

Prospects for Large-Scale use of Geothermal Energy In the Republic of Dagestan

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ABSTRACT

The problems of the state and prospects of geothermal energy use in the Republic of Dagestan, including the resource base, technology and investment projects are considered. It is shown that in the North Caucasus Federal District, Dagestan has the greatest explored reserves of geothermal water and the most favorable set of geological and geothermal conditions for their large-scale use in the energy sector and in the urban economy.

The geological and geothermal conditions in the Northern Dagestan and adjacent areas of the Stavropol Territory and the Chechen Republic were studied according to the data of drilling and development of oil and gas fields. Dozens of fields of interest to create geothermal binary cycle power plants (GPP) based on groundwater circulation systems (GCS) are identified. The features of the structure and fractured zones for deposits with carbonate water bearing rocks (limestone and dolomite) opening at depths of 4100-4800 m are found. The reservoir temperature is 175 °C, permeability is more than 1 Darcy, overpressure is 65 bar, mineralization of the brine is 118 g/l.

In the other regions of Dagestan there are no conditions for the development of competitive industrial geothermal power plants and therefore geothermal system of heat supply with intermediate heat exchangers are wide spread. The new introduced systems are usually upgraded to electro- and thermo generating facilities operating in the cogeneration mode. The maximum production rates are 3000 m³/day, the formation temperatures – 105-110 °C. The productive horizons are represented by Caragan and Chokrak sandstones occurring at depths up to 3000 m.

Reuse of depleted oil fields for the secondary appointment will create in the Northern Dagestan unparalleled geothermal cluster and will give impetus to the development of geothermal production, industrial and tax potential of the Republic. Oilmen of Dagestan have already begun to collect and analyze data to evaluate the potential from introducing the binary technology in the Northern Dagestan. Previously the capacity of binary geothermal power plants is estimated to 300-500 MW with annual output of 2,1-3,5 billion kWh of electric power, which would be a substantial reserve to cover the deficit of the Dagestan power grid in winter.

1. INTRODUCTION

Geothermal energy implies primarily generation of the electrical power due to subsurface heat. Development of geothermal power engineering in the world involves huge sums of money every year. The volume of investments to the development of geothermal energy in the world in 2008 amounted to \$ 3,3 billion.

Presently, there are three geothermal power plants in the Kamchatka region of Russia: Pauzhetskaya, Verkhne-Mutnovskaya and Mutnovskaya ones, where technical solutions are implemented, proposed by a number of ENIN specialists. The total capacity of these plants is of 81,2 MW, electricity production is of 0,5 billion kWh. This allows meeting 25% of needs in electricity for the area, where the price of electricity is the highest in the Russian Federation, the cost exceeds 10 rub./KWh.

In the North Caucasus Federal District, the Republic of Dagestan has the greatest explored reserves of geothermal waters, which are characterized by a set of favorable geothermal and geological conditions for their large-scale use (Israpilov, 1991). Therefore, under the leadership of ENIN in 70–90th the works were performed for substantiation and creation of geothermal power plants based on circulating systems in the anomalous thermal fields of the North Caucasus. In these studies many organizations were involved both power and oil and gas industries, including the Associations such as Stavropolneftegaz, Dagneft and Stavropolenergo.

In Dagestan, the attempts to create geothermal power plants (GPP) were undertaken twice: in 1965 on the field Karaman near Makhachkala and in 1982 on the field Tarumovka. According to the developed at ENIN tasks deep to 5 thousand m special geothermal wells were drilled and tested at the Kayasula field in Stavropol Krai and the Tarumovka field in Dagestan. It was created and successfully tested a geothermal circulation system at the polygon Kayasula; the basic elements of power plant equipment on Freon 142b are tested, the project was worked out and construction launched of an experimental Kayasula GPP with capacity of 3 MW. These works were stopped in 1991 and since new attempts to build geothermal power plants in the Caucasus were not undertaken.

