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Methods and Recommendations for Investment Substantiation of Geothermal Power Plant Developments

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ABSTRACT

The utilization of low temperature geothermal energy sources is one of the key solutions to the problem of heat supply in many regions of Russia in the 21st century. This tendency can be explained by Russia's lack of domestic conventional power resources, the high cost of transporting them from other regions, certain advantages of geothermal sources, the scientific basis of their development, word-wide industrial experience, and the country's specific heat supply systems. Russia's great variety of geologic and geothermal conditions determines the conditions of construction of a geothermal heat supply systems (GHSS). The user requirements result from a wide range of demands for heating, operating temperatures, and the distance heat must be transferred. A total of about 150 factors influence the design variables and technological parameters of GHSS. Therefore, an adequate assessment of the expediency of the development of geothermal resources is only possible if the evaluation of the parameters involved has been carried out accurately. This problem can be solved using economic and mathematical models for the construction and operation of GHSS. The first economic and mathematical model (EMM) was conceived in 1971 with the aim of GHSS optimization. A group of models has since been developed to simulate the operation of stations utilizing various technologies of heat extraction and the various uses of that heat. The EMM-based ratio test of the major natural conditions that exert influence on design variables (technological, energy and economic parameters and GHSS operating factors) has made it possible to develop these models and recommend the use of a new express method aimed at their analysis in different regions of Russia. The EMM methods and express analysis created can form the basis of GHSS design and, in particular, the provision of investment substantiation and formulation of business plans. Examples of regions in Russia with geothermal source potential are also provided.

1. INTRODUCTION

The further development and prosperity of Russia depends to a large extent on its possibility to meet its own energy requirements while maintaining hydrocarbon fuel and power exports. At the present stage of the country's development, the sale of energy resources is a major source of state revenue. However, oil resources are rapidly being depleted at their current export volume. Further, there is a limit to the marketable supply of natural gas. Coal reserves have decreased significantly since the disintegration of the USSR, whilst the remaining reserves require a considerable increase in current investments. In addition, these coal deposits are characterized by their decreasing quality. Additional expenses for are also growing due to ecological protection.

Under these conditions, especially on account of the sharp rise in the cost of fuel transportation, the electricity supply in the European part of the country has grown considerably worse. There aren't any substantial conventional power resources in the regions of the central Russia, which are characterized by a fairly dense concentration of population and industry. Therefore, the estimated cost of meeting annual heat supply requirements in eight regions (oblasts) is about 55 million tons of fuel oil equivalent (f.o.e.), as shown in Table 1.

The search for heating alternatives to fossil fuels has been under way for several decades. The use of low-temperature geothermal energy sources for regional heat supply is one of the basic trends in the quest to solve this problem in the 21st century. This is because of the inherent advantages of geothermal resources, the scientific basis of their development, world-wide industrial experience, and the country's specific heat supply systems.

The problem can be solved using the theory of the development of low-temperature geothermal resources that has been shaped by scientists worldwide.

- Technical schemes for geothermal heat generation via geothermal circulation systems (GCS) have been developed by Boguslavsky (1984, 1994), Khakhaev (1994), Dyadkin (1995), Lund (1995), and Mahler (1995).

- Theories of hydrodynamic, thermophysical and geomechanical processes of geothermal energy utilization have been developed by Dyadkin (1995).

- A method of geological and economic assessment of geothermal resources and the general principles of evaluation of geothermal reserves have been developed by Boguslavsky (1980, 1984, 1994,1995) and Dyadkin (1995).

- The mapping, regional assessments and appraisal of geothermal resources in Russian territory have been carried out by Boguslavsky (1984, 1995).

- Methods of technical and economic evaluation of the parameters and factors of GCS, GHSS and geothermal power plants (GeoPP) have been developed by Boguslavsky (1984, 1994, 1995, 1995).

- Mathematical and economic models of GCS, GHSS and GeoPP, which enhance their parameters and factors to work out technical regulations at the stage of designing these plants, have been developed by Boguslavsky (1981, 1995).

