THE PRESENT STATE OF GEOTHERMAL ENERGY UTILIZATION IN RUSSIA

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ABSTRACT

At the end of 1994, geothermal energy was used in Russia mostly for space and district heating and for industrial and agricultural purposes. Six towns and eight big settlements with total population of about 220,000 used geothermal district heating systems. The total area of geothermaly heated greenhouses was about 340,000 m^2. Electric energy generated at geothermal power stations remains negligible: the installed capacity of the only operating Pauzhetskaya station (Kamchatka) is 11 MW,. Another plant at the Mutnovsky geothermal field is currently under construction and is expected to have 80 MW, installed by 2000. Now 413,000 tons of steam and 38 mln m^3 of water with temperature >60 ^{0}C are extracted from the Earth per year. The proven geothermal resources in Russia provide hope for a significant increase in the Utilization of the Earth's deep heat and a significant contribution to Russia's power budget in the near future.

INTRODUCTION

At the end of 1991 the USSR had disintegrated into separate republics. The energy and fuel industries united formerly as a single system. had been separated also, such that the economic situation became worse in all of these republics including Russia.Some fossil fuel, hydro-electric and nuclear power plants fell outside of Russian boundaries. Large deposits of coal, oil, and gas, and the areas rich in geothermal resources were also disenfranchised. The growth of prices for oil and coal, on one hand, and the imperfection of the existing nuclear plants in need of reconstruction, on the other hand. provoked the government to build power plants using natural gas. During the winter of 1991-92 such plants provided 54% of the total energy produced in Russia.

In the future. a significant contribution to the energy budget of Russia can be provided by geothermal resources. Some promising results in this direction were obtained and described formerly (Kononov, Dvorov,1990). Unfortunately, the whole system of prospecting and extraction of geothermal resources was disrupted with the cessation of state financial support for geothermal projects. The groups formerly involved in this activity were re-organized and the efficiency of their work decreased Sharply. The forms of property changed and joint-stock companies have now been created using private and State capital in different proportions. Among these companies there are, for example, "Intergeotherm Co" which provided the construction of geothermal power plant in Nicaragua. and "Geotherm Co." Organized for accelerated construction of Mutnovsky power plant and pipeline to the town of Elizovo.

The main efforts in geothermal development are handled by the joint-stock company "Burgasgeotherm" having four local branches in Krasnodar and Stavropol territories, Daghestan republic, and Kuril-Kamchatka region.

GEOTHERMAL RESOURCES OF RUSSIA

Analyses of geological, geothermal and hydrogeological data show that in the territory of Russia there are several hydrogeothermal provinces. Each Province has different resources of geothermal capacity and different conditions for heating the Earth's entrails: the Scythian and West-Siberian plates: the East European and Siberian platforms: the folded belts of the Caucasus, Ural, Altai and Sayan; the Baikal rift zone: the Chukotka-Katasian volcanic belt: and the Kuril-Kamchatka region of recent volcanic activity.

The values of regional heat flow in Russia vary from 25-35 mW/m^2 in ancient shields and Paleozoic fold structures, to 75-95 mW/m^2 in mountain structures of Cenozoic miogeosynclines and regions of Cenozoic tectonomagmatic activity.

Two types of confined Water systems can be distinguished: strata and fissure systems. Aquifers in undeformed sediments were found mainly on the Scythian epi-Paleozoic and West Siberian epi-Hercynian plates as well as in young foredeep and inner depressions of the Alpine belt, composed of Mesozoic-Cenozoic rocks. Temperatures of these waters reach 100-200 °C. Aquifer systems are found also in the sedimentary cover of the East European and Siberian pre-Cambrian platforms and the related Piedmont troughs, composed of Paleozoic rocks. The temperatures of the thermal water in this Systems ranges from 50-70 °C and, rarely, to 100 °C at a depth of 3000 m.

