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Estimates of Geothermal Resources in Belarus and the Country Update

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ABSTRACT

The energy supply industry in Belarus is based mostly on the use of different kinds of fossil fuels (gas, oil, coal). Smaller percentage of energy production is based on the use of local fuels (peat, firewood, wood chips, etc.). Installations to use wind and solar energy as well as biomass to generate electricity are still at the experimental stage. There are no nuclear electric stations in the country. Therefore, Belarus is dependent on the energy import from neighbors, first of all, of the natural gas and crude oil supply from Russia.. The country produces itself only around 20% of the annual consumption of raw oil and a few percents of requested natural gas. Therefore the problem to increase the utilization of local sources of energy, including its renewable kinds is evident. The geothermal energy belongs to them and is available in the subsurface within practically the whole territory of Belarus. But the most promising areas for the underground heat extraction are the Pripyat Trough and the Brest Depression, located in the southeastern and southwestern part of the country, respectively, Zui, Levashkevich (2000); Zui et al. (2002).

Resources of the geothermal energy are dependent on a number of parameters. Depths to geothermal horizons, the ambient temperature of rocks, the composition and content of dissolved chemicals within these reservoirs are the primary factors, influencing both the estimated geothermal resources, and technical possibilities of their exoploitation. The deeper the geothermal horizon within the platform cover, the higher is its temperature and the higher is the dissolved chemicals content of warm groundwater and brines, saturated rocks. For instance, the latter parameter is the most critical one complicating the geothermal resources exploitation from deep geothermal horizons of the Pripyat Trough both from technological and economical points of view.

1. GEOLOGICAL BACKGROUND

A junction of geologic units of different age and origin takes place within the territory of Belarus. Three deep sedimentary basins exist in the northeastern, southeastern and southwestern parts of the considered area. They are the Orsha Depression, Pripyat Trough and the eastern part of the Podlyaska-Brest Depression, respectively. The main part of the latter one is stretched into the territory of Poland and only its easternmost margin is traced in southwestern Belarus, Fig.1.

The Pripyat Trough is the deepest sedimentary basin within the territory of Belarus. Its crystalline basement is subdivided into many blocks by deep faults, which is reflected in variable depths of them. In turn, its platform cover has a complex geological structure with two salt bodies of the Devonian age. The Intersalt deposits separate the Upper Salt and Lower Salt complexes within the trough. The total thickness of the platform cover varies in a wide range from 0.5 km at the margin with the Polessian Saddle till 5.0 – 5.5 km along the southern marginal fault, separating the trough from the Ukrainian Shield, and the northern limiting fault, separating it from the Bobruisk Buried Inlier, North-Pripyat Arm and the Zhlobin Saddle. The Bragin-Loev Saddle joins the Pripyat Trough with the Dnieper-Donets Depression, the main part of which is located in the territory of the Ukraine.

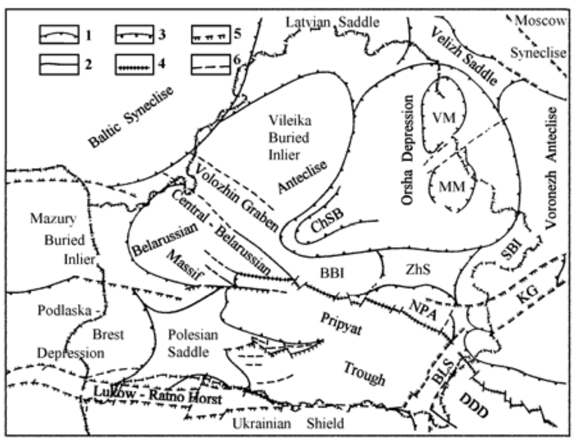

Figure 1: Main geological units within the territory of Belarus; Geology (2001), modified.

Legend: Borders and structures: 1 – the largest, 2 – large, 3 – medium. Platform Faults: 4 – super regional, 5 – regional, 6 – sub regional and local. Abbreviations: BBI – Bobruisk Buried Inlier, ChSB – Cherven Structural Bay, DDD – Dnieper-Donets Depression, KG – Klintsy Graben, MM – Mogilyov Mulde, NPA – North-Ptipyat Arm, SBI – Surazh Buried Inlier, VM – Vitebsk Mulde, ZhS – Zhlobin Saddle.