- Experimental work and pilot schemes to verify feasibility and the working efficiency of technical schemes have been carried out by Boguslavsky (1984), Khakhaev (1994), Dyadkin (1995), Lund (1995), and Mahler (1995).

- Experience has been accumulated and generalized in geothermal resource development on a commercial scale by Boguslavsky (1984, 1995), Dyadkin (1995), Lund (1995), and Mahler (1995). The specific characteristics of heat supply significantly stimulate the use of geothermal energy in the regions of Russia:

- a high degree of centralization of heat supply systems in cities and towns;
- the length of time for which the heating systems have been used and their extensive deterioration;
- the short supply of fossil fuels and the difficulties in delivery to customers;
- the density of both urban and rural populations.

2. TECHNICAL-AND-ECONOMIC ASSESMENT OF THE PROSPECTS OF THE DEVELOPMENT OF RUSSIA'S GEOTHERMAL RECOURCES

2.1. Methodological principles

A great variety of geologic and geothermal conditions of production horizons characterizes the constraints of GHSS construction, and a wide range of heat loads, operating temperatures, and heat transfer distances define the basic user requirements.

A total of about 150 factors influence the design variables and technological parameters of GHSS. Therefore, an adequate assessment of the expediency of the development of geothermal resources is only possible if the evaluation of the parameters involved has been carried out accurately. The analysis of the influence of the aforementioned conditions and requirements on the GHSS parameters, exergy, and economic characteristics of the station operation is of vital importance.

This problem can be solved on the basis of economic and mathematical models of GHSS construction and operation. The first economic and mathematical model (EMM) was developed in 1971 with the aim of GHSS system optimization. A group of models has since been developed to simulate the operation of geothermal plants utilizing various technologies of heat extraction and for various uses of that heat by Boguslavsky (1981, 1995). Optimization evaluation was performed for various geological, geothermal, and thermal energy conditions in central regions of Russia on the basis of the GHSS model, comprising a GCS with a natural reservoir and a heat pump plant (HPP).

The key criterion of the optimization of GHSS operation was the net present value (NPV). The capital investment, production cost, fossil fuel savings (natural gas used as reference), and cost-to-performance ratio were chosen as the estimation criteria. Projects with an NPV>0 are deemed profitable and should be approved for investment. This means that as long as the economic life of GHSS endures, it will offset initial expenses and will ensure profit in accordance with the assigned discount rate. If NPV<0, then this project is unprofitable. If the NPV=0, then it does not produce a profit. The investment differentiated with respect to the main construction projects and the resulting effects could be indicated generally in terms of GHSS and two systems (GCS and HPP).

Fuel conservation practice characterizes (in fuel equivalent-f.o.e.) the difference between heat production and fossil fuel consumption for electric power generation, which is consumed by GHSS auxiliaries. In addition, fossil fuel economy is defined as the difference between heat production and estimated heat generation of an electric power boiler plant for electricity generation, the latter of which is consumed by GHSS auxiliaries.

The cost-to-performance ratio states the cost per unit of heat generation of a thermal power plant and the unit cost of GHSS heat supply intended for a user (i.e. equal capacity). If the value of this criterion is greater than one, then the construction of a geothermal station is believed to be economically feasible. The use of other business planning criteria is hardly indispensable at the current stage of design work.

A computer-operated technique of evaluation and optimization was developed for business plan on the basis of the EMM of geothermal systems, including natural reservoirs, by Boguslavsky (1995). This technique is believed to mainly facilitate the implementation of investment substantiation, as it can offer a consumer design, technological, and economic parameters and factors of GHSS that fit specific natural conditions. These are optimal not only on account of average criteria, and therefore quite discrete, but a certain financial scenario of the realization of a project is also considered which links mutual interests and responsibilities of both investors and consumers.