The confined sedimentary water Systems are characterized by a gradual increase in temperature, pressure and salinity with depth, as well as by fairly regular changes in the chemical and gas composition of the water.

Thermal water reservoirs in fractured rocks mainly occur in the areas of Baikalian (Timan), Hercinic (Ural) and Cenozoic (Kamchatka, Caucasus) fold belts, as well as in the old cratons, dissected by Cenozoic rifting (Baikal rift zone). The most prospective hydrothermal resources Of Russia occur in Kuril-Kamchatka region of recent volcanism, regions of Cenozoic tectonic activity - the Caucasus, the Baikalian rift and in sedimentary covers of the Scythian and West Siberian Paleozoic plates (Kononov, 1992; Shpak et al, 1994).

The total thermal effect of the hydrothermal resources utilized depends on the method of their exploitation. According to calculations by B.F.Mavritsky et al (1983) the discharge of thermal waters (from 40 up to 140 °C) under natural outflow conditions can be 17.4 m^3/s and the corresponding thermal effect about 101 million GJ/yr. With pumping (but without re-injection of residual water) it is possible to extract much more water, 225 m^3/s, and its thermal effect will increase to 961 million GJ/yr. Exploitation of high-salinity thermal waters and brines requires their re-injection to avoid environmental pollution. The utilization of 5% of their Storage only or 752 m^3/s will allow extracting up to 3,500 million GJ/yr which will substitute 119 million tans of conventional fuel. Presently. 413,000 tons of steam and 38 million m^3 of water with temperature >60 °C are extracted in Russia per year.

ELECTRIC POWER GENERATION

In 1990 the generation of electric energy in the former USSR amounted to about 1,720,000 GWh/yr. At the end of 1994 in Russia it amounted 912,000 GWh/yr. Of the total electric energy produced. 68.0% was supplied by fossil fuel power stations, 18.2% by hydroelectric stations and 13.8% by nuclear power stations. Electric energy generated at geothermal power stations remains negligible: the installed capacity of the only Operating Pauzhetskaya station (Kamchatka) is merely 11 MW_e (table 1).

TABLE 1. PRESENT AND PLANNED PRODUCTION OF ELECTRICITY IN RUSSIA

	Geothermal		Fossil Fuels		Hydro		Nuclear		Total	
	Capacity MW_e	Gross prod. GWh/yr	Capacity MW_e	Gross Prod. GWh/yr	Capacity MW_e	Gross Prod. GWh/yr	Capacity MW_e	Gross Prod. GWh/yr	Capacity MW_e	Gross Prod. GWh/yr
In operation in January 1995	11	28.3	140000	622000	39000	165000	21000	125000	200000	912000
Under construction in January 1995	110	750	9000		1000		1000		11000	
Funds commited, but not yet under construction in January 1995	250	2300								
Total projected use by 2000	110	750	150000	707000	42000	173000	22000	135000	214000 214000	1015000 1015000

Pauzhetskaya station has three units (2 x 2.5 MW_e and 1 x 6 MW_e) (table 2).

The total number of wells drilled on this field is 79. Eleven of them are exploited now producing the Cl-Na fluid with TDS about 3.0-3.5

TABLE 2. UTILISATION OF GEOTHERMAL ENERGY FOR ELECTRICAL GENERATION IN RUSSIA IN DECEMBER 1994.

'Data for 1994 if available, otherwise for 1993. Please Specify which

Locality	Power Plant Name	Year Commis-sioned	No of Units	status	Type of unit	Unit Rating MW_e	Total Instal-led cap. MW_e	Annual Energy Prod.[1] GWh/yr	Total under Constr. or Planned MW_e
Kamchatka									
Pauzhetsky field	Pauzhet-skaya power station	1966	1	N	MI-2.5	2.5	11	28	21
		1966	2	N	MK-2.5	2.5			
		1980	3	N	MK-6.0	6.0			
Mutnovsky fild	Mutnov-skaya Station	1998	1		Kamch.20	20.0	80	577	160
		1999	2		Kamch.20	20.0			
		2000	3		Kmch.20	20.0			
		2001	4		Kamch.20	20.0			
Kuril islands									
Iturup	Okean-skaya Station	1996	1		Direct scheme with conden-sator for mixed	6.0	12	40	30
		1996	2			6.0	18	60	
		1997	3			6.0			
		1998	4			6.0			
		1999	5			6.0			

