr-5 (Srpska Crnja)	18.3	Flowing	75	4,61	2,69	The drill hole is negative to hydrocarbons. There is a built-in filter and was tested fo HGT needs. Conserved with re-activating possibility. Increased phenol content is a limiting factor in the use of these waters.
5	DP-1 (Bačko Dobro Polje)	14,66	Flowing	57	2,89	0,82	The drill hole is negative to hydrocarbons. There is a built-in filter and was tested fo HGT needs. Conserved with re-activating possibility.
6	Kps-1/H (Kupusina)	3,30	Flowing	72	6,94	3,92	The potential user is the Apatin Agro-industrial Coop. Increased phenol content is a limiting factor for using this water for sport, recreational and balneological purposes.
7	NS-2/H (Novi Sad)	2,70	With pump	35	2,17	0,51	
8	NS-3/H (Novi Sad)	6,83	Flowing	38	1,09	0,53	Located near the Naftagas Company Complex in Sangaj. After testings, an eruption device was mounted on the drill.
9	NSb-1/H (Novi Sad)	17,06	With pump	23	1,54	0,51	Located in the Stara gradska bolnica Clinic Centre. After testings, an eruption device was mounted on the drill.
10	Pb-3/H (Prigrevica banja)	14,00	Flowing	53	5,94	3,97	The drill hole was made with the aim to provide additional quantities of thermo-miner waters for Junakovic Spa. After completion, the drill hole was equipped with drill head.
11	Prg-1/H (Prigrevica)	2,70	With pump	43	6,09	4,00	The drill hole was made in the Junakovic Forest.
12	So-1/H (Sonta)	2,50	With pump	43	6,66	6,19	The potential user is the cord manufacturing coop of the Apatin Agro-industrial Cooperative.
13	Sr-2/H (Srbobran)	5,50	Flowing	54	3,59	0,76	The drill hole is located on the property of the Pig Farm, which should have been the potential user. The system was not built.
14	Vrb-3/H (Vrbas)	13,00	Flowing	54	2,94	0,58	The potential user was the sport and recreation centre in Vrbas.

15	Zob-1/H (Zobnatica)	3,3	With pump	36	3,96	0,29	The drill hole is located on the property of the Agro-industrial Coop from backa Topola. The water should have been used for sport and recreation.
16	BK-1/H (Banatski Karlovac)	15,70	With pump	27	0,42	0,05	It was planned, that the drill hole, in case of positive results, would serve to supply the outdoor pool.
17	Ja-1/H (Janošik)	9,56	With pump	35	3,51	2,13	It was planned, that the drill hole, in case of positive results, would serve to supply the spa and recreation centre. .
18	Ki-4/H (Kikinda)	4,70	Flowing	57	-	-	Located within the Galad Pig Farm, aimed to heat the farm.
19	Vbc-1/H (Vrbica)	16,70	Flowing	82	6,86	3,39	The drill hole is positive, conserved by cement shields above the tested intervals. Increased phenol content is a limiting factor , especially in the deepest interval.
		4,30	Flowing	68	4,50	0,34	
		4,80	Flowing	54	4,41	0,21	
20	Ži-1/H (Žitište)	3,30	With pump	44	4,27	0,22	It was planned, that – in case of positive results- the user would be a slaughterhouse, wherein the drill hole is located.
21	Zr-1/H (Zrenjanin)	4,00	With pump	45	4,28	0,47	Supplementary testings were made in 2001. The possible user may be the Zrenjanin Carpet Factor using the drill for its technology.
22	Inđ-1/H (Inđija)	13,33	Flowing	56	4,09	2,51	It was planned, that – in case of positive results- the drill hole serves sport and recreational purposes and hotbeds and nurseries.
23	Kup-1/H (Kupinovo)	42,84	Flowing	51	0,81	0,08	
24	Kup-2/H (Kupinovo)	15,00	Flowing	45	1,10	0,13	The drill hole was intended to supply greenhouse heating for Kupinovo Production Unit.
25	Šaj-1/H (Šajkaš)	6,00	With pump	39	1,9	1,45	Positive, testing ongoing. The user is the Buducnost Organisation and will use it to supply The future sport and recreation centre.

