

CONDITION AND PERSPECTIVES OF DEVELOPMENT OF GEOTHERMAL ENERGY IN CRIMEA

G. BABENKO¹

¹*Council of ministers of Autonomic Republic of Crimea,
13,Kirova avenue, c. Simferopol, Ukraine; 95005 E-mail: mintop7@ark.gov.ua*

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ABSTRACT

In report «Condition and perspectives of development of geothermal energy in Crimea» are stated the main tendencies of development of modern geothermal energy industry in Autonomic Republic of Crimea. Crimea, among other regions of Ukraine, is the less supplied with own traditional resources. But, taking into account the unique natural possibilities of peninsula, intention to create one of prestige world resorts, the base is formed for practical utilization of renewable resources of energy in all branches of economy. Main attention in report is given to problems of development of energy potential of geothermal bore holes, to strategic reserves of thermal water, to creation on the base of these bore holes the system of heating supply, destined for production of heating, of electrical energy and development of industrial complexes.

1. INTRODUCTION

Modern economic development of any region, including Crimea, depends primarily upon supply of fuel and energy resources. Taking into account that particularity of Crimea, which produces by own electrical power plants 7% of consumed electrical energy and where traditional resources are absent, self cost of their production is considerable, perspective direction in energy industry is development of renewable resources of energy, energy potential of that is large enough. In this framework an important role take environmental aspects, particularly, prevention of appearance of heating effect and decrease of contaminant exhausts to atmosphere. Taking into account that complex of realized measures for return to Crimea its status of prestige sanatorium and resort region, preservation of primary natural potential of peninsula is possible with the active utilization of alternative resources of energy.

Climate conditions of south bank of Crimea are like to climate of Mediterranean countries and are characterized by long-lasting and dry summer, by absence of strong frosts, that creates ideal conditions for receipt of thousands of people for rest. Taking into account that experience of countries developed in the field of resort business, it is important to provide the comfort of rest with utilization of environmentally clean resources of energy.

In Crimea the works are started practically in all directions of utilization of energy potential of renewable resources of energy:

- Utilization of sun radiation,
- Wind potential,
- Energy potential of hydro resources,
- Geothermal resources,
- Creation of bio energy installations.

Perspective of real return of these resources in development of economy of Crimea provides:

- Decrease of energy consumption for own needs of companies,
- Amelioration of heating supply in certain districts of Crimea,
- Supply of warm water supply for sanatorium and resort objects,
- Definition of ways of economic growth of districts that are the most favorable for attraction of foreign investments.

Council of ministers of Autonomic Republic of Crimea works the complex strategy of implementation of renewable resources of energy in energy balance of Crimea as energy-effective technologies, recently adopted law of Ukraine «About alternative resources of energy» №555 of February 20, 2003 legally defined the state level of support of this direction as a main tendency in formation of modern energy industry.

2. MAIN RESULTS OF UTILIZATION OF GEOTHERMAL ENERGY POTENTIAL

2.1. Potential of geothermal resources of Crimea

Generally works on receipt of geological and geothermal data were started, when "Crimea-geology" generalized and analyzed the results, received during the process of exploratory mining of geothermal bore holes, including temperature measurements of thermal water, that enabled formation of maps of geo isotherms and to prepare map – scheme of geothermal resources of Crimea peninsula (**Map**).

Analysis of hydro-geo-chemical researches demonstrated that the content of rocks of geothermal water layers is carbonate and silicate mountain rock, temperature of it is 50°-80°C at a depth of 1000 -2000 m. Results of exploratory mining approve the possibility of utilization of these water carrying layers. Their hydraulic characteristics, particularly thermo-artesian character of water carrying layers, allow to realize industrial exploration, with no need of utilization of electrical pumps for restitution of water balance.

According to estimations of experts of TACIS program, heating and hydraulic characteristics of deep water carrying layers of Crimea peninsula, at very high capacity of geothermal bore holes, that sometimes achieve 500-1000 cub m per day, allow to select two or three the most perspective terrains for utilization of energy of thermal water (Table 1).

These are Novoselovskij, Oktiabrskij terrains, North Sivash site and region of Tarhankut peninsula.