In those years, the experts of ENIN Dagestan branch, as well the Associations Dagneft and Caucasian field management on the use of geothermal heat (now JSC "Geotermneftegaz") carried out a survey of potential areas for creating an industrial scale geothermal power plant on the basis of data obtained in the exploration and exploitation of oil fields.

The cavernous fractured carbonate deposits of Neftekumsk Permian and Triassic suites are offered for high-priority development to create circulation systems, which are drilled-in by several dozen wells at depths of 4100-4800 m. Thickness of this reservoir in the central zone is 50-170 m, the average temperature is of 175 °C, there is more than 1 Darcy of permeability, the overpressure is of 65 bar, salinity of brine is of 118 g/l. Conducted in the similar reservoir at Kayasula field treatments of the bottomhole zone with hydrochloric acid increased inflow and injection of brine 400 to 5000 m³/day.

Dagestan does not have sufficient fuel and power resources to meet the needs of the economy and social sphere (4,36 million tons of equivalent fuel, including up to 100% of solid fuel and up to 90% of natural gas are imported). Electricity shortage is especially noticeable in autumn and winter, when the water content of mountain rivers is reduced three times. In these circumstances, to reduce tension of energy balance one can force using the renewable energy resources (RES) and primarily geothermal energy.

2. GEOTHERMAL ENERGY RESOURCE BASE

The total natural potential of geothermal water in Dagestan is estimated 10 to 50 million tons of equivalent fuel/year. Approximately three quarters of the potential falls on the plain and foothill parts, and the rest - to the Southern Dagestan (Israpilov, 1991).

Thermal waters in Dagestan are divided into:

- medium-temperature (40-100 °C), intended for use in heating systems (Table 1).
- high-temperature > 100 °C geothermal brines suitable for electricity generation.

Table 2 shows the characteristics of a number of potential fields for production of geothermal brines at depleted oil fields.

Predicted resources of fresh and brackish geothermal water of the Apsheron complex are estimated in 9,5 million m³/day. Thus more than 15% of these resources have temperature about 40 °C that using heat pumps is equivalent to obtaining 16 million Gcal/year.

Table 1. Initial data for calculation of technical and economic development parameters for medium-temperature geothermal fields

Name of a field	H, m	T _w , °C	Available development wells	Available injection wells	New development wells	Injection flow rate, m ³ /day	Design pressure of injection, MP	Capacity, m ³ /day
Kizlyar	3000	100	23	17	17	2500	3,0	42500
Thernair	2000	100	10	10	18	2000	3,0	20000
Makhachkala-Thernair	1300	55	21	-	21	-	-	-
North Kizlyar	3000	105	2	2	4	3100	2,5	6200
Rechninskoe	2800	105	6	4	6	1900	3,0	7600
Kalinovskoe	2160	90	3	2	3	2400	3,0	4800
Izberbash	1200	55	12	-	12	-	-	-
Kordonovka	2300	100	4	2	4	2600	2,5	5200
Krainovka	2700	90	2	-	2	-	-	-
Terekly-Mekteb	1850	85	4	2	4	1300	3,0	2600
Chervlenye Buruny	1250	80	3	2	2	700	1,6	1400
Kayakent	900	55	4	-	4	-	-	-
Babayurt	2300	105	3	2	2	2300	1,7	4600
Yurkovka	2200	90	6	4	6	2500	2,5	10000
Komsomolskoe	2500	90	1	1	1	1700	2,5	1700
Bolgarsky Khutor	2650	90	4	3	4	3000	3,0	9000
Bolshaya Areshevka	2700	90	3	3	3	3000	2,3	9000

The promising for use fields are the fields of plain and foothill Dagestan in the zone of intersection of the longitudinal and transverse deep faults: Tarumovka, Kochubey, Jubileynaya, Sukhokumsk, Selli, Gasha, Achi-Su. Maximum output of wells are up to 7000 m³/day, the formation temperatures are up to 190 °C. The productive horizons are represented with Lower Triassic limestones and sandstones of Jurassic, Lower Cretaceous and Chokrak, whose thickness achieves 400 m at depths of 3800-5200 m (Aliyev et al., 2010, Sharafutdinov et al., 2001, Sabanaev et al., 2008).