2.2. Geologic-and-geothermal conditions

Geological and geothermal conditions are of primary importance when performing technical and economic assessments of the development of geothermal resources. The assumed technique incorporates 14 factors that belong to this group. According to experience and investigations conducted, 5 reservoir properties exert influence upon various parameters of GHSS: reservoir depth, temperature, net thickness, permeability, and pressure. It is rather difficult to choose representative and generalized geological and geothermal characteristics that unify various conditions in Russia, particularly with provisions for the simultaneous use of several thermal water-bearing layers and deeper aquifers. After carrying out the analysis of the geological and geothermal conditions, the potential user load requirements and the marginal economic parameters, the following has been approved

Natural reservoir depth ……......…1; 1.5; 2; 2.5 and 3 km.
Reservoir thickness …................25, 50, 75, 100 and 150 m
Temperature of reservoir..............30, 40, 50, 60 and 70 ^{0}C.
Rock permeability of reservoir...0.05; 0.1; 0.2; 0.3; 0.4 Darcy.
Reservoir pressure...hydrostatic.

2.3. The influence of natural conditions on technical and technological parameters of GHSS

The influence of the basic geological-and geothermal conditions on the NPV, investment in GHSS construction, and plant output cost has been studied in detail and is described in a number of scientific papers and transactions (Boguslavsky 1984, 1995, 1995). As shown in the sensitivity analysis in Figure 1, the maximum estimated criteria fluctuation (involving GHSS construction investment in particular) results from alteration of rock permeability in productive strata. However, major changes occur within the permeability range of up to 0.3-0.4 darcy, and at higher permeabilities, its influence on technical and economic characteristics (TEC) is apparently of negligible importance. This also holds true for the natural reservoir thickness. This value considerably affects TEC up to 40-70 m, after which this influence diminishes abruptly. Therefore, TEC of the production of geothermal energy always depends largely on the temperature of reservoir rocks and their depth.

2.3.1. GHSS heating capacity definition

The assessment of economic expediency of the GHSS heat capacity under various conditions of reservoir temperature and depth has been carried out with the specification that the principle of calculation (at the optimal level) be excessively higher than its value for the two well GCS module. The heat carrier temperature at the point of customer delivery was designated as 40-90ºC. The cost of electricity was taken as 50 USD/MW and that of fossil fuels (natural gas) was designated as 124 USD/ton f.o.e. according to the world market conjuncture.

A computerized procedure of estimation made it possible to create an economic-mathematical model of GHSS and optimize its parameters while analyzing up to several thousands of variants. According to the results of this modeling, the highest optimal values of specified heat capacity of GHSS (determined by the design engineers from the five coldest days within a year) ranged from 4 to 74 GJ/h, as displayed in Figure 2.

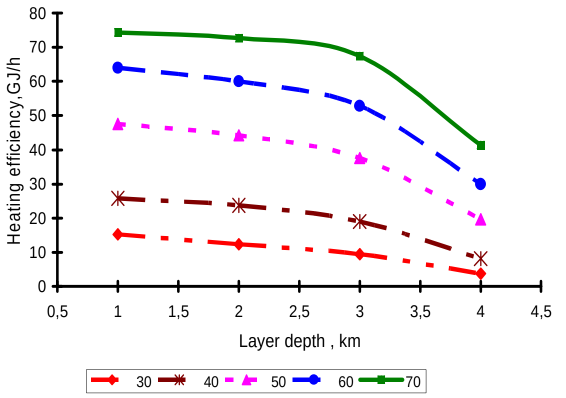

Figure 2: Temperature and layer – dependent GHSS optimal module heating efficiency

It is important to have an equation for the rapid evaluation of GHSS heating efficiency to formulate business plans, develop investment projects and carry out other pre-investment feasibility studies. This is possible due to the approximation of the economic and mathematical model values, as shown in Equation 1:

$$Q = -a \cdot H^3 + b \cdot H^2 - c \cdot H + d \text{ ; [GJ/h]} \qquad (1)$$

$$a = 1.6 \cdot 10^{-4} \cdot t^{2,295} \text{ ; } b = 7.1 \cdot 10^{-3} \cdot t^2 - 0.38 \cdot t + 7.269 \text{ ;}$$

$$c = 12.5 \cdot 10^{-3} \cdot t^2 - 0.698 \cdot t + 16.232 \text{ ; } d = 1.846 \cdot t - 37.8 \text{ ,}$$

where, *a,b,c,d* are numerical coefficients; *H* is the natural reservoir depth in km, and *t* is the layer temperature in °C.