The lower geothermal horizon of the trough is related to Devonian sediments overlying the crystalline basement and underlying the complex of the Lower Salt. Its depth reaches sometimes 4.5 –5.5 km depending on the considered basement block. Temperature values range here from about 70 till 110-120 ˚C. A stagnant regime exists here, brines filling the pores and cracks in rocks have the dissolved chemicals content up to 400-420 grams per liter (g.p.l.), Kudelsky, et al. (1985).

The intersalt deposits separate the Upper Salt and Lower Salt complexes within the trough. The depth to their roof is on average 2.0 –3.0 km. High salinity brines were observed within this complex. The content of dissolved chemicals here is lower than in the sub-salt geothermal horizon, but still reaches on average up to 180-300 g.p.l. A thickness of the permeable intersalt deposits ranges from 100 meters in the western part of the area up to 1000 meter observed in a few wells of the southern and southeastern parts.

Sediments overlying the Upper Salt form the upper geothermal complex. Its thickness varies from about 300 meters above some of salt domes and swells till around 1.5 – 2 km in some of local areas. Temperature values at the base of this sedimentary complex range from 18-20˚C to 48-50 ˚C.

The sedimentary cover within the easternmost part of the Podlaska-Brest Depression varies on average from c.a. 0.5 km along its margin with the Mazury-Belarussian Inlier of the Byelorussian Anteclise, Lukow-Ratno Horst and the Polesian Saddle till 1.5 km close to the polish border. A few dozens of deep boreholes were drilled here, but their area distribution within the depression is irregular. The maximal recorded temperature at the base of sedimentary cover doesn't exceed 37-40 ˚C. A specific feature of the depression is the deep position of the fresh water base. It reaches in some localities up to 1.0 – 1.3 km.

Very thin sedimentary cover overlies the crystalline basement of the Central Byelorussian Massif. Its thickness ranges approximately from 90 to 150 meters. Within the rest of geological structures of the Byelorussian Anteclise, Polesian and Latvian saddles, Bobruisk and Surazh buried inliers and the Zhlobin Saddle it usually ranges from 100 to 500 meters. Dozens of boreholes within their limits were studied in geothermal respect. In most cases there are no laterally extended water-confining layer and the fresh water zone frequently was encountered at the surface of the crystalline basement. The temperature at the base of the sedimentary cover ranges from 8-9 till 13-17 ˚C.

In contrast to the Pripyat Trough, which represents now the best studied area of Belarus in geothermal respect, as hundreds of deep boreholes were drilled in the course of oil prospecting, the Orsha Depression is poor studied by drilling until now. Only a few boreholes reached the surface of the crystalline basement. The highest thickness of the platform cover within the Mogilyov and Vitebsk muldes of the Orsha Depression reach 1.7 – 1.9 km, Aizberg et al. (2004). It diminishes to 0.5 – 0.7 km in the direction of the Zhlobin Saddle, Vileika Burried Inlier, Cherven Structural Bay, Surazh Butied Inlier and the Latvian Saddle. The Orsha Depression has its continuation into the territory of Russia, where it joins with the Moscow Syneclise. Reliable temperature data measured at the surface of the crystalline basement in both muldes are absent. The estimated values are in the range 20-35 ˚C.

2. TERRESTRIAL TEMPERATURE FIELD

The geothermal exploration in Belarus was started since 1954 when the first temperature log, recorded in one of deep boreholes of the Pripyat Trough, was published, Belyakov (1954), but the most of temperature-depth records and heat flow density determinations were fulfilled during eighties and nineties of the past century.

Now temperature logs are available for more than 500 shallow and deep boreholes drilled in the whole country within all geological units. The Institute of Geological Sciences recorded around 50 percent of them, when the second part represent diagrams recorded in the process of the routine industrial logging fulfilled by drilling companies.

