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Geothermal Development in Russia: Country Update Report 2000-2004

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ABSTRACT
Currently the development of Russia is characterized by complex utilization of non-conventional energy sources. It can be justified by the fact that the cost of fossil fuel (gas, mazut) has increased more than ten times for the last years.

As is well known, Russia possesses unique reserves of geothermal resources. Main regions of geothermal study and use are Kuril Islands, Kamchatka Region, Northern Caucasus, West Siberia, Baikal rift area, Chukotka, Far East Region, Sakhalin Island, as well as Kaliningrad region.

Utilization of geothermal resources in Russia is especially important for heat supply to northern territories of our country.

In Russia more than 45% of total energy resources are used for heat supply of cities, settlements and industrial complexes. Up to 30% of those energy resources can be provided using heat of the earth.

Under financial support of the GeoFund (the World Bank/GEF) utilization of geothermal heat is planned in the following four regions of Russia: Omsk Region (heat supply of Chistovo settlement), Krasnodar Krai (heat supply of Ust-Labinsk and Labinsk towns as well as complex geothermal use in Mostovskoy Region), Kaliningrad Region (energy and heat supply of Kaliningrad and Svetly towns), Kamchatka Region (heat supply of Yelizovo district, construction of Verkhne-Mutnovsky binary power plant and 2nd stage of Mutnovsky GeoPP of 100 MW_e capacity).

1. INTRODUCTION
In Russia power and heat generation is based on fossil fuel utilization (coal, oil and gas) and operation of nuclear and hydro power plants. Contribution of geothermal energy is so far comparatively modest, although the country possesses significant geothermal resources. Contemporary economical situation in Russia depends on development of its energy potential. Difficulties with fuel transportation make the problem of power supply sounder, particularly in northern and eastern regions of the country.

Hydrothermal resources of our country were under investigation long time ago. As far back as in 1983 the Atlas of the USSR thermal water resources was prepared, which included the explanatory note comprising 17 maps, among which the Map of the USSR thermal water and the Map of potential reserves of thermal water in the USSR (both in the scale 1:10 mln), as well as more detailed maps of commercial reserves of thermal water from main aquifer systems in most promising regions [Atlas of thermal waters (1983), Mavritsky, Shpak, Otman… (1983)]. These regions cover practically the whole area of active volcanism in Kamchatka and Kuril Islands, also zones of young folded belts and most recent rift genesis (in Caucasia, Okhotsko-Chukotsky volcanic belt, Baikal rift area), and here and there on epipaleozoic Scythian and West Siberian platforms.

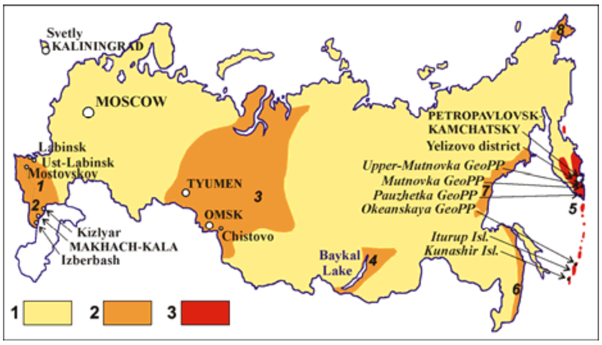

Figure 1: Promising geothermal area of Russia 1 – Northern Caucasus (Alpine area), 2 – Northern Caucasus (platform area), 3 – West Siberia, 4 – Baikal adjacent area, 5 - Kuril-Kamchatka region, 6 – Primorje, 7-8 – Okhotsko-Chukotsky volcanic belt

1 - 3 – regions differentiated by hydrothermal resources utilization: 1 – suitable for heat supply to buildings with application of heat pumps; 2 – promising for "direct" utilization (heat supply to residential and industrial buildings, heating of greenhouses and soils, in the cattle breeding industry, fish farming, for grain, tea leaves and seaweed drying, in industrial manufacture, for chemical elements extraction, for increase of a reservoir recovery, for frozen rocks melting, in balneology), as well as for heat generation with application of heat pumps and power production at binary cycle GeoPP with utilization of low boiling agents; 3 – regions of active volcanism being most promising for "direct" utilization, heat and power generation at binary plants with application of intermediary low boiling agents, as well as for construction of high capacity GeoPP (operating on steam-water cycle) on steam and hydrothermal fields.