Estimations showed tolerable precision in the EMM results with calculated values according to the introduced regression equation (Equation 1).

2.3.2. GHSS hydrodynamic characterization

To select the GHSS equipment, it is necessary to assess the hydrodynamic parameters of the system using aggregated data. According to the EMM data, specific discharge of a well does not sensibly depend on the natural reservoir depth, but it falls substantially when temperature rises. Rapid evaluation of this can be performed using Equation 2:

$$W_{ud} = 342.34 \cdot t^{-1.048} \text{ [m}^3\text{/GJ]} \qquad (2)$$

The specific discharge and vacuum pumping pressure drop as the temperature and depth of the reservoir increase. The increase of the well rate to cover the GHSS heating power growth results in incremental head pressure losses in the GHSS circuit and must be controlled by the existing discharge and standard sized.well pumps Calculation of the specific discharge and vacuum pumping pressure can be performed according to Equation 3:

$$P_{sp} = a \cdot t^b \text{ ; kPa/(m}^3\text{/h)} \qquad (3)$$

$$a = 99.15 \cdot e^{0.857 \cdot H} \text{ ; } b = -0.46 \cdot H^{0.5}$$

2.3.3. The annual fuel saving determination

Energy-dispersive analysis of the GHSS operation has been carried out on account of a considerable station service power consumption, particularly to meet the demands for thermal transformation. In this case, fuel savings have been defined as the difference between the displacement of fossil fuel consumption by geothermal heat generation, and the predicted fuel consumption required for electric-power production by the GHSS, as shown in Figure 3.

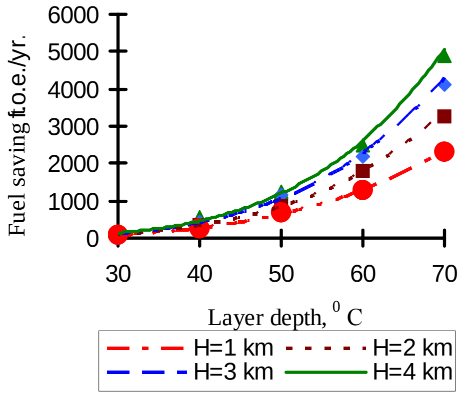

Figure 3: Annual fossil fuel saving when a boiler plant is replaced by a GHSS module, depending on the layer temperature –t and depth - H.

The annual fossil fuel savings when the boiler plant is replaced by the GHSS module can be defined depending on the layer temperature and depth according to Equation 4:

$$T_{ec} = A \cdot t^b \text{ [t f.o.e./yr.];} \qquad (4)$$

$$a = 5.13 \cdot 10^{-5} \cdot \exp(0.254 \cdot H) \text{; } b = -0.119 \cdot H + 4.4 \text{ .}$$

The GHSS output within the entire temperature and depth range of thermal water-bearing layers is 15-45% higher than the auxiliary power consumption.

2.3.4. Specific GHSS service consumption definition

Specific power consumption for heat generation hardly depends on the layer depth but it is linearly dependent on its temperature (Lund 1995, Mahler 1995, Boguslavsky 1994). HPP consumes as much as 80% of the plant use, as can be shown using Equations 5-7.

$$Y_{GHSS} = -0.775 \cdot t + 138.4, \text{ [kWh/G]} \qquad (5)$$

$$Y_{HPP} = -0.573 \cdot t + 113.7, \text{ [kWh/G]} \qquad (6)$$

$$Y_{GCS} = -0.199 \cdot t + 24.7, \text{ [kWh/G]} \qquad (7)$$

2.4. The influence of natural factors on economic indicators of GHSS

An effort has been made to convert cost estimates into dollar equivalents for predictive appraisal due to the uncontrollable and unpredictable trends of prices and tariffs. Based on experimental and theoretical data of the US experience with due regard to the period of transition in the countries of the former USSR (low-paid manpower, state producers' goods monopoly, etc), corrective ratios have been used, which take the ruble exchange rate into account. These ratios correlate with the technical and economic calculations of the "Baltic project" made by Danish specialists and with the materials of the engineering estimate made by German experts (Mahler 1995). The probable degree of approximation and conditionality of these ratios are chosen using a comparative character of assessment criteria.