Several temperature distribution maps were prepared using this temperature database for the whole territory of Belarus but only till the depth of 500 meters, as within geological units covered by the thin sedimentary cover (the Belarussian Anteclise, Polessian, Zhlobin, Latvian saddles and adjoining inliers) only a few boreholes were drilled deeper into the crystalline basement. The temperature distribution at the depth of 500 meters for the considered area is shown in Fig. 2.

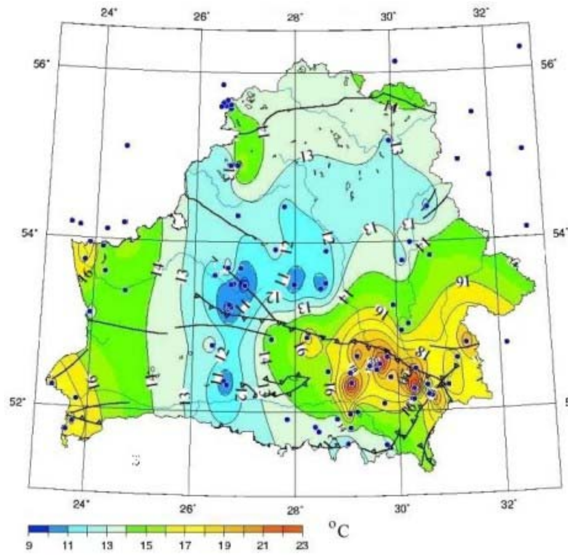

Figure 2: Temperature distribution within the territory of Belarus for the depth of 500 m.

Legend: Dots show the locations of those boreholes, temperature readings in which at the depth of 500 meters were used to compile the map. Only a part of boreholes with available temperature logs are shown here.

Whereas the Pripyat Trough is the best studied geologic unit in Belarus, the byelorussian part of the Podlaska-Brest Depression is less investigated in geothermal respect. Only a couple of dozens deep boreholes exist now here, drilled mostly to the north of Brest town. Being added by the data from shallow holes, they still give the general information on the temperature distribution pattern within its platform cover. Around 100 temperature logs recorded in shallow boreholes are available at present within the Byelorussian Anteclise includind adjoining saddles and inliers.

A zone of lower temperature of 11-13 ˚C is stretched from the the Ukrainian Shield into the Latvian Saddle and the Moscow Syneclise, see Fig.2. It crosses the northern part of the Orsha Depression as well. Anomalies of increased temperature 14-16 ˚C exist within the Pripyat Trough, Brest Depression and the Mazury Buried Inlier near Grodno town. The highest temperature values up to 20-25 ˚C correspond to the northern zone of the Pripyat Trough, where the geothermal anomaly exists within the northern part of the Pripyat Trough. Here the recorded temperature is on average two times higher than in its southern part at comparable depths.

An asymmetry of the terrestrial temperature field exists within the whole platform cover of the trough. Fig. 3 shows a simplified temperature distribution pattern at the depth of 4 km within the Pripyat Trough. Anomalously high temperature above 80 and even 90 ˚C exist within the northeastern part of the studied territory. Recorded temperature values are again almost two times lower in the southern and especially southwestern part of the trough relatively to the area of the positive temperature anomaly.

The complex geometry of salt bodies and sedimentary complexes reflects in the temperature distribution over the whole Pripyat Trough area. Low temperature values around 35 ˚C were observed within the western part of the trough. Lower temperature values around 40-45 ˚C were recorded in the southern part of the trough. The main potential consumers of geothermal energy are towns and settlements.

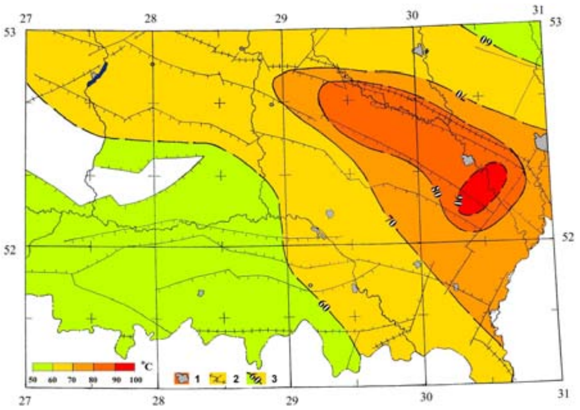

Figure 3: Simplified temperature distribution pattern at the depth of 4 km within the Pripyat Trough.