So far 66 thermal water and steam-and-hydrothermal fields have been explored in Russia. Half of them is in operation providing approximately 1.5 mln Gkal of heat annually, which is equal to the annual replacement of almost 300 thous. t of conventional fuel [Vartanjan, Komjagina…. (1999)].

In Caucasia and Ciscaucasia thermal waters make multilayer artesian basins in sediments of Mesozoic and Cenozoic era. Mineralization and temperature of these waters vary significantly: in fore deeps at depths of 1-2 km - from 0.5 to 65 g/kg and from 70 to 100°C respectively, while on the Scythian platform at depths of 4-5 km – from 1 to 200 g/kg and from 50°C to 170°C also respectively [Kononov, Polyak and Kozlov (2000)].

In Dagestan total amount of explored thermal water reserves makes 278 thous. m^3/day with flowing operation, and with used water reinjection – 400 thous. m^3/day, herein heat potential being equivalent to the annual replacement of 600 thous. t of conventional fuel. Main explored thermal water resources with temperature between 40-107°C and mineralization between 1,5-27 g/l are located in the Northern Dagestan. For the last 40 years 12 major thermal water fields have been discovered and 130 wells have been drilled and prepared for exploitation in this region (Fig. 2). However presently only 15% of the potential of known thermal water reserves is used [Aliev, Palamarchuk and Badavov (2002)].

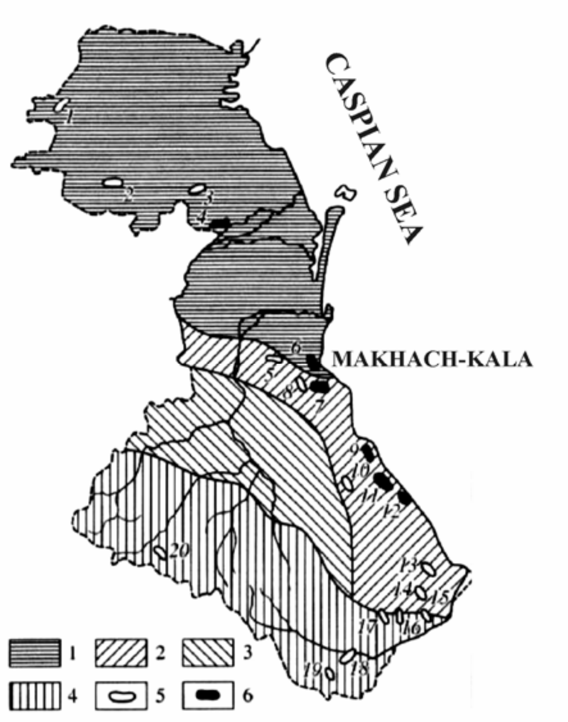

Figure 2. Major hydro-geothermal fields in Dagestan
1-4 – sediments (1 – quaternary, 2 – neogene, 3 – cretaceous, 4 – jurassic); 5 – promising areas; 6 – hydrothermal fields.
Thermoanomalic areas (numbers on the Fig.): 1 – Bazhigan, 2 – Terekli-Mekteb, 3 – Tarumovka, 4 – Kizljar, 5 – Istisu, 6 – Makhach-Kala, 7 – Talgi, 8 – Zaunzabbash, 9 – Izberbash, 10 – Salgabak, 11 – Kajakent, 12 – Berikey, 13 – Belidgi, 14 – Choshmenzin, 15 –Giljar, 16 – Adginaur, 17 – Rychalsu, 18 – Akhty, 19 –Khnov, 20 –Khzanor

Besides the economical viability of widely located low potential geothermal resources utilization for heat and power generation is becoming more and more evident; such resources are mostly available in mineralized water fields with temperatures between 30-80°C (sometimes even up to 100°C) at depths between 1-2 km. Such resources are located in the central part of Middle-Russian basin (Moscow syneclise) that comprises 8 regions: Vologodsky, Ivanovsky, Kostromskoy, Moskovsky, Nizhegorodsky, Novgorodsky, Tverskoy and Yaroslavsky. There are also promising opportunities to efficiently utilize thermal waters in Leningrad and especially Kaliningrad regions. Efficiency of their utilization can be provided through application of heat pumps and binary circulating systems.