- **NOVOSELOVSKIJ TERRAIN** in administrative bounds includes Saki and Razdolnenskij districts; by hydro geological characteristics is a part of Terrain Crimea Artesian pool. Total drilled 17 thermal bore holes. Resource of geothermal energy is a neocom water-carrying horizon. Thickness of water carrying horizon is 37-191 m. Productive thickness makes 69-72 % of the whole thickness. Water carrying horizon of neocom sediments is a pressured one. All drilled bore holes are water carrying. Maximum capacity of bore holes at condition of self pouring is fixed in southern and central zones of studied terrain (15-20 l per sec). Depth of lying of water containing rocks is from 900 m at the south to 1400 m at the north sites. Temperature of rocks at Novoselovskij terrain is fully researched till the depth of 1500 m. and is changed for depth of 1000 m and 1500 m up to 48°- 69° C and 65,6°- 90° C accordingly. By chemical compound underground thermal waters at Novoselovskij terrain are characterized from 2-3 g/l up to 35-38 g/l. Content of microelements the terrain: iodine - from 0 to 11,5 mg/l, bromine - from 10 to 81,8 mg/l, boron - from 8 to 117,5 mg/l. Waters are mineral: food, curative and food. For a number of bore holes there are conclusions of Odessa Scientific and Research Institute of resortology.

According to data received as a result of experiments, energy potential at capacity of one geo-circulating system of about 500 cub m per day and average temperature of water at output from bore holes of 55°C makes 4562 Gcal per year with economy of 650 tons of conditional fuel per year. At coefficient of utilization of 40%, heating and energy potential of one geo-circulating system is estimated as 1825 Gcal per year.

Table 1. THE MOST PERSPECTIVE SITES OF CRIMEA FOR UTILIZATION OF GEOTHERMAL RESOURCES

№	Terrain	Depth (M)	Consumption (l per second)	Temperature at opening of bore holes (°C)	Mineralization (g/l)	Energy potential (TJ/year)				Equivalent of conditional fuel (tons/year)				Period of execution of geological exploratory works, years
						One Geothermal Station		Geothermal resources		One Geothermal Station		Geothermal resources		
						Theoretical	Real	Theoretical	Real	Theoretical	Real.	Theoretical	Real.	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	Novoselovskij	890-1400	до 35	47-69	6-38	19,5	7,6	573	229	650	260	19554	7822	1980...90
2	Oktiabrskij	1040-2400	до 57	56-95	2-38	49,0	19,6	734	293	1668	667	25000	10000	1986...94
3	Jankoj	1600-1900	до 11,6	70-75	20-30	55,0	22,0	298	119	1877	751	10170	4068	1992
4	Tarhankut	1000-1500	до 27,8	40-50	18-25	27,5	11,0	183	73	938	375	6260	2504	1994
5	North-Sivash	1300-1600	до 27,8	45-65	25-34	27,5	11,0	596	238	938	375	20336	8134	1991...94

- **OKTIABRSKIY TERRAIN** in administrative bounds includes Krasnogvardejskij and North part of Simferopol districts, geological structure of them makes formations of Paleozoic, Mesozoic and Kainozoic periods. Thermal waters are contained in neocom water carrying horizon. Productive thickness of horizon makes about 50-70% of whole volume of rocks of neocom. Water tension of cover of neocom horizon is of thickness of 500-900m. Capacity of bore holes at pouring makes 17-20 l per second, achieving 47-57 l per second (in area of villages of Novo-Alexeevka and Piatihatka). Temperature of thermal water depends on depth of water carrying horizon and makes 50°-89° C. Temperature of water at pouring makes 53°-81°C. Thermal waters in south part of terrain are fresh and have weak mineralization (0,8-3 g/l), mineralization increases up to 37-44 g/l at North direction. Mineralized underground waters (over 10 g/l) contain iodine (up to 31.3 mg/l); bromine (up to 132,7 mg/l) and are the food, food and curative, curative. For a number of bore holes there are balneologic conclusions of Odessa Scientific and Research Institute of resortology.

According to data received as a result of experiments, energy potential at capacity of one geo-circulating system of about 1000 cub m per day and average temperature of water at output from bore holes of 67°C makes 11690 Gcal per year with economy of 1668 tons of conditional fuel per year.

This site is the most perspective for heating supply of living towns especially in North part of terrain, where the temperature at pouring may achieve 80°- 85° C.

- **NORTH-SIVASH SITE** administratively is located within the bounds of Jankoj district and Genichesk district of Kherson region.