Legend: 1 – main towns and settlements, the potential consumers of geothermal resources, 2 – faults, 3 – isotherms, ˚C.

Terrestrial temperatures at the basement surface reach maximal values 37-40 ˚C at the depths of 1300-1450 meters within the byelorussian part of the Podlaska-Brest Depression near the Belarus-Poland border. Temperature field is poor studied at deep horizons of the Orsha Depression. A few available temperature diagrams allow us to estimate it to be 25-30 ˚C at the base of the sedimentary cover (1500-1800 meters).

3. OUTLINE OF GEOTHERMAL RESOURCES

The estimates of the density of geothermal resources were fulfilled a few years ago, Zui, Levashkevich (1999); Zui, Levashkevich (2000). The published data represented very preliminary results as the geothermal horizons, their thickness, porosity, etc were not taken into account. They showed that the territories of the easternmost part of the Podlaska-Brest Depression and, especially, the Pripyat Trough represent the Primary interest for practical use of geothermal resources. Therefore, later the main attention was given to investigate in more details geothermal resources of the Pripyat Trough.

Nowadays the density of geothermal resources was calculated for a number of geothermal horizons of warm water and brines within the Pripyat Trough using the standard approach, Hurter, Haenel (2002). They are: "(a) the Intersalt sediments, (b) the Upper Salt complex, (c) the Devonian strata, covering the Upper Salt and (d) overlying the latter one so-called "above-the salt deposits". For details of calculations, see in this volume, Zui, Mikulchik (2005). The approach used to estimate the density of geothermal resources is similar for all mentioned above geothermal complexes. We didn't consider the so-called "under-the-salt" carbonate and terrigenous complex of rocks, as well as the Lower Salt thickness. The former one includes brines with the content of dissolved chemicals up to 400-420 g.p.l. and there is no the international practice to use such geothermal brines for the geothermal energy production. The roof of the Lower Salt complex occurs at considerable depth, which complicates the effective use of borehole heat exchangers for a heat extraction from hot and dry rock salt bodies. An example of the geothermal resources density in t.o.e. for the Upper Salt complex is shown in Fig. 4. They have a considerable differentiation within the trough area and range from 0.5 up to 4-4.5 t.o.e./m^2 depending on the salt layer thickness and their temperature. The highest values correspond to the northern zone of the trough. The prevailing values 1.25 – 2 t.o.e/

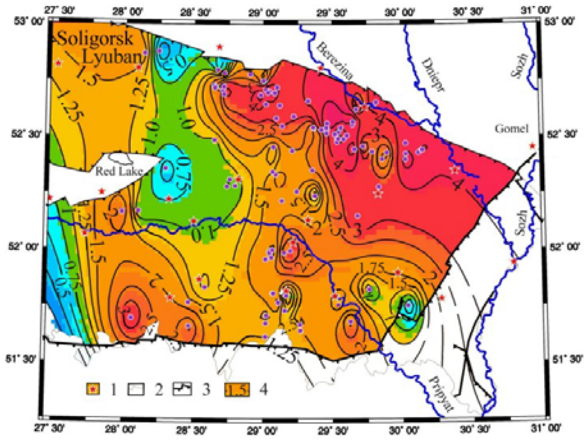

Figure 4: Density of geothermal resources within the Upper Salt geothermal complex of the Pripyat Trough.

Legend: 1 – main towns and settlements, the potential consumers of geothermal resources, 2 – the border of Belarus, 3 - faults limiting the Pripyat Trough, 4 – Isolines of the density of geothermal resources, t.o.e. ./m^2 are typical for its central and southern parts. The details of the calculations and the similar map for the intersalt complex are described in this volume as well, Zui, Mikulchik (2005).