g/kg and enthalpy of 790 kJ/kg on **average.** The hottest water (up to 210 ^{0}C) **was** encountered at the depth of 300-500 m. The total discharge of springs and wells of Pauzhetskaya System is 330 kg/s. The production wells **are** connected to the power station by three steam-supply pipelines. Besides, there are 10 wells used for reinjection and **16** wells for observations.

Another station at the Mutnovsky geothermal field is Situated 70 km of the city Petropavlovsk-Kamchatsky and is currently under construction. It is expected to have the first phase of about 80 MW_e installed by 2000. This thermal power Station will use four generator units (4 x 20 MW_e). The geology of the Mutnovskaya geothermal system and its hydrogeological and geothermal conditions were given by Ostapenko et al. (1987).

The total **area** of this geothermal system, based on geophysical and geochemical data, is 21.7 km^2. The important peculiarity of this system is the presence vapor-dominated **zone** within the depth interval of 700-900 m below the ground surface. The enthalpy of the fluid is 2,100-2,700 kJ/kg. There **are** thermal waters with temperatures of 250-310 ^{0}C and enthalpy of the fluid 1,000-1,500 kJ/kg above and below this **zone**.

Fifty sight (58) wells 255-2.100 m in depth were drilled in this field (of this total 17 wells are for production, 24 far observation and **16** for injection). The total productivity is 330 kg/s with on **average** enthalpy of 1.640 kJ/kg.

Taking in mind the geological. geothermal and economic conditions, there **are** 9 geothermal areas in Kuril-Kamchatka region for constructing power plants with aggregate capacity of 380-550 MW_e. By the year 2,010 the installed capacity of Mutnovskaya geothermal power Station is hoped to increase to 210 MW_e, and Pauzhetka plant - to 18 MW, (both in Kamchatka). Also it is proposed to build **a** power station on Iturup island (Kuriles) with 30 MW, of installed capacity. There are 9 wells prepared for exploitation.

Geothermal prospecting was also carried **out** in the Northern Caucasus. At **Some** sites there are favorable prospects for constructing geothermal power plants with heatexchangers and reinjections of wastes. One of these Sites is at Kayasulinskaya, where construction of a pilot plant of *3* MW_e is planned by the year 2,000. There **are** however, Some technological problems: high TDS >**100** g/kg, relatively low temperatures - 150-170 ^{0}C and high injection pressure **up** to 7 MPa and more. These difficulties make utilization of these fluids troublesome.

DIRECT USE OF THE EARTH'S HEAT

Direct use of the Earth's heat is most widespread in the following regions of the Russian Federation: Northern Caucasus, pre-Caucasus, West Siberia, Baikal and Kuril-Kamchatka. Hydrothermal resources are used for space and district heating, for different industrial and agriculture purposes, cow and pig farming fish-farming, etc (Table 31

In Daghestan, thermal water is fully supplied to the towns Izberbash, Terekly-Mekhteb, Chervleny Buruny and Tarumovka and Partially supplied to towns Makhach-Kala, Kizlyar, Kayakent. The total number of inhabitants from these towns using thermal waters for space and district heating has reached 200,000. In Chechen republic, thermal water (TDS 5 g/kg and temperature 80-90 °C) is used for district heating in a small part of Grozny with 5.000 inhabitants.