Thermal waters of West Siberia platform form a big artesian basin in the platform cover being almost 3 mln. km^2 in area extent. At depths down to 3 km resources of thermal water with temperatures between 35 and 75°C and mineralization between 1 and 25 g/kg are evaluated at 180 m^3/s. Injection of high mineralized thermal waters and brines requires their reinjection after using their heat potential to prevent pollution of the environment. Utilization of even 5% of their reserves will allow generating 834 mln Gkal/year, which will save 119 mln. t of conventional fuel [Atlas of thermal waters (1983), Mavritsky (1971)].

In *Baikal adjacent area* there are numerous thermal resources, flow rate of which may often reach many thousand of cubic meters a day with temperature varying between 30 and 80°C and higher. Usually mineralization of such waters does not exceed 0,6 g/l. If consider the chemical content of thermal waters, mostly they are alkaline, sulfate or sodium bicarbonate. The majority of these resources is located in Tunkinsky and Barguzinsky cavities and along the coastline of Baikal lake.

There are also thermal water resources in *Primorje and Okhotsko-Chukotsky volcanic belt*. Thermal waters of Chukotka are of most interest here. In Table 1 main parameters of these thermal waters are given based on the results of their investigation made in the summer of 2002 by the Russian Academy of Sciences.

Hydrothermal resources of Eastern Chukotka

Table 1

Fields	Temperature, ^{0}C		Natural	
	measured	forecast	Flow rate, l/s	Heat efflux, MWth
Chaplinsky	88	> 110	46	17
Kivaksky	43	> 86	10	1.8
Senjavinsky	80	> 110		
Arakamchechensky	38	> 85	< 6	< 1
Kukunsky (Lorinsky)	58	>116	65	16
Dezhnevsky	60	>69	5.1	1.3
Mechigmensky	97	> 144	63	24
Tumanny	L56	> 133	6.4	1.5
Bezymjanny	21	> 69	<10	<< 1

Most promising for practical utilization are hydrothermal resources of Kuril and Kamchatka region [Kononov and Poljak (2000), Kononov and Sugrobov (1996), Sugrobov (1995)].

In Kamchatka along with 11 major high temperature steam and hydrothermal systems, there are also almost 150 groups of low potential sources of low mineralized (1-5 g/kg) waters containing mostly Cl-Na. Location of most promising for exploration and utilization hydrothermal systems of Kamchatka, including those being in operation and recommended for prioritized exploration works, are given in Fig. 3.

Levels of low potential systems' development can be found in Table 2. The Institute of Volcanology (FED of RAS) estimates that such resources can cover demand in heat in the amount of 1345 MWth for at least 100 years.

Low temperature hydrothermal resources of Kamchatka

Table 2

No on the map	Fields	Heat efflux MWth	Temperature (°C)		Res-ervoir area, (km^3)	Reservoir heat en-ergy, (10^{18} Joule)	Level of develop-ment
			Reso-urces (meas ured)	Reser-voir (fore-cast)			
12	Tym-latsky	5,0	47,.5	115	3,7 ± 1,1	1,1.5 ± 0,34	
13	Palans ky	7,5	95,0	105	9,7 ±2,9	2,75 ± 0,8	
14	Rusa-kov-sky	57,8	76,5	90	15,0 ± 4,5	3,64 ± 1,1	
15	Anav-gaisky	7,4	52,0	115	2,2 ± 0,7	0,68 ± 0,2	Drilled
16	Essov-sky	4,4	65,0	104	4,5 ± 1,3	1,26 ± 0,38	District heating Heating of greenhouses
17	Push-chin-sky	1.5	46,0	110	3,7± 1.1	1,1 ± 0,33	Drilled
18	Naly-chev-sky	9,4	75,0	143*	16,5 ± 4,9	6,37 ± 1,9	
19	Mal-kinsky	9,4	83,0	128*	3,7 ± 1,1	1,28 ± 0,33	Drilled
20	Pin-achevs ky	0,8	12,5	53,5 (meas) 95 (forec)	2,2 ± 0,7	0,56 ± 0,17	Drilled
21	Nachi kinsky	4,2	81,0	106*	2,2 ± 0,7	0,63 ± 0,19	Drilled
22	South Berez-hny	0,2	20,0	90	3,0 ± 0,9	0,73 ± 0,22	Drilled
23	Paratu nsky	8,2	81,5	110	15,0 ± 4,.5	4,46 ± 1,34	District heating Heating of greenhouses and swim-ming pools
24	Verk-hne-Paratu nsky	20,6	70,5	110	13,5 ± 4,0	4,01 ± 1,2	Drilled

Main high potential (steam and hydrothermal) systems of Kamchatka are Mutnovsky, Pauzhetsky, Koshelevsky, Bolshebanny and Kireunsky fields.