2.4.1. Defining capital expenditures on the construction of an optimal GHSS module

Capital expenditures on the construction of an optimal GHSS module depend considerably upon the depth and, in case of shallow wells, are contingent nominally on the layer temperature, as shown in Figure 4. It is difficult to overestimate the potential of the express investment calculation. Equation 8 allows complex calculations of demands for capital expenditures with valid approximation to EMM results.

$$K_{GHSSsp} = a \cdot t^2 - b \cdot t + c; \text{ thousands of USD/(GJ/h)} \qquad (8)$$

$$a = -0.00317H^3 + 0.016H^2 + 0.0127H - 0.0052;$$
$$b = 4.13 \cdot H - 1.634;$$
$$c = 27.29 \cdot H^3 - 164.04 \cdot H^2 + 431.96 \cdot H - 175.94$$

2.4.2. NPV Determination

e The objective function that indicates economic expediency (NPV) determines the potential construction of GHSS for heat supply of residential communities, industry, and agriculture. If the layer depth is more than 3-4 km and its temperature is less than 50-60ºC, then the activity of GHSS is unprofitable. GHSS operation is also unprofitable if the layer depth is over 2-3 km and its temperature is less than 30-40ºC, as shown in Figure 5. The NPV can be calculated using Equation 9.

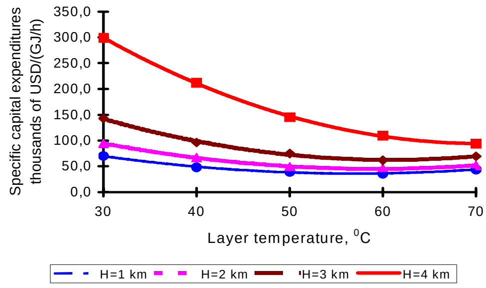

Figure 4: Specific capital expenditures into GHSS construction versus layer temperature and reservoir depth

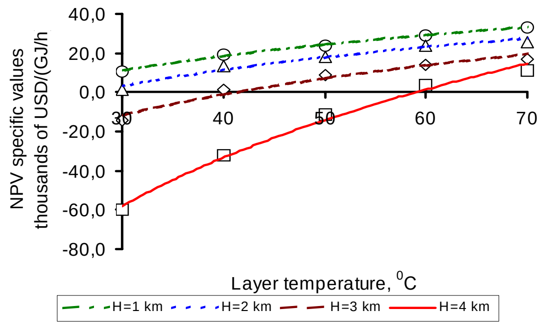

Figure 5: NPV specific values versus layer temperature – t and depth – H

$$NPV_{spvalue} = a \cdot \ln(t) - b; \text{ thousands of USD/(GJ/h);} \qquad (9)$$

$$a = 6.027 \cdot H^3 - 33.5 \cdot H^2 + 60.81 \cdot H - 7.21;$$
$$b = 24.6 \cdot H^3 - 135.1 \cdot H^2 + 249.3 \cdot H - 60.9$$

3. GHSS PARAMETERS AND RATIOS FOR INVESTMENT SUBSTANTIATION

Information is required that incorporates consolidated but reliable parameters and ratios of the construction and operation of GHSS for pre-investment feasibility studies, including the development of capital spending projects, the formulation of business plans, etc. Technological, engineering, energy and economic parameters of GHSS have been estimated at the request of the regional authorities, plant managers, heads of agricultural enterprises, and public utility companies. The calculations have been made for several dozens of projects, and the data on some of them located in different regions of Russia are given in Tables 2-5.