The fulfilled calculations of the density of geothermal resources allowed us to estimate the geothermal potential of the other studied geothermal complexes as well. Results are given in Table 1.

Table 1. Geothermal potential of the Pripyat Trough.

Geothermal complex	Average density of geothermal resources, J/m^2	Geothermal potential, J
	Same, t.o.e/m^2	Same, t.o.e.
Sediments, overlying the "above-the-salt" Devonian rocks	7525735630	$1{,}74033 \cdot 10^{20}$
	0,255875011	5 917 109 639
Devonian rocks, overlying the Upper Salt	4740604961	$1{,}09626 \cdot 10^{20}$
	0,161181	3 727 310 625
Upper Salt complex	80234404305	$1{,}85542 \cdot 10^{21}$
	2,72797	63 084 306 250
Intersalt Rocks	15977516015	$3{,}6948E \cdot 10^{20}$
	0,543236	12 562 321 967

The geothermal potential represents the averaged density of geothermal resources in J/m^2 (or in t.o.e) multiplied by the area of the complex in m^2, which is 23125 km^2, or 23125000000 м^2. In other words, it is the portion of geothermal energy within the Pripyat Trough in Joules or in t.o.e., which could be recovered by the existing at present time technology.

The density of geothermal resources varies in a wide range within each of geothermal complexes of the Pripyat Trough. Therefore, their averaged values were used. The geothermal potential was calculated by multiplication of these averaged values by the area of the trough. The results are given both in Joules and in tons of oil equivalent (t.o.e.) in Table 1.

Now similar investigations are undertaken to estimate the density of geothermal resources for the eastern part of the Podlaska-Brest Depression. Only very preliminary information is available now on the density of geothermal resources within the Orsha Depression. The same concerns the Byelorussian Anteclise adjoining saddles and inliers. The summary of the density of geothermal resources within Belarus is shown in Fig. 4.

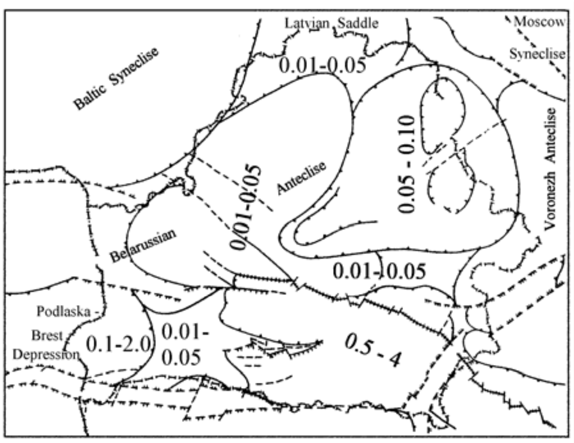

Figure 5: Simplified chart of the density distribution of geothermal resources within Belarus in t.o.e/m^2. See Figure 1 for the Legend.

4. GEOTHERMAL INSTALLATIONS

Geothermal energy in Belarus was not used until the last time. Only recently the first step was undertaken in the direct use of underground heat for space heating. A few small geothermal installations in the central and one in the northeastern Belarus in water-supply station of Polotsk town were recently put into operation. Both of them use a cold fresh water from the main collector with the ambient temperature less than 10 C to operate a heat pump with the heat power of 230 kW. Their total geothermal power of all available installations in the country exceeds 500 KW. It is expected to construct one more small geothermal installation in western Belarus during 2005 for a local greenhouse and another installation in the water-supply station in Soligorsk town, located in the southern part of the country. But these works are not started yet.

Since 1997 several small heat pump systems were installed in Belarus for heating of waterworks and sewage header buildings mostly in the Minsk District in particular in the "Minskvodokanal" Company, Zhidovich and Belyi (2003), see Table 2. The practice of their exploitation proved that all them as economically profitable.

Table 2. Main parameters of heat pump installations for heating of waterworks and sewage header buildings, Zhidovich and Belyi (2003).