Table 2. Approximate volumes of electricity generation with using of the wells at depleted oil and gas fields

Name of a field	Depth of bedding of the working horizon, m	Temperature of water in the mouth, °C	Capacity of wells, m ³ /day	Number of available wells	Possible capacity of GPP, MW	Possible power generation, mln. KWh
Russky Khutor	3400	130	50 000	10	12	90
Yuzhnosukhokumsk+Martovskoe	3500	135	50 000	10	12	90
Sukhokumsk+V. Sukhokumsk	3600	140	50 000	10	12	90
Ravninnoe+Perekrestnoe	4300	150	50 000	10	25	187
Dakhadaevskoe+Solonchakovoe	4400	160	160 000	32	80	600
Yubileinoe+Kumukhskoe	4400	160	160 000	32	80	600
Stepnoe+Vostochno-Stepnoe	3600	150	400 000	80	200	1500
Ozernoe+Beshkolskoe	4500	165	400 000	80	200	1500
Kochubey+Tarumovka	5500	175	400 000	80	200	1500
Severo-Kochubey+Dushetskoe	5000	170	200 000	40	100	750
Maiskoe+Kapievskoe	3600	140	200 000	40	48	360
Makhachkala-Tarki	3500	140	40 000	8	10	75
Achi-su	3200	120	40 000	8	10	75
Babayurt	3500	140	50 000	10	12	90
Total:			2 250 000	450	1001	7507

Initial design specifications: The flow rate of one production well is assumed 10 thousand m³/day; a number of hours of use per year for GPP is 7500 h; the temperature of geothermal water pumped into the ground is of 40 °C; the limiting injection pressure (to overcome the resistance of the stratum) is of 15 MP; Stavropol type binary cycle GPP working on Freon R-142b.

3. STATE OF PRODUCTION AND USE OF GEOTHERMAL WATER

The JSC "Geotermneftegaz" is engaged in extraction of geothermal water in the Republic of Dagestan. Actually only 0,02 million tcf/year, representing 0,2 % of gross potential or 10% of proven reserves (118,45 m³/day), is used. On the balance sheet of "Geotermneftegaz" there are 120 wells, three commercial fields and five district heating stations. Annual production is 4 million m³ of geothermal water to provide 100 thousand Gcal of heat.

Basically thermal water is used in Makhachkala and Kizlyar towns. The average annual production at Makhachkala water intake is 570 thousand m³ of water with temperature of 42–58 °C at the mouth and salinity 3,38–5,39 g/l. Most of the produced water is used for heating and hot water supply, a small portion goes to the bottling of medical-table water. Intensive development is mainly in winter. Thermal water of the Thernair water intake at 105 °C and salinity of 25 g/l is fed through the heat exchangers to heating and hot water supply of public housing in Airport Highway in Makhachkala 1.

The annual production of thermal water on the Kizlyar water intake is 1750 thousand m³, the temperature at the mouth of 50–107 °C, salinity is 5–10 g/l. Thermal water is used for heating the municipal Kizlyar public housing.

Slow development of geothermal power engineering in Dagestan and Russia as a whole compared with the US and the EU, is due to the lack of government support measures (introduction of special tariffs on energy and preferential investment credits). There is an urgent need to adopt a federal law on the development of renewable energy sources, the preparation of which has dragged on for several years.

4. PROSPECTS FOR THE DEVELOPMENT OF GEOTHERMAL ENERGY

Accounting the large number of wells drilled, the share of geothermal energy in power balance of Dagestan may be increased by full use of the medium-temperature thermal water (Table 3). Since the costs of exploration and drilling make up to 80% of investment in geothermal heating system, the full development of proven geothermal fields have to be cost effective.