TABLE 3. UTILIZATION OF GEOTHERMAL ENERGY FOR DIRECT HEAT IN RUSSIA IN DECEMBER 1994

[1] I=Industrial process heat
D=Space heating
B=Bathing and swimming
G=Greenhouses
F=Fish and other animal farming

[2] Energy use (TJ/yr)=Annual average water flow rate (kg/s) x (Inlet temp.(°C) Outlet temp.(°C)] x 0.1319

Locality	Type	Maximum Utilisation Temperature (°C)		Annual Utilisation	
		Inlet	Outlet	Average Flow Rate kg/s	Energy Use[2] TJ/yr
Kamchatka	D,B,G	80	30	455	2700
Magadanskaya territory	D	60	30	14	80
Precaucasus					
Krasnodarsk territory	D,G,F	75	30	262	2100
Stavropol territory	D,G	90	30	24	360
Northern Coucasus					
Kabardino-Balkariya	G	70	30	10	50
Chechen republic	D.G	80	30	220	1200
Dagestan republic	D,G,I	80	30	255	1690
Total				1240	8180

By the end of 1994 the total number of direct-use geothermal Wells was 367. Of this total about 185 wells are for production. 10 for reinjection, and 86 for observation. The space and district heating Systems supplied by thermal waters, partially or completely, include Some cities in the Northern Caucasus, West Siberia, and Kamchatka. The total number of inhabitants of Russia using thermal waters for this purposes has reached 220,000.

In the Northern Caucasus thermal waters are associated with multi-layered aquifer systems in Mesozoic-Cenozoic sediments. The temperature of waters ranges from 50-70 °C (the area around Makhach-Kala) to over 150-170 °C (the Kayasulinsky field). The Salinity of this waters range widely from 0.9-2.1 g/kg (Khankala areal and 3-8 g/kg (the Makhach-Kala region) to 100-200 g/kg (the Kayasulinsky and Tarumovsky fields).

In the future there is the possibility of heating the entire towp with this water.

Also promising for direct heat use are the thermal Waters of the sedimentary cover of the West Siberian plate. Its total hydrothermal resources (with Convenient temperatures and TDS) are estimated about 180 m^3/s (Mavritsky,1971). These waters are located at a depth of about 3,000 m in the marginal parts of the basin. They are used for space heating of several buildings in the towns of Tyumen, Omsk and of Some small settlements in Western Siberia.

Thermal waters of Springs are used for space heating resorts and Separate buildings near Baikal Lake and along the Baikal-Amur railway.

In Kamchatka, thermal Cl-Na waters with TDS 1-5 g/kg and temperatures of 80-100 °C are utilized for space heating in the settlements of Paratunka, Pauzhetka, Esso and Anavgay.

Construction of geothermal pipelines for transmission of thermal water 80 km from the Mutnovsky power plant to the town of Elizovo is **underway.** One town and a few big settlements will be heated by this thermal water.

TABLE 4. SUMMARY TABLE OF GEOTHERMAL DIRECT HEAT USES

[1] Inst. thermal power (MW_t) = Max. water flow rate (kg/s) x [Inlet temp. (°C)] x 0.004184

[2] Energy use (TJ/yr) = Annual average water flow rate (kg/s) x [Inlet temp. (°C) - Outlet temp. (°C)] x 0.1319

	Installed Thermal Power[1] MW_t	Energy Use[2] TJ/yr
Space heating	95	3700
Bathing and swimming	7	260
Greenhouses	100	3960
Fish and other animal farming	4	130
Industrial process heat	4	130
Total	210	8180

The use of thermal waters for industrial purposes in Russia is still minimal (Table 4). They are used in wool washing and production of paper (Caucasus), wood drying and fabrication of concrete blocks (pre-Caucasus), for the heating of oil fields to increase oil extraction (West Siberia, Bashkiriya). Also, iodine, bromine and others valuable components are extracted from thermal brines. At present the construction of a chemical Plant using thermal brines in the South Sukhokumsk region (Daghestan) is being planned.