4. CONCLUSION

1. The low temperature thermal water-bearing layer development is technologically possible and economically sound in a considerable amount of Russian territory.

2. The capacity and range of utilization of geothermal energy in the 21st century must assure a significant position in the supply-demand balance of Russia.

3. The ratio test of the influence of the key natural factors on the design, technological, energy and economic parameters and GHSS operating conditions has made it possible to develop and recommend the use of a new express method aimed at their analysis in different regions of Russia.

4. A wide range of efficient module heat capacities and other competitive parameters of GHSS render possible the use of low-temperature geothermal power for consumers in a considerable amount of Russian territory that is rich is geothermal resources.

5. The considered examples of GHSS parameters in different regions of Russia and intended for various consumer requirements allow the assessment of specific characteristics of geothermal plants.

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Table 1: Predictive heat consumption by industry (I), agricultural enterprises (A.E.) and the municipal housing sector (MHS) in central regions (oblasts) of Russia from 2000-2010

Regions (oblasts)	Heat consumption, million of tons of f.o.e. a year						
	Total	Cities and towns			Rural communities		
		I	MHS	Sub-total	AE	MHS	Sub-total
Vladimirskaya	6.1	3.0	2.2	5.2	0.6	0.3	0.9
Vologodskaya	6.6	3.3	1.5	4.8	1.2	0.6	1.8
Ivanovskaya	5.0	2.6	1.8	4.4	0.4	0.2	0.6
Kostromskaya	3.0	1.3	0.9	2.2	0.5	0.3	0.8
Nizhegorodskaya	18.6	11.5	4.7	16.2	1.2	1.2	2.4
Novgorodskaya	3.7	2.0	0.9	2.9	0.5	0.3	0.8
Tverskaya	6.1	2.8	2.0	4.8	0.8	0.5	1.3
Yaroslavskaya	5.6	2.8	2.0	4.8	0.5	0.3	0.8
Total	**54.7**	**29.3**	**16.0**	**45.3**	**5.7**	**3.7**	**9.4**