5. GEOTHERMAL PROJECTS OF THE REPUBLIC OF DAGESTAN IN THE SPHERE OF HEAT SUPPLY

5.1. Geothermal heat supply of Makhachkala town. Aim of the project is to expand the use of geothermal water in the north- west of the city on the basis of available spare capacity of the Thernair water intake. Currently, only two wells are working that is 30% of proven reserves, which provides delivery of 42 thousand Gcal of heat. The project envisages transfer of drilled earlier 11 exploratory wells to production and injection ones, use of separated combustible gases for heating up feed water in the hot water system and modernization of heat distribution station in Makhachkala 1 to give 180 thousand Gcal of "pure" heat. The estimated cost is 226 million rubles. The payback period is 3 years.

Table 3. Possible replacement of natural gas volumes due to the full development of explored reserves of medium-temperature geothermal water for the period up to 2030 (the data of "Geotermneftegaz")

Name of a field (site, water intake)	Explored reserves, thousand m ³ /day	Temperature of geothermal water, °C	Output of geothermal water, thousand m ³ 2012 (in fact)	Output of heat, Gcal 2012 (in fact)	Output of heat, Gcal 2030 (forecast)	Investments required mln. rub.	Natural gas saving, mln. m ³ /year
Izberbash	4,54	55-60	576 576	19224	90000	100	15,65
Kayakent	0,3	45-59	73 000	2160	27000	50	4,70
Makhachkala	10,2	38-62	594 289	13138	150000	210	26,1
Thernair	21,5	50-105	683 283	37944	120000	135	20,86
Kizlyar	34,0	46-107	2 318 425	49200	500000	685	86,95
Kordonovka	4,15	44-103	9 155	4500	45000	70	7,82
Chervlenye Buruny	1,0	85-86	-	-	36000	65	6,26
Terekli-Mekteb	1,4	86-88	-	-	40000	70	6,95
Rechninsky	5,9	42-104	-	-	100000	160	17,4
Kalinovka	5,4	57-92	-	-	37000	65	6,43
Krainovka	1,6	40-42	-	-	20000	40	3,48
Tarumovka	22,46	62-90	-	-	560000	850	97,40
Total:	118,45		4254728	126166	1725000	2500	300

5.2. *Transformation of Kizlyar in a "smokeless" town.* The purpose of the project is to reconstruct the obsolete heating system for three districts of Kizlyar using geothermal water in dual circuit and installation of heat pumps. The need in reconstruction caused by the low economic efficiency of heat supply from existing heat distribution stations built over than 30 years ago.

The other goals are ensuring the needs of the town of Kizlyar in the natural heat and turning it into a "smokeless" city in the Southern Russia. The estimated cost is 154 million rubles. The payback period is 4,5 years.

5.3. *The Kizlyar energy-biological complex* is a new construction and the most famous geothermal project in Dagestan. The idea and scientific and technical grounds have been developed at the Institute for Geothermal Research, Russian Academy of Sciences (Aliyev et al., 1999). Practical implementation of the project in the Northern Dagestan is carried out by JSC "Geotermneftegaz" based on wells drilled for exploration of aquifers in Chokrak, Apsheron and continental deposits (Investment projects, 2005).

The obtained water is ideal for power generation on the binary cycle, heating greenhouses and poultry houses, for feed any fish plants, as a nutrient medium in the production of microalgae, and can be used in spa and drinking water treatment as an analogue of the Aniva mineral water.

The project will allow solving two problems:

- sturgeon growing can significantly minimize the damage from oil production on the Caspian shelf;
- creation of nature friendly food production will increase the industrial and tax potential of Dagestan.

The estimated cost of the project is 840 million rubles. The payback period is 6 years from the beginning of financing and 3 years from start of producing.

6. CREATION OF GPP BASED ON DEPLETED OIL AND GAS FIELDS

At the ENIN polygon Kayasula a technology for creating and operating an underground circulation system in the fractured carbonate reservoir has been developed and tested, including the method of bottom zone acidizing, allowing 5-6 fold increase in flow rate of lifting and injection wells and chemical-free ways to prevent scaling and corrosion mitigation of equipment when producing and applying high-temperature (170 °C) geothermal brine with salinity of 100 g/l.