Level of development of high potential hydrothermal resources of Kuril and Kamchatka area are shown in Table 3. The Institute of Volcanology [Sugrobov (1995)] estimates that discovered in this area hydrothermal resources (excluding resources of Kronozky protected area) might provide power generation in the amount up to 1130 MWe for the next 100 years.

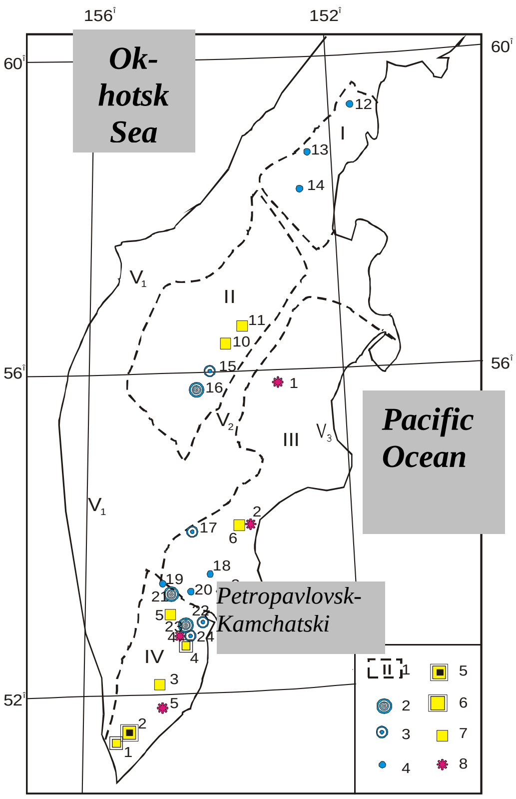

Figure 3. Hydro geothermal fields of Kamchatka 1 – hydro geothermal areas (I – Northern, II – Eastern, III – Middle, IV – Southern, V – Western), 2-4 – low temperature fields (2 – in operation, 3 – explored, 4 – promising for exploration), 5-7 – high temperature fields (5 – in operation, 6 – explored, 7 – promising for exploration)

High temperature hydrothermal resources of Kamchatka

Table 3

No	Fields	Heat efflux (MWth)	State of the heat transfer fluid on the surface	Reservoir average T, °C (max in brackets)	Reservoir area, km^3	Reservoir heat en-ergy, 10^{18} J	Estimated maximum energy capacity, MWe
1	Koshelevsky	314		220	37.5±11.2	22,27±6,7	215 ±64
1a	Nyzhne-Koshelevsky	104		220(240)	17,5±5,2	10,4±3,11	100 ± 30
2	Pauzhetsky	104	Saturated steam and water	200(220)	45±13,5	25,8±7,73	186±56
3	Khodutkin-sky	122	Water at t 88 °C	200	30±9	16,2±4,8	117±35
4	Mutnovsky	546		220	80±24	47,5±14,2	460±138
4a	North-Mutnovsky	129		220(301)	30±9	17,82±5,3	172±52
5	Bolshebanny	79		200(171)	15±4,5	8,1±2,43	58±17
6	Karymsky	146		200	37,5±11,2	20,25±6,1	146±44
10	Apapelsky	17		200			
11	Kireunsky	24.5		200	17,5±5,2	9,45±2,83	68±20

On Kuril Islands fields of Gorjachy Pljazh (Kunashir Island), Okeansky field (Iturup Island) and Paramushirsky field (Paramushir Island) are located having different levels of development and exploration.

Despite such abundance of geothermal resources, Kamchatka and Kuril Islands feel strong lack of heat and electricity.

2. POWER GENERATION

Presently power plants operating on fossil fuel generate 69% of total energy balance of Russia. Additionally 20% and 11% are generated by hydro and nuclear power plants respectively. Geothermal power plants account only for 0.08% despite certain increase in number and capacity of geothermal power plants if comparing to the previous period (Table 4).