Thermal waters are part of sand alevrolit layer of Paleogen age. Depth of lying is 1300-1800 m. Debits of bore holes make 2400 cub m per day; temperature of layer water varies within the limits of 50-78 °C. Temperature at pouring is 45-65 °C. Waters are under pressure. Mineralization of layer water makes 26-33 g/l. Wateri are also industrial, content of iodine varies within the limits of 25-33 mg/l. Besides that they are valuable mineral curative and there is balneologic conclusion for them form ЦНИИКиФ.

In village Medvedevka of Jankoj district geo-circulating system is created.

- **TARHANKUT TERRAIN** in administrative bounds is located in Chernomorskij district of Crimea and by geological characteristics is defined by considerable lowing of Paloezoic and more young formations formed with terrigenic and homogenic sediments from low carbon to neogenic and quarterial periods, their whole thickness is 5,5-6,0 km. Water carrying horizon is of hydrocarbonates and mergels that provide necessity of acid treatment of bore holes. During research of characteristics of bore holes flows of thermal water were received from 0,01-0,34 l/sec to 29 l/sec. Temperature mode in west part of Tarhankut peninsula is rather specific. Terrain is characterized with geothermal gradients, on the depth of 2,1-2.2 km the character temperatures are 105°-107° C, at the depth of 3,5 km - 136°-150 C. There are perspectives for creation of Geo Heating and electicity power plant. But for these purposes research and exploratory, experienced works are needed. Mineralization of water makes 13-21 g/l. Water are of chloride-calcium type: content of iodine -14,44 mg/l; of bromine -22-50 mg/l; of boron-22-30 mg/l. At a number of bore holes there are extreme concentrations of iodine (89,1), bromine (130-132) and boron (to 140 mg/l). By gas compound, water carrying layers contain methane. Energy potential of geothermal water for this site is defined as 6570 Gcal per year or 938 tons of conditional fuel per year at calculation of capacity of one geo-circulating system of 600 cub m per day.

But industrial development of geothermal collectors, that contain thermal water, due to the depth of bore holes and necessity of large enough investment capitals is not economically reasonable.

Temperature mode and chemical characteristics of geothermal water of the given regions may be utilized in the following areas:

- a) Systems of heating supply in living sector.

For needs of heating in separate houses and in buildings with centralized heating systems.

б) Agriculture, hothouse production and fishing.

Heating of hothouses is one of the most economically profitable means of utilization of geothermal water. Taking into account the considerable needs of hothouse production in heating energy, for heating of hothouses the water is used with the temperature of 14° - 60° C.

в) Resort and curative complex.

Equipment of balneological centers and utilization of geothermal water in institutions of resort and recreation complex is one of the main factors of development of sanatorium treatment in Autonomic Republic of Crimea.

2.2. Main results of practical utilization of geothermal resources in Crimea

Now researched more than 40 bore holes potentially may be used at condition of considerable capital investment, that brakes their industrial utilization. We plan realization of analysis of potential possibilities of geothermal resources of Crimea, and in this connection we do hope on cooperation with International Financing Organizations. Their participation will enable to create strategy of utilization of geothermal resources of Crimea. That will provide primary, creation of conditions for resolution of problem of prevention of change of environmental climate during the process of formation of own stable energy base of Autonomic Republic of Crimea, possibility of preparation of pilot geothermal projects and execution of special researches on realization of mechanism of financing of geothermal projects.

In this connection we can negotiate that bore holes, that practically are ready for works, are researched and examined in details.

So, shortly I'll stress on the results that received state companies «Crimea geology» and Institute of technical heating physics of National Academy of Sciences of Ukraine. In (Table 2) we present geothermal circulating systems that were created and exploited during different years.

Practical development of geothermal energy for heating supply of agricultural objects in Crimea was always of great importance. At the beginning of 80th in living towns of Novoselovskij site: Iljinka, Trudovoje, Sizovka there were created the systems of geothermal heating supply on the base of two large bore holes. Heating potential of thermal water was utilized for heating network and water supply water in systems of heating and warm water supply. According to calculations of Institute of technical heating physics it was defined, that at mining of two bore holes in v. Iljinka thermal water would fully supply heating capacity of warm water supply and part of capacity for heating. This offer provided economy of traditional fuel for 50%, decrease of contamination of environment.

Results of works on development of geothermal resources even during this period defined importantly economic and environmental reasonability of complex utilization of thermal waters on the territory of 30-40 agricultural objects.

2.3. Perspectives of implementation of pilot projects in geothermal energy industry

Results of previous years and large-scale plans of utilization of thermal water on this site are the basic ones and allow to count on utilization of own natural resources for resolving of social and economic matters in this region.