According to ENIN instructions the design and project of the deep up to 5 km geothermal lifting well of large diameter was elaborated, capable with minimal friction loss to provide the flow rate up to 10 thousand m³/day at full compensation of temperature elongation of the flow string.

Table 4. Promising geothermal projects

Name of a project	Planned years of implementation	Volume of required investments, mln. rub.	Output of thermal water, million m ³	Production of thermal energy, Gcal	Volume of production mln.rub./year	Number of created workplaces
Geothermal heat supply of Makhachkala town	2010 - 2012	327,6	2,9	180,0	56,3	70
Transformation of Kizlyar in "smokeless" city using geothermal water	2010 - 2012	222,4	2,8	120,0	51,8	60
Kizlyar energy-biological complex *	2010 - 2012	840,0	1,3	66,8	1531,5	500

* Grant of the President of the Republic of Dagestan (The order number 74-rp of 24.11.2009)

The tests were conducted of the power plant equipment elements on Freon 142b: a heat exchanger, a steam generator and an air condenser, which allowed to perform the approbation of calculation methods of a boiling and heat exchange in systems with low-boiling working bodies.

All the technological problems of GPP creation were also solved based on combination of circulation systems with power installations on low-boiling working fluids, having ability to work efficiently in arid areas without cooling water at low winter air temperatures (Vasilyev et al., 1994 , Vasilyev et al., 1997).

According to the international experience and the experimental design data on Stavropol GPP, the total investments are divided approximately equally between the drilling cost and the cost of a power plant construction. For specific capital investments \$ 1000/KW in widely used power installations of the firm Ormat on low-boiling working fluid, the specific capital investments in GPP in Dagestan can be estimated at \$ 2000/KW, which are comparable with the values for modern fossil fuel thermal power plants. It should be expected that in the absence of expenses for fuel, which are up to 60% of the electricity cost on the heat power plants, and making maximum use of existing wells at the depleted oil and gas fields (Table 2), geothermal power plants will be competitive with fossil fuel power plants. Absence of harmful emissions should also improve the competitiveness of geothermal power plants.

The potential resources of geothermal brines (140-230 °C) of fractured reservoirs in limestone of Permian and Triassic estimated at 0,5 million m³/day allow to build on their base the geothermal power plants on a low-boiling working fluid with a total capacity of 300 MW. Annual electricity production will make up 2,25 billion kWh, and it will meet 25% of the Republic of Dagestan needs at a level of 2030.

For practical confirmation of such plants competitiveness under current economic conditions, it is proposed in the next five years to build a pilot GPP with capacity of 10-25 MW in one of mentioned areas. It is supposed to use existing idle oil wells for re-injection of brine cooled at the station (Council Recommendation, 2009).

At this stage, to save time and money it is recommended to use as the main equipment the geothermal energy modules of the Israeli company Ormat running on low-boiling working fluid with air condensers, and further establishing the issue of domestic equipment at one of the Russian factories by licensing.

Successful implementation of this project together with power generation will provide orders for manufacturing technological equipment in the Republic of Dagestan.

Further when developing the technology of reservoir pressure maintaining for porous reservoirs the total capacity of geothermal power plants in Dagestan could achieve 1000 MW with an annual output of 6 billion kWh of electricity.

7. CONCLUSIONS

In Dagestan, due to the depletion of proven oil and gas reserves, there are favorable conditions for geothermal energy development based on reuse of wells on exhausted oil and gas fields.

On this basis, commissioning of at least 300 MW of electric capacity can be carried out and 2,25 billion kWh of power can be generated in the long term by 2030.

At current prices for fuel and energy the geothermal power plants in terms of specific investments will be comparable with fuel power plants, and on the cost of electricity and environmental friendliness can exceed them.

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At the explored deposits of thermal water it is possible to create systems of geothermal heating with saving of natural gas in the rate of 300 million m³ per year.

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