Present and planned production of electricity

Table 4

	Geo-thermal		Fossil Fuels		Hydro		Nuclear		Other Renew-ables		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	Capacity MW_e	Gross Prod. GWh/yr
In operation in January 2004	77		151 000	558 000	43 600	155 000	21 200	108 000			216 000	822 000
Under construction in January 2004			1 200	2 800	530	460					1 770	3 420
Funds committed, but not yet under construction in January 2004												
Total projected use by 2010	19 7	800	155 000	580 000	45 000	162 500	24 200	124 000			224 300	867 000

At present in Kamchatka the following geothermal power plants operate from geothermal resources: three GeoPP with the installed capacity of 12 MWe and 50 MWe on Mutnovsky and Verkhne-Mutnovsky fields and with the installed capacity of 11 MWe on Pauzhetsky field [Povarov, Tomarov and Koshkin (1994)].

Utilization of geothermal energy for electric power generation as of December 31, 2004

Table 5

Locality	Power Plant Name	Year Commisioned	No. of Units	Status[1)]	Type of unit[2)]	Unit Rating MW_e	Total Installed Capacity MW_e	Annual Energy Produced GWh/yr	Total Under Constr. or Planned MW_e
Kamchatka									
Pauzhetka hydrother-mal system	Pauz-hetka	1966	2		1F	2.5	5		
		1980	2+ 1		1F	5+ 6	11	35	
		2000	3		1F	5+ 6	11		
		2004	3		1F	5+ 6	11		18
Severo-Mutnovka hydrother-mal system	Verk-hne-Mut-novka	1998	1		1F	4	4		
		1999	2		1F	4	12	50	
		2001	1		1F +B	3+ 6			12
	Mut-novka	2002	2		1F	25	50		50
		2004	2		1F	25			100
Kuril Islands									
Paramushir Isl.	Ebeko	1998	1	N	1F	2	2		
Iturup Isl.	Okean skaya	1999	4	N	1F	2	8		
		2000	1		1F	1,7			
		2001	2		1F	1,7			
		2004	2		1F	1,7	3,4		17
Kunashir Isl.	Gor-yachii Plyaz h	2004	2		1F	1.7	2,6		
TOTAL							34	85	197

[1)] N = Not operating (temporary), R = Retired.
[2)] 1F = Single Flash

On Kuril Islands (Kunashir and Iturup Islands) two small GeoPP with the capacity of 2,6 MWe and 3,4 MWe are in operation.

The Projects of construction of binary Verkhne-Mutnovsky GeoPP (6.5 MWe) and the second 100 MWe stage of Mutnovsky GeoPP are under development.

The Pauzhetky power plant was put in service in 1967. At that time its installed capacity was 5 MWe. Later the capacity was increased up to 11 MWe. Three units are in operation: 2 units of 2.5 MWe each and 1 unit of 6 MWe (Table 2). Seven wells extracted 240 kg/s of fluids with enthalpy 760-800 kJ/kg. In total 79 productive wells were drilled on this field, so the capacity of the plant can reach 18 MWe, when 3 new 6 MWe units will be commissioned instead of old ones.

The high-temperature North Mutnovsky thermal field has long been considered as the primary object for electric power production in Kamchatka. In total, 82 bore holes 255 to 2266 m in depth were drilled here. A vapor-dominated reservoir containing fluid (steam) with enthalpy 2100-2700 kJ/kg was found at depths of 700-900 m. It is underlaid by a liquid-dominated reservoir holding fluids with enthalpy 1000-1500 kJ/kg (T=250-310 ^{0}C). Now, 17 wells producing 330 kg/s of fluids with enthalpy 1600 kJ/kg in average are ready for exploitation. Due to efforts of SC Geotherm founded by the regional administration, Kamchatskenergo and RAO UES of

Russia, the first set comprising three 4 MWe units Tuman 4K manufactured at Kaluga Turbine Works SC is now in operation on the upper sector of the field called Verkhne-Mutnovsky sector. Two other units, single flash (3 MW) and binary cycle with organic actuating fluid (6.5 MW), are under construction in this sector now (Table 5). In 1999, the construction of a power line transmission from the field to consumers was completed. The project of the next set in the Dacha sector of the same field (Mutnovsky power plant) was developed by SC Geoterm. Nauka (Russia), WEST JEC (Japan) and GENZL (New Zealand) consulted this project. The capacity of this set for the first stage is 50 MWe; it will be increased up to 200 MWe in the future (Table 5). The project was supported by the loan (USD 99.9 mln) from the European Bank of Reconstruction and Development. Furthermore, this loan will provide maintenance of bore holes and additional geophysical investigations to refine the geothermal resources of this sector.