Thermal waters are used for agricultural purposes in the Same regions of the Northern Caucasus, Pre-Caucasus and Kamchatka. The total area of greenhouses heated by thermal waters after disintegration of the former USSR has declined and in the Russian Federation it now amounts to about 340,000 m^2 The big greenhouses are located in Ternair region 165,000 m^2), in the Mostovskoy region 1180.000 m^2), in Paratunka geothermal field 160,000 m^2) and in some other places.These greenhouses are used mostly for growing tomatoes, cucumbers and flowers. The thermal waters are also utilized for heating cow and pig farms and poultry-yards. Artificial ponds for fish farming are heated with thermal waters in several places of Pre-Caucasus, West Siberia and Kamchatka.

About 150 bath resorts, and 40 bottling factories using thermal and mineral waters operate in a number of areas in the Northern Caucasus. Pre-Caucasus and Baikal regions, Eastern Siberia, the Far East and Kuril-Kamchatka region.

The multipurpose utilization of thermal Waters can give the best results. An example, is the complex Utilization of thermal water (75 °C) in the Mostovskoy region. Thermal water there is used for heating the greenhouses, space heating, cow-sheds, pig farms and poultry yards. The heat from geothermal waters is used in concrete blocks fabrication and wood drying. Thermal waters with residual temperature of 20-30 °C are then utilized to heat a swimming pool and artificial Ponds for fish farming.

Further utilization of geothermal resources is associated with the creation of circulation systems and the use of heat pumps.

Hydrofracturing experiments were carried out in the Tyrnyaus geothermal area (Northern Caucasus). Here, 85 m^3 of water under pressure of 60 MPa was injected for 46.5 min into granitic rocks with temperature 210 °C at the depth interval of 3,721-3,820 m. Unfortunately, this experiment was unsuccessful because of injection tube breaks at the depth interval of 3,606-3,610 m (Slysarev et al.1991).

Construction of a geothermal circulation System using a natural Collector was begun in Yaroslavl area. The injection bore hale was drilled here in the beginning of 1993. This hole penetrated the aquifer, composed of sand-clay deposits, including water with temperature more 60 °C, at the depth of 2250 m. The drilling of the exploitation borehole was began at 800 m from the first one. The water rate in circulation contour is projected as 100 m^3/hour, capacity - 55 MW_t, heat production - 25,000 Gcal/year. According to calculations, this system will pay out its cost after 8 years of exploitation (Khakhaev, Pevsner, 1993).

CONCLUSIONS

Further utilization of thermal water is anticipated to include the enlargement of district heating systems, growth of refrigeration and air conditioning Systems and increased greenhouses area. Thermal waters Will also be used to thaw frozen rocks and wash ore deposits located in the Russian permafrost areas. The valuable components will be extracted from thermal brines.

At present, 14 geothermal centers of Russia are administering in geothermal projects. These centers are located in Moscow, St. Petersbourg, Makhach-Kala, Gelendjik, Kazan, Yaroslavl, Ekaterinbourg, Novosibirsk, Apatity, Arkhan-gelsk, Samara, Yakutsk, Petropavlovsk-Kamchtsky, Yuzhno-Sakhalinsk. They include 26 scientific Institutes, 2 universities and 5 project bureaus. A large number of highly qualified engineers and 27 doctors of sciences (geology and technical) are involved in geothermal projects. Some of the biggest projects aimed at studying and utilizing geothermal energy Russian Federation are the following:

1. The constructions of the Mutnovskaya (Kamchatka) and Oceanskaya (Iturup, Kuriles) geothermal power plants. The construction cost of the Mutnovskaya station is 512 mln US$.

2. The construction of geothermal pipeline of 80 km long from Mutnovsky power plant to the town of Elizovo (the cost is 120 mln US$).

3. The project of building a chemical plant for extracting valuable components from thermal brines (Daghestan).

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