Now in Crimea geo-circulating systems are used as heating points in village Jantarnoje of Krasnogvardejskij district and in v. Medvedevka of Jankoj district.

By temperature data particularly on bore holes in village Jantarnoje at Oktjabrskij terrain the maximum values of temperature, 89° C и 81° C at pouring were fixed, that allows to provide experience and industrial exploitation of this heating point for about 10 years. Particularly on this object the requirements for project solutions practically are fixed, constructions of main and additional equipment, technological modes, execution of them provides non-accident and high

efficient work of geothermal heating point. For increase of efficiency of utilization of potential of geothermal bore holes of this object and of possibility of its more complete utilization the project of creation of technological complex is examined aiming at creation of a range of installations of processing of agricultural products of district, particularly, creation of hothouses, of refrigerating installations, of vegetable and fruit storage, of drying installations, of lines for processing of food products, and also of balneological center. Calculations demonstrated that for realization of this project we need geothermal installations for heating of capacity of 20 MW. Realization of this project has a strategic meaning not only for Crimeaa, but for Ukraine, because it enables large-scale utilization of environmentally safe resource of energy in agro industrial complex. We really estimate the necessity of important investments– about 6,5 mln USD. Preliminary technical and economic estimation demonstrates that creation of this complexa (Table 3) will change not only economic situation of region, but also will ameliorate ecology.

**Table 3. Economical characteristics of project
«GEOTHERMAL TECHNOLOGICAL COMPLEX IN VILLAGE JANTARNOJE»**

Characteristics	Values
1. Capital expenses, thsnds USD	6 500
2. Exploitation expenses, thsnds USD	200
3. Amortization, thsnds USD	260
4. Economical characteristics	
4.1. Annual heat production, MW per hour	51 200
4.2. Total capital investment, USD /KW	433
4.3. Productive costs of heat, USD / MW per hour	3,9
4.4. Annual economy of conditional fuel, tons per year	7 500
4.5. Decrease of exhausts of CO ₂ , tons per year	16 400
4.6. Period of refinancing, years	5

In village Medvedevka of Jankoj district, that was mentioned above, together with Institute of technical heating physics of national Academy of Sciences of Ukraine starting from 2001 the works are held to create a pilot object of geothermal energy with utilization of environmentally clean circulating technology. Exploitation of heating electric center station allows to provide not only heating supply of living sector of village, but also to provide it with electricity. We plan that and works are open for installation of system of utilization of natural gas from thermal water for production of electricity. According to technical and economic calculations that makes the annual supplied population and production site for 1500 MW per hour of electricity and 10000 MW per hour of heating energy. That will be one of the first scientific and production objects where due to effective utilization of natural possibilities the matters of heating of village will be resolved, environmental norms of utilization of geothermal water will be respected and the mechanism of creation of profitable self-financing supply of companies with heating will be established. Creation of this object is also an expensive measure -that is about 3,0 mln USD. But (Table 4) the project allows to create not only the resource of electric energy with utilization of environmentally safe technologies, but also provides economic growth of this region.

Table 2. CHARACTERISTICS OF BI-HOLE GEOTHERMAL CIRCULATING SYSTEMS IN CRIMEA

№	Terrain, village	Hole depth, m	Hole debit, cub m per day	Temperature of water, °C	Mineralization, g/l	Capacity of collector, m	Capacity, MWt	Heating supply objects	Annual fuel economy, Tons of conditional fuel
1	2	3	4	5	6	7	8	9	10
<u>Novoselkovskij terrain</u>									
1.	Iljinka	1200	1300	57	-	100	1,0	Living village	500
2.	Sizovka	1400	1700	61	18,0	93	1,0	Living village	500
3.	Trudovoje	1160	2100	53	8,0	110	1,0	Hothouses, Warm water supply	700
4.	Zernovoje	1100	2000	50	5,0	110	1,0	Hothouses, Warm water supply	500
5.	Kotelnikovo	1500	1600	65	30,0	100	2,0	Living village	1 000
<u>Oktiabrskij terrain</u>									
6.	Jantarnoje	2300	2000	85	30,0	200	5,0	Living village	5 000
7.	Novo-Alexeevka	1360	4000	54	-	200	3,0	Milk farm, living village	-
8.	Rovnoje	1569	3200	62	8,0	150	3,0	Living village	1 500
9.	Krasnogvardejsk			85	30,0		60,0	City districts	30 000
10.	Piatihatki	1300	1000	51	-	80	1,0	Warm water supply	2 500
<u>North Sivash terrain</u>									
11.	Medvedevka	1500	1100	67	8,0	80	1,0	Living village	1 000