The North Mutnovsky thermal field, however, is not the only site suitable for geothermal electric power generation in Kamchatka (Fig. 2). The very promising site is also the partially explored Nizhne-Koshelev thermal field containing fluids with enthalpy up to 2800 kJ/kg. One more site of the same kind is the Bolshe-Bannoe field where the natural heat output by thermal water was estimated at 79 MWth. This field is already explored, and the rate of boiling water discharge was evaluated at 285 l/s. There is the similar field in the Center of Kamchatka: the Kireuna field, where the boiling water is estimated to provide 24 MWth. Besides, there is the Semyachik field adjacent to the Kronotsky protected area (Natural Park) including the famous Geyser Valley. The limited use of the Semyachik field (for construction of a small power plant of 5 MWe in capacity) could help for the development of tourist service in the protected area. Except for the geothermal resources of the Kronotsky protected area, such resources revealed in Kamchatka to date could provide the electric power generation of 1130 MWe [Sugrobov, (1995)].

Besides high-temperature fluids with enthalpy more than 700 kJ/kg, the lower temperature hot water with stratal temperatures up to 150 ^{0}C can be used for power generation in binary cycle installations with heat-exchangers utilizing low-boiling liquids (freon, isobutane, etc.). A similar experimental installation with capacity of 800 kWe was designed by specialists from the RAS Siberian Branch in the early 1960s and was successfully tested at the same time on the Paratunka Springs of Kamchatka. Unfortunately, the installation was subsequently abandoned.

Beyond Kamchatka, the Kuril Islands are distinguished by the most promising conditions for geothermal electric power generation. The Okeansky power plant (3,4 MWe) on Iturup Island of the archipelago is projected in future for generating 17 MWe (Fig. 1). Here 9 wells are ready for exploitation. Another power plant (2.6 MWe) was constructed on Kunashir Island, the most southern Island of the archipelago (Table 5).

3. DIRECT UTILIZATION

Depending on temperature level low potential hydro thermal resources in Russia are utilized for heating of residential and industrial buildings, green houses, in cattle breeding industry, fish farming, for grain, tea leaves drying, in some other industries (for example, for wool washing, paper production or wood drying), for extraction of chemical elements, increase of a reservoir recovery and the last but not the least in balneology (baths and swimming pools).

18 explored thermal water fields of Krasnodar Krai and Republic of Adygeja are distinguished for their big heat potential (900 thous. Gkal/year). This number corresponds to 71,2% of total heat energy generated in the region in 2000. At the same time in district heating systems less than 5% of this potential is used. Experience of complex utilization of thermal waters in Mostovskoy region became widely known. The injected water with temperature of 75 ^{0}C is used for heating of greenhouses (220 000 м^2), residential buildings (10 000 residents), and after that is further used for heating of cattle farms, pig farms and poultry farms. Besides thermal water heat is used in the process of concrete blocks production and wooden blocks drying. Thermal water with residual temperature of 20-30 ^{0}C is delivered to swimming pools as well as to artificial ponds in fish farming. At present with financial support from the GeoFund (the World Bank/GEF) utilization of thermal resources of Mostovsky region will be further developed, including district heating of Labinsk and Ust-Labinsk cities.

It is envisaged that geothermal district heating system of Labinsk city will utilize projected commercial resources of thermal water amounting to 40 thous. м^3/day. The district heating system will comprise heat networks, three automated thermal points, seven productive wells and seven reinjection wells. The flow rate of each productive well varies between 2550 and 3770 м^3/day with water temperature between 105 and 117 ^{0}C and water mineralization of 13-15 g/l. Pressure at the wellhead is 2.5 kg/sm^2. The calculated heat capacity of the system is 70 MWth. Annual heat energy generation – 100 thous. MWh. The capital cost totals to USD 28 mln. The payback period for the district heating system of Labinsk city is 6-7 years. Annual fossil fuel savings will exceed 100 thous. t of conventional fuel. The Project for construction of the district heating system of Ust-Labinsk city will be analogous to the one for Labinsk.