Heat pump installation	Source of heat / Heat extraction system	HP number and their heat power, kW.	Number and type of compres-sors
WSS "Vitskovsh-china", Minsk District.	DWS	1 x 40	Piston rotary, 1 pcs.
	IHM		
WSS "Vodopoy", Minsk District.	DWS	1 x 45	Helical, 1pcs.
	DT		
WSS "Felitsia-novo", Minsk District.	DWS	1 x 81	Piston, 1pcs.
	DT		
SS-19, Minsk	Underground water	1 x 120	Helical, 2 pcs.
	DT		
River intake station, Polotsk town.	River water	1 x 230	Screw compres-sor, 2 pcs..
	IHM		

Abbreviations used in Table 2: WSS – Water-supply station, SS – sewerage station, IHM - Intermediate heat medium, DT - Direct takeoff, DWP – Drinking water supply.

Figure 6: Heat pump installation in a water-supply station near Minsk, Zhidovich and Belyi (2003).

An example of the "Carrier" heat pump coupled with a heat exchanger installed in a water-supply station, located near Minsk is shown in Fig. 6. The system is used for space heating of a building located nearby.

Only a few examples of direct use of geothermal resources are available at present in Belarus. The total installed heat power of the heat pump systems, included into Table 2 exceeds 500 kW. Besides this, there are around 10 more heat pumps installations, which use the heat of different technological processes to feed heat pumps, such as sewage systems, cooling contours of electric transformers, returnable water in different technological systems, etc, Zhidovich (1998). Until now there are no geothermal stations for centralized large-scale space heating or warm water supply in the country.

5.CONCLUSIONS

The Pripyat Trough and the Podlaska-Brest Depression are the most promising areas in Belarus for direct utilization of geothermal energy. Dozens of abandoned deep wells, drilled within the Pripyat Trough for oil prospecting and plugged later as nonproducing ones, represent the interest for geothermal energy extraction. Their use will increase the economic feasibility of such projects. The geothermal conditions of the trough are similar to those in the western Lithuania, where the Klaipeda Geothermal Plant was put into operation. The construction of a pilot geothermal station would be useful to stimulate the practical utilisation of geothermal resources in the country.

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THE COUNRY UPDATE

TABLE 1. PRESENT AND PLANNED PRODUCTION OF ELECTRICITY

	Geothermal		Fossil Fuels		Hydro		Nuclear		Other Renewables (wind)		Total	
	Capac-ity MWe	Gross. Prod. GWh/yr	Capac-ity MWe	Gross. Prod. GWh/yr	Capac-ity MWe	Gross. Prod. GWh/yr	Capac-ity MWe	Gross. Prod. GWh/yr	Capac-ity MWe	Gross. Prod. GWh/yr	Capac-ity MWe	Gross. Prod. GWh/yr
In operation In Jan. 2004	No	No	N/A	25900	N/A	19.6	No	No	No	No	N/A	25920
Under construction	No	No	No	No	No	No	No	No	No	No	No	No
Funds committed, but not yet under construction in Jan. 2004	No	No	No	No	No	No	No	No	No	No	No	No
Total projected use by 2010	N/A	N/A	N/A	N/A	N/A	N/A	No	No	N/A	N/A	N/A	N/A

Note: At the moment we have no plans yet for the "total projected use by 2010". We are trying to get money for such a project including a small test (pilot) experiment on practical use of geothermal energy. At present there is no the utilization of geothermal energy for electricity production in Belarus. This table is not complete, as not all requested data are available.

TABLE 3. UTILIZATION OF GEOTHERMAL ENERGY FOR HEAT AS OF 31 DECEMBER 2003

Locality	Type[1)]	Maximum utilization					Capacity[2)] (MW_t)	Annual utilization	
		Frow rate (kg/s)	Temperature (◦C)		Enthalpy (kl/kg)			Energy[3)] (TJ/yr)	Capacity Factor[4)]
			Inlet	Outlet	Inlet	Outlet			
WSS "Vitskovshchina", Minsk District.	H	N/A	c.a. 9	c.a. 3	N/A	N/A	0.0 40	N/A	N/A
WSS "Vodopoy", Minsk District.	H	N/A	c.a. 9	c.a. 3	N/A	N/A	0.045	N/A	N/A
WSS "Felitsianovo", Minsk District.	H	N/A	c.a. 9	c.a. 3	N/A	N/A	0.081	N/A	N/A
SS-19, Minsk	H	N/A	c.a. 9	c.a. 3	N/A	N/A	0.120	N/A	N/A
River intake station, Polotsk town.	H	N/A	c.a. 6	c.a. 3	N/A	N/A	0.230	N/A	N/A