Q_{max}– maximum registered flow of the drill hole, T_{iz} – water outgoing temperature, M – water mineralisation, S – water salinity

Aside of the indicated ones, there is a number of drilled and tested hydrothermal drill holes, which have never been used for production because there were no users. Some of these drill holes were drilled as exploratory holes aimed at surveying the geothermal potentials of the observed regions. No sufficient care was taken about them in view of finding possible users. The opportunities for exploiting geothermal waters from the drill holes shown in the table above are rather diversified, but, first and foremost, we must aim at their use for energy needs as much as possible. By analysing the observed drill holes from flow, outgoing temperature, mineralisation point of view, we can divide them into several groups.

1. Exploiting drill holes for energy needs in:
    - Backi Petrovac - for agricultural needs – greenhouse heating or heating of the recreational pool.
    - Backo Dobro Polje - for agricultural needs: heating greenhouses and the pig farm.
    - Kupinovo-for agricultural needs: heating greenhouses, drinking water, fish breeding and fish spawning.
    - Srbobran – for agricultural needs: heating greenhouses and heating part of the Elan Cooperative (farm).
    - Kupinovo-for agricultural needs: heating greenhouses, drinking water and space heating.
    - Sonta- for agricultural needs: heating greenhouses.
    - Prigrevica Spa – heating the Junakovic Spa, balneology.
    - Inđija – for space heating, recreation, hot sanitary water supply for households, balneology (NIS-Naftagas and NIS-Inzenjering have already developed a Study on Exploitation).
    - Srpska Crnja: for greenhouse heating with the possibility of using the gas from the gas bearing layer.

2. Exploiting drill holes for recreational purposes in Novi Sad (three holes: NS-1/H, NS-2/H, NS-3/H,) and in Becej for recreational pools and Janosik (spa).

3. Exploitation for industrial water supply of the hospital from the drill hole in Novi Sad (NSb-1/H).

3.3.4. Conserved drill holes, which were hydrocarbon negative but tested for hydrothermal needs

The basic data about conserved, hydrocarbon-negative drill holes, tested for hydrothermal needs are depicted in Table 10. The flow of these drill holes is given as a maximum flow, which was used for hydro-dynamic measurements, or the maximum flow was established at the beginning of the drilling process. These drill holes could be used for the production of thermo-mineral waters and, practically, they are treated as drill holes from the third group.

Table 10: The flow of hydrocarbon-negative, hydro-thermal drill holes

No	Drill –Locality	Q_{max} (l/s)	Testing method	T_{iz} (^oC)	M (g/l)	S (g/l)
1	BM-1 (Bački Monoštor)	15,0	Flowing	73	6,78	3,57
2	Pg-1 (Palić border)	3,3	Flowing	65	6,9	4,07
3	Ks-1 (Kikinda farm)	4,3	Flowing	63	2,41	1,55
4	NK-5 (Novi Kneževac)	10,8	Flowing	65	10,54	6,74
5	Pd-2 (Padej)	3,3	Flowing	46	3,45	-
6	VS-5 (Banatsko Veliko selo)	4,2	Flowing	73	2,55	0,851
7	VSts-1(Vojvoda Stepa-north)	3.5	Flowing	56	4,44	0,29

Q_{max}– maximum registered flow of the drill hole, T_{iz} – water outgoing temperature, M – water mineralisation
S- water salinity

Besides the hydro-thermal drills, NIS-Gaspromnjeft accomplished testings on a number of hydrocarbon-negative drill holes aimed at establishing the opportunities for exploiting thermo-mineral waters. Most of the drill holes were eliminated after testing, while some of them, where the results were more favourable, were conserved.

Figures 5, 6 and 7 show the drilling schedule of hydro-thermal drill holes, the geothermal water production and the distribution of hydro-thermal utilities in Vojvodina.