In Dagestan thermal waters are mostly used for district heating of towns such as Izberbash, Terekli-Mekteb, Chervleny Buruny, Tarumovka and partially of cities such as Makhachkala, Kaijakent and Kizljar. A reviewed more detailed project for geothermal district heating system of Kizljar city was prepared. In Dagestan total territory of heat supplied buildings is 280 thous. м^2. Not far from Makhachkala there are big green houses being heated from thermal waters. Somewhere such waters are used for heating cattle, pig and poultry farms. Thermal water is also utilized at several resorts [Aliev, Palamarchuk and Badavov (2002), Gadzhiev, Kurbanov, Suetnov, etc. (1980)].

Kaliningrad region is also rich in resources of thermal water with temperature between 60 and 110 ^{0}C. Here also with financial support from the GeoFund (the World Bank/GEF) it is planned to construct district heating systems operating on geothermal resources for Kaliningrad and Svetly cities. Thus, for example, not far from Svetly city reserves of thermal water with temperature up to 100 ^{0}C were discovered at depths of 2500-2800 m, therefore it is planned to construct 50 MW geothermal heat power plant, and 4 MW binary GeoPP.

It is also envisaged to drill wells, partially reconstruct heat networks of the city, construct balneological swimming pools, advanced green houses, aquaparks, industrial facilities utilizing thermal waters (in particular for iodine and bromine production). The project cost is USD 23 mln. The project payback period – 5 years. Heat and power supply system for Kaliningrad will be similar to the one of Svetly city.

Unfortunately, huge hydrothermal resources of West Siberia are practically not utilized. Thermal waters are used here for heating of some buildings in Tjumen and Omsk towns, and in several small settlements. Besides, such waters are utilized here and there for fish farming, iodine and bromine production, as well as for warming oil-bearing bed to increase reservoir recovery. However at present with financial support from the GeoFund (the World Bank/GEF) it is planned to construct district heating system for Chistovo settlement in Omsk region.

In Baikal adjacent area utilization of numerous thermal resources seems very promising, especially along Baikal-Amur main line. At present such waters are utilized only for heat supply to several resorts, as well as in swimming pools.

In Kamchatka direct use of thermal waters is implemented in green houses in a number of settlements: Paratunka, Pauzhetka, Esso, Anavgaja, etc. Besides there are balneological hospitals on Paratunka river and in Nachikah. In all the above mentioned stttlements, as well as in other places of thermal resources (Nalychevsky, Khodutkinsky, Malkinsky, Valley of Geysers, etc.), thermal waters are used in swimming pools.

In Kamchatka another project is planned to be implemented with financial support of the GeoFund (the World Bank/GEF): construction of heat and power supply systems of Elizovo region with utilization of local geothermal resources. Elizovo region is the most developed and populated region of Kamchatka. Its population is 60 thousand people. The central airport of Kamchatka is located close to Elizovo, 32 km away from the main city of Kamchatka – Petropavlovsk-Kamchatski. It is envisaged that thermal waters will be delivered through the main pipeline from Verkhne-Paratunsky, Paratunsky and Ketkinsky fields. Water temperature varies between 45 and 90 ^{0}C; water mineralization is 1.5 g/l; thermal waters contain mostly chloride, sulphate, natrium; total flow rate is 47100 м^3/day. Mutnovsky and Verkhne-Mutnovsky GeoPP will provide 40 MW of electricity to enable heat pumps to be used for heat supply of Elizovo. The Project envisages reconstruction of main heat networks of the city, construction of heat pump stations and automated thermal points, construction of balneological swimming pools, greenhouses for vegetables, fruits and flowers growing, hotels with saunas and aquapark not far from the airport, as well as industrial facilities all utilizing geothermal resources. Total consumption of thermal water will be 300 l/s. Water temperature at the heat pump installation inlet will be 75 ^{0}C, while at the outlet - 10-20 ^{0}C. At the heat network inlet water temperature will reach 80 ^{0}C. Geothermal resources will cover 92% of heat demand in Elizovo with reduction of 1 Gkal cost in 2-3 times.