**Table 4. Economical efficiency of project
«GEOTHERMAL DEMONSTRATIONAL INSTALLATION
IN VILLAGE MEDVEDEVKA OF JANKOJ DISTRICT
OF AUTONOME REPUBLIC OF CRIMEA»**

Characteristics	Values
Capital expenses, thsnds USD	3000,0
Including:	
Drilling bore holes	2300,0
On-land complex	700,0
Productive expenses, thsnds USD per year	70,0
Amortization, thsnds USD per year	120,0
Annual heat production, MW per hour per year	10 000
Production of electricity, MW per hour per year	1 500
Productive costs of:	
Heat, USD 3a MW per hour	6,3
Electricity, USD 3a 1 KW per hour	0,011
Annual economy of conditional fuel, tons per year	2 000
Decrease of exhausts of CO ₂ tons per year	3 819

According to data of Institute of technical heating physics of National Academy of Sciences of Ukraine the total potential of thermal waters of Crimea is estimated as 475 thsnds cub m per day, that in perspective allows to create the systems of geothermal heating supply of total capacity of 1400 MW and geothermal electrical power plants of capacity of 200 MW.

The most considerable researches are made for Novoselovskij site of thermal water, where in number of villages there are acting geothermal bore holes. We offer to examine industrial system of geothermal heating supply of Krasnogvardejsk, of district with considerable reserves of thermal water, that needs the complex of environmentally safe heating supply, competitive with traditional systems that work on organic fuel. Project is to our mind, very distinctive technological installation for utilization of natural resources, as from economic, as well as from environmental points of view. Capacity of object is estimated about 85 MW, with annual economy of 40 thsnds tons uia conditional fuel, and decrease of contaminating exhausts foe 87,6 tons per year. Expenses make 34 mln. USD with creation of 14 bore holes of depth of 2800 m and additional geological researches (Table 5). But for the present time there are enough geological, technical and economic bases for this really a large-scale project.

**Table 5. Prognosis of economic characteristics of project
«KRASNOGVARDEJSKIJ PROJECT OF GEOTHERMAL WATER SUPPLY»**

Characteristics	Values
1. Capital expenses, thsnds USD	34 000
2. Exploitation expenses, thsnds USD	1 002,4
3. Economical characteristics	
3.1. Annual heat production, MW per hour	258 560
3.2. Total capital investment, USD /KW	425
3.3. Productive costs of heat, USD / MW per hour	3,38
3.4. Annual economy of conditional fuel, tons per year	40 000
3.5. Decrease of exhausts of CO ₂ , tons	87 600
3.6. Period of refinancing of investments, years (tax on profit 30%) at price of 37 USD for MW per hour	5

We should note that Autonomic Republic of Crime is strongly interested in this project because of many reasons, one of them is a real perspective cooperation with one of the priority scientific institutions of Ukraine– Institute of technical heating physics of national Academy of Sciences of Ukraine, that many years by its researches contributes to amelioration of economic and

environmental conditions of peninsula. Krasnogvardejsk Project is a new large-scale exploration of utilization of geothermal potential of Ukraine in Crimea that approves the possibilities of natural environmentally safe technologies. Implementation of this project allows providing district with stable heating supply that is of great importance at conditions of valley Crimea. We count on support of World Bank in this project and from our side will do our best for its efficient realization.

3. CONCLUSIONS

The present material characterizes economic perspective of one of compounds of unique energy potential of renewable resources of energy in Crime – of geothermal energy.

To summarize we can formulate a number of conclusion:

1. Geothermal resources of Crimea allow creating economically profitable and environmentally safe systems for supply of certain branches of economy of heat and electrical energy.
2. Creation in certain districts of region the objects of heating supply of living villages with utilization of new geothermal technologies allows to ameliorate social and economic situation in the given districts and in the whole Crimea.
3. Present projects of creation of scientific and industrial complexes are the beginning of works on realization in Ukraine of economically reasonable technologies with utilization of environmentally clean resource of energy.
4. At condition of cooperation of Autonomic Republic of Crimea with representatives of international financial organizations in area of exploration the strategy of utilization of geothermal energy in Crimea an important state job of creation of own environmentally safe energy base will be realized.