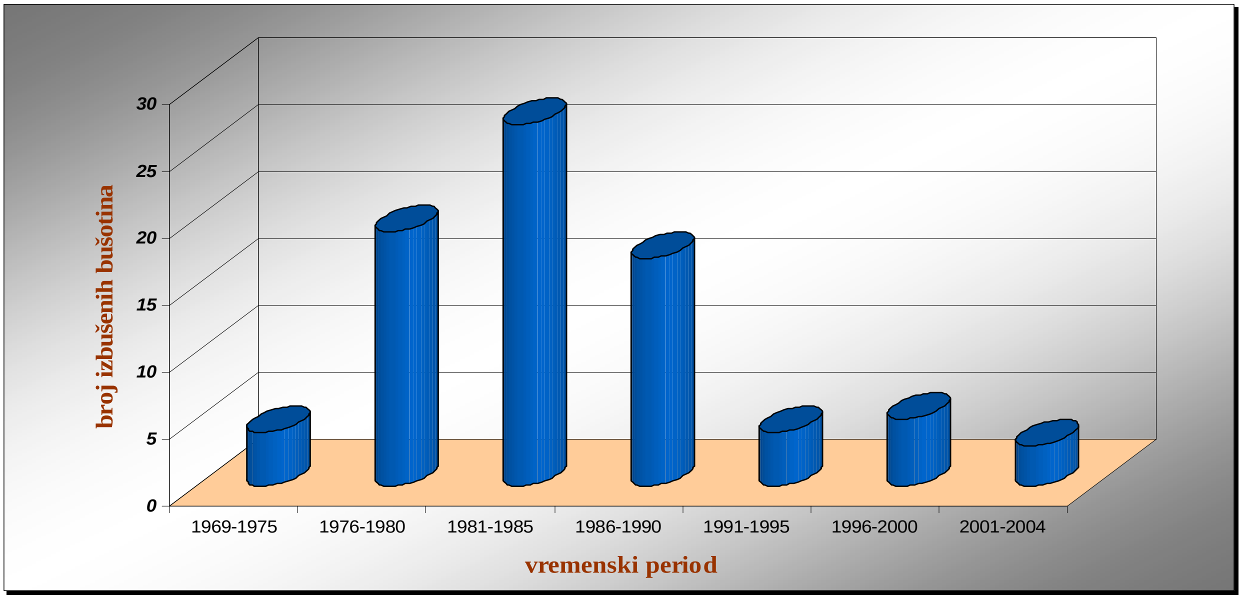

Figure 5: The schedule of geothermal hole drilling

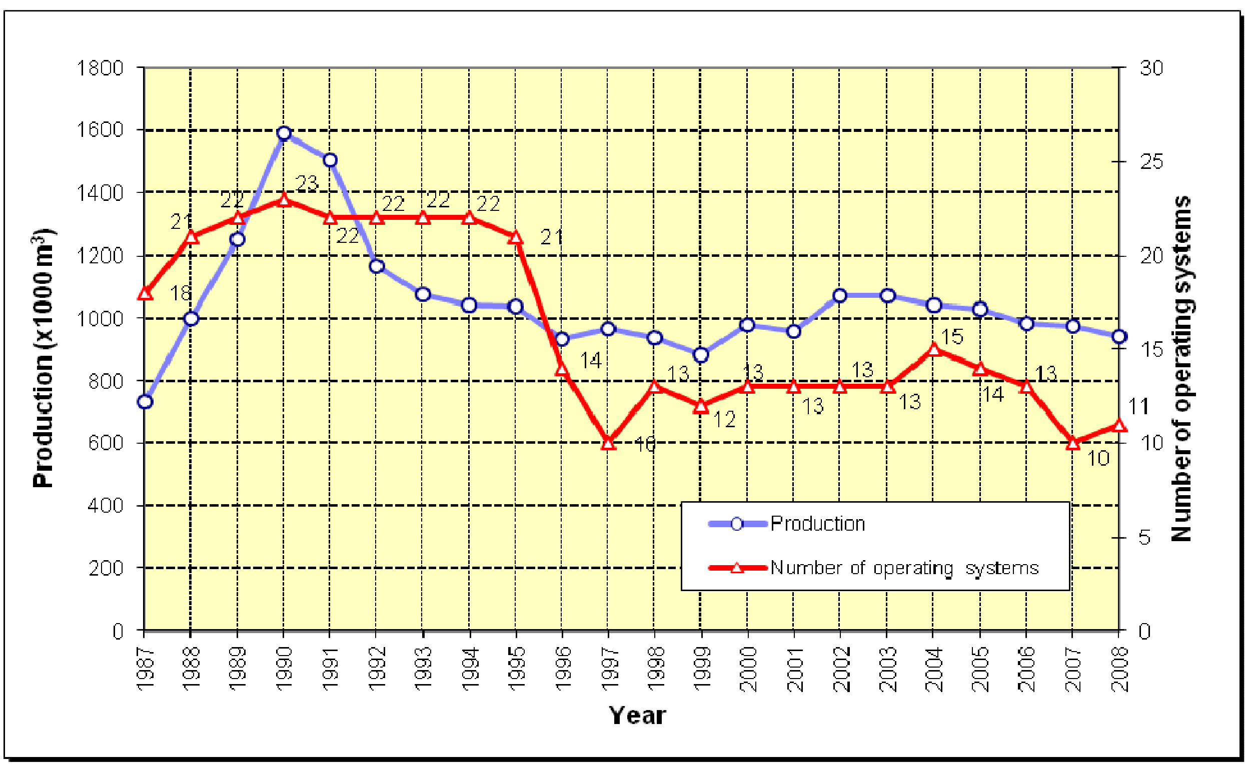

Figure 6: Geothermal water production

Figure 7: The distribution of hydrothermal utilities

4. FINAL REMARKS AND CONCLUSIONS

Our experiences up to now in the exploitation of geothermal waters in Vojvodina showed, that there is interest in the use of this type of energy. Occasional surveys made among the geothermal energy users in Vojvodina indicate their full satisfaction with the effects of its use. More importantly, there have been no major operational failures or standstills in the existing systems and they provide high operational safety. High investment costs and the lack of finances are major issues.
A total of 79 thermo-mineral drill holes were drilled in Vojvodina (about 65,300 m drilled, the average drill depth is 827 m, while the deepest drill is 2,520 m deep). Drill holes are the most numerous in Backa – 48, followed by Banat with 18 and the least number of them is in Srem – 13. The optimum flow of drill holes on flowing, most often, ranges from 10 to 15 l/s, while the outgoing temperature are between 45 and 65 °C. In the period from 1986 to 2004, the total implemented production was about 19.886.000 m^3.
The use of alternative energy sources in the AP of Vojvodina goes on at varying pace. The reasons for the unbalanced use of certain alternative energy sources are: different interests of the users, the price of the equipment and the unit price of the produced energy in relation to traditional energy sources.

The support and help by the broader community is imperative, so that the current users of alternative energy sources continue with it and also, that new users opt for the use of these types of energy. Departing from the importance of using alternative energy sources and the potential opportunities for financing projects from this field also by foreign funds, it is necessary to harmonise these projects with the international standards.

Systems using geothermal energy but not operating at the moment should be re-activated. In cases, where activating the production for existing users of geothermal energy is impossible, the finding of new users should be considered in cooperation with the municipal administration bodies (Table 2). It is also necessary to contact potential users of geothermal energy (Table 3) for established drill holes, which have not been used so far.