Direct use of geothermal resources in different regions of Russia as of December 31, 2002

Table 6

Region	**Type**[1]	**Maximum use**			**Capacity**[2] **(MW)**	**Average annual use**		
		Flow rate (kg/s)	**Temperature (^{0}C) at the inlet**	**Temperature (^{0}C) at the outlet**		**Average flow rate, kg/s**	**Energy**[3] **TJ/year**	**Load Factor**[4]
KURIL-KAMCHATKA REGION								
Kamchatka	H, B, G	532	85	30	122	372	2 701	0.7
***Kuril Islands* (Kunashir)**	H				20			
NORTH CAUCASIA								
Scythian platform								
Krasnodar Krai	I, D, C, H, B, G	370	80	30	77	222	1 465	0.6
Stavropol Krai	D, H, G	60	100	30	18	36	335	0.6
Adygeja	D, H	49	80	30	10	25	162	0.5
Submontane trough								
Kabardino-Balkaria	G	70	70	30	2	6	33	0.5
Dagestan	I, H, B, G	339	80	30	71	203	1 340	0.5
Karachi-Cherkess	W	25	65	30	4	13	58	0.5
North Osetia	W	21	60	30	3	10	41	0.5
TOTAL		> 1466			327	> 888	> 6135	

Notes:
[1] I = industrial processes; D =drying of agricultural products (grain, vegetables, fruits); C = cattle and fish farming; H = heat supply; B =balneology, swimming pools; G = green houses; W=hot water supply;
[2] Capacity (MW) = Maximum flow rate (kg/s) [temperature at the inlet (^{0}C) – temperature at the outlet (^{0}C)] 0.004184;
[3] Consumed energy (TJ/year) = Average flow rate (kg/s) [temperature at the inlet (^{0}C) – temperature at the outlet (^{0}C)] 0.1319;
[4] Load Factor =Average annual consumed energy (TJ/year) 0.03171 / Capacity (MW)

At the same time the ecological situation will improve through replacement of 132.2 thous. t/year fossil fuel utilization by geothermal resources. Annually in this region 25 heating boiler houses emit over 2.5 thous. t of noxious elements and 300 thous. t of CO_2. The Project cost is USD 50 mln with the payback period - 5 years.

Besides, on Kunashir Island geothermal heat, which will be used for district heating for South Kurilsk city, is successfully utilized for heating cold water at 20 MWth two-circuit installation.

General rate of direct use of geothermal resources in Russia

Table 7

	Installed capacity (MWth)	Average annual energy consumption (TJ/year = 10^{12} J/year)	Load factor
Heat supply	110	2 185	0.63
Green houses heating	160	3 279	0.65
Cattle and fish farming	4	63	0.5
Drying of agricultural products	4	69	0.55
Industrial processes	25	473	0.6
Swimming pools, baths	4	63	0.5
TOTAL	307	6 132	

4. CONCLUSION

Summarizing the situation with geothermal energy utilization in Russia first of all we should mention once again that in Kamchatka three geothermal power plants are in successful operation: 12 MW and 50 MW on Verkhne-Mutnovsky and Mutnovsky fields respectively and 11 MW on Pauzhetsky field [Povarov (2000)].

On Kuril Islands (Kunashir and Iturup) there are two small GeoPP with capacities of 2.6 MW and 3,4 MW respectively, which are also in successful operation.

The Projects of construction of binary Verkhne-Mutnovsky GeoPP (6.5 MW) and the second stage of Mutnovsky GeoPP with the installed capacity of 100 MW are presently under development.

Direct use of geothermal resources is mostly developed in Kuril-Kamchatka region, Dagestan and Krasnodar Krai (Table 6), and first of all for heat supply and green houses heating (Table 7). Development of geothermal resources is also very promising in such regions as West Siberia, Baikal adjacent area, Chukotka, Primorje, Sakhalin. Besides economical viability of utilizing widely available low potential geothermal resources (located in mineralized water with temperature between 30 and 80/even 100 ^{0}C) fields at depths of 1-2 km for heat and power supply is quite evident. Such resources can be found in the central part of Middle Russian basin (Moscow syneclise) comprising 8 regions: Vologodsky, Ivanovsky, Kostromskoy, Moskovsky, Nizhegorodsky, Novgorodsky, Tverskoy and Yaroslavsky. There are also promising opportunities to utilize thermal water in Leningrad and especially in Kaliningrad regions.

With financial support of the GeoFund (the World Bank/GEF) utilization of geothermal heat is planned in the following four regions of Russia: Omsk Region (heat supply of Chistovo settlement), Krasnodar Krai (heat supply of Ust-Labinsk and Labinsk towns as well as complex geothermal use in Mostovskoy Region), Kaliningrad Region (energy and heat supply of Kaliningrad and Svetly towns), Kamchatka Region (heat supply of Yelizovo district, construction of Verkhne-Mutnovsky binary power plant and 2nd stage of Mutnovsky GeoPP of 100 MWe capacity).

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