1) I = Industrial process heat, A = Agriculture drying (grain, fruit, vegetables), F = Fish and animal farming, H = Space heating and district heating (other than heat pumps), B = Bathing and swimming (including balneology), G = Greenhouse and soil heating, O = Hot water supply

2) Capacity (MWt) = Max. flow rate (kg/s)[inlet temp. (◦C) – outlet temp. (◦C)] x 0.004184

3) Energy use (TJ/yr) = Ave. flow rate (kg/s)[Inlet temp. (◦C) – outlet temp. (◦C)] x 0.1319

4) Capacity factor = [Annual energy use (TJ/yr) x 0.03171] / Capacity (MWt)

This table is not complete, as not all requested data are available.

TABLE 5. SUMMARY TABLE OF GEOTHERMAL DIRECT USES AS OF 31 DECEMBER 2003

Use	Installed capacity[1)] (MWt)	Annual energy use[2)] (TJ/yr=10^{12} J/yr)	Capacity factor[3)]
Space heating[4)]	0.52	Around 10.0	Around 0.8
Greenhouse heating	No	No	No
Fish and animal farming	No	No	No
Agricultural drying[5)]	No	No	No
Industrial process heat[6)]	No	No	No
Basing and swimming[7)]	No	No	No
TOTAL	0.52	Around 10.0	Around 0.8

1) Installed capacity (thermal power)(MWt) = Max. flow rate (kg/s) x [inlet temp. (◦C) – outlet temp. (◦C)] x 0.004184

2) Annual energy use (TJ/yr) = Ave. flow rate (kg/s)[inlet temp. (◦C) – outlet temp. (◦C)] x 0.1319

3) Capacity factor = [Annual energy use (TJ/yr) x 0.03171] / Capacity (MWt)

4) Includes district heating

5) Includes drying and dehydratation of grains, fruits and vegetables

6) Excludes drying and dehydratation

7) Includes balneology

TABLE 7. ALLOCATION OF PROFESSIONAL PERSONNEL TO GEOTHERMAL ACTIVITIES (RESTRICTED TO PERSONNEL WITH A UNIVERSITY DEGREES)

(1) Government (4) Paid Foreign Consultants

(2) Public Utilities (5) Contributed Through Foreign Aid Programs

(3) Universities (6) Private Industry

Year	Professional Person-Years of Effort					
	(1)	(2)	(3)	(4)	(5)	(6)
2000	3	No	No	No	No	No
2001	3	No	No	No	No	No
2002	3	No	No	No	No	No
2003	4	No	No	No	No	No
2004	4	No	No	No	No	No
Total	4*	No	No	No	No	No

Note: 4* means the same people were working in previous years in the Laboratory of Geothermics (since 2003 there is 1 specialist, working outside the Laboratory of the Institute of Geological Sciences, Minsk. Nobody graduated special courses in Geothermal energy utilization.

TABLE 8. TOTAL INVESTMENTS IN GEOTHERMAL IN (2004) US$

Period	Research & Development Incl. Surface Explor. & Exploration Drilling Million US$	Field Development Including Production Drilling & Surface Equipment Million US$	Utilization		Funding Type	
			Direct Million US$	Electrical Million US$	Private %	Public %
1990-1994	No	No	No	No	No	No
1995-1999	0.05	No	No	No	No	0.05
2000-2005	0.075	No	No	No	No	0.075

Note: Money was given to estimate Geothermal potential (resources) of the Brest Depression. No money was given for geothermal drilling or other things.