As it can be seen from the attached tables, there is a large number of drilled and tested hydro-thermal drill holes (some already equipped) capable of exploiting thermo-mineral water for diverse needs. Finding users for these drill holes in which significant financial sources were invested during their construction is a priority. The assistance of the respective local self-government would be invaluable in that.

Besides the hydro-thermal drill holes, in Vojvodina, a massive number of drill holes were made for hydrocarbon-explorations and comprehensive geophysical surveys were accomplished as well. A synthesis of all available data enables a sufficiently reliable overview of hydrogeological characteristics of specific localities in view of water quality, flowing and outgoing temperature, likewise in designing new hydrothermal drill holes.

New drill holes are to be made for specific users only, who should commit themselves to finance, partly or fully, the execution of works. The design of all works, the drilling, equipping and testing of drill holes, and the building of aboveground hydrothermal systems can fully be implemented with the use of domestic resources.

Based on the data presented in this paper, the average flow per a single drill hole is about 9,5 l/s and the average outgoing temperature of the water is 48,8 °C. The total thermal potential (power) of these, exploitable drill holes (having established systems) is about 50 MW and heating oil savings may amount to about 22,700 tonnes in a heating season.

Based on experiences from the world and our country, it is estimated, that the Pannonian Basin's geothermal waters in Vojvodina, with regard to their physical-chemical and geothermal features, could be used in the following fields:

- in agriculture for heating greenhouses,
- in livestock and poultry breeding for heating farms,
- in industry, as industrial hot water,
- in balneotherapy and in sport, recreation and tourist centre,
- for heating households and other facilities,
- for supplying sanitary hot water for households,
- in fishery.

In order to use the available geothermal potential on the territory of the AP of Vojvodina more efficiently, it is necessary to submit to local self-governments the list of non-used hydrothermal drill holes in municipalities.

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