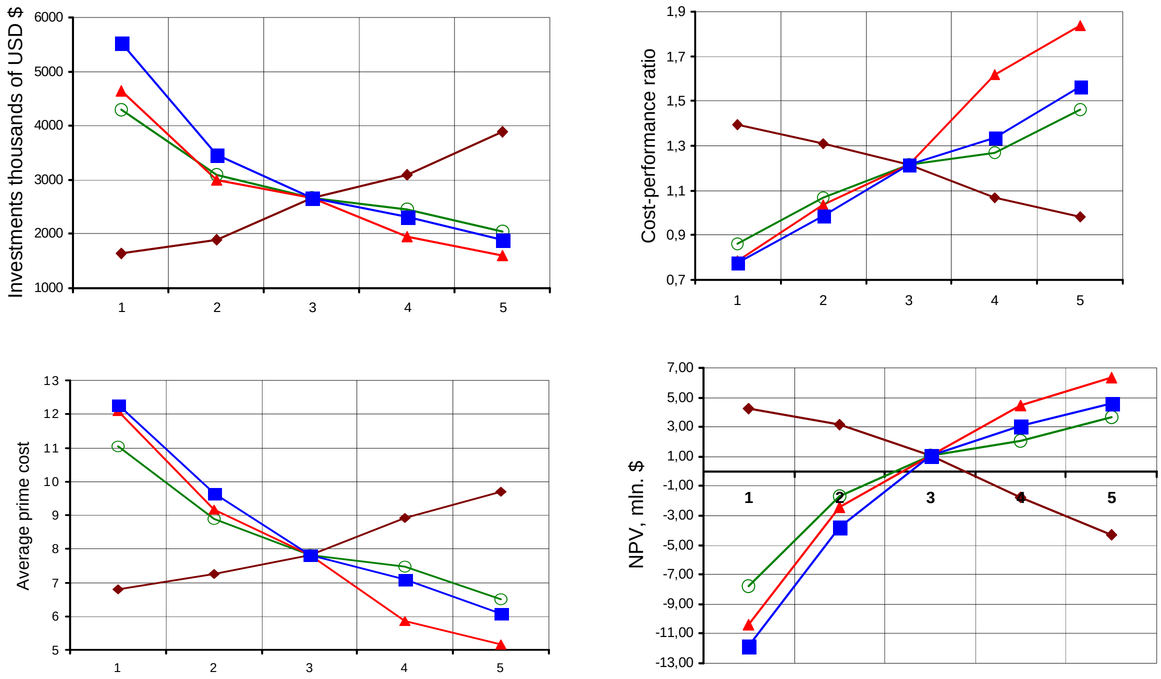

Figure 1: Influence of geothermal conditions on the major economic characteristics of GHSS

Table 2: GHSS initial design data

Parameters and factors	Kaliningrad region		Yakutia		Kamchatka		Vologda region	Pskov region	Kostroma region	Yaroslavl	
	Devon	Cambrian	Vilyuisk	Vuktyl	Field 1	Field 2	Devon	Town. of Palk.	Town of Bui	Village of Medyagino	Town of Rybinsk
GHSS heating capacity, GJ/h *	40.0	40.0	25.0	25.0	25.0	25.0	100.0	35.8	56.8	25.0	5.0
Submitted hot water, oC **	90.0	90.0	90.0	90.0	90.0	90.0	90.0	90.0	110.0	90.0	90.0
The fulfilled cold water, oC ***	40.0	40.0	40.0	40.0	40.0	40.0	55.0	55.0	70.0	55.0	55.0
Reservoir rock temperature, ^{0}C	40.0	70.0	110.0	55.0	115	140.0	50.0	50.0	53.0	56.0	25.0
Permeability of reservoir rock, darcy	3.0	1.7	0.7	0.67	1.0	0.7	2.0	0.7	2.7	0.46	2.5
Reservoir thickness, m	75.0	45.0	500.0	800.0	300.0	300.0	137.0	40.0	174	104	125.0
Producing well depth, m	1,000	2,000	3,350	2,100	1,600	2,200	1,644	900	1,970	2,190	1,030
Price per m^3 of water, USD	0.01	0.01	0.1	0.1	0.09	0.09	-	0.011	0.8	0.01	0.1
Price per kWh of electric power, USD	0.0468	0.047	0.05	0.05	0.05	0.05	-	0.02	0.056	0.05	0.05
Price per t of fuel (per t of f.o.e.), USD	86.9	86.9	124.0	124.0	124.0	124.0	-	57.1	110.0	129.0	124.0
Discount coefficient	0.09	0.09	0.09	0.09	0.09	0.09	-	0.09-	0.09	0.9	0.09

* Maximum (design) heating capacity of GHSS within the 5 coldest days.
** Maximum delivery /heating water in the straight pipeline.
*** The same but in the return pipeline.

Table 3: Design and technological parameters of GHSS

Parameters and factors	Kaliningrad region		Yakutia		Kamchatka		Vologda region	Pskov region	Kostroma region	Yaroslavl	
	Devonian	Cambrian	Vilyuisk	Devonian	Field 1	Field 2	Devonian	Township of Palkino	Town of Bui	Village of Medyagino	Town of Rybinsk
Well diameter, m	0.2	0.2	0.1	0.15	0.1	0.1	0.2	0.15	0.2	0.2	0.15
Spacing of wells, m	1,000	1,000	300	250	250	200	750	500	600	400	350
Maximum discharge pressure, MPa	1.09	2.56	0.39	0.61	4.25	1.77	1.29	5.98	2.15	3.49	1.06
Maximum well flow rate, m^3/h	275.3	158.8	46.1	113.5	64.2	51.3	227.4	123.7	260.2	156.4	81.8
Temperature of geothermal heat transfer medium/thermal liquid, ^0C	39.0	67.2	100.9	52.8	104.5	131.0	47.8	47.5	51.4	52.6	24.0
GCS module operation life, year	22.6	27.1	29.5	28.8	32.9	39.7	22.8	17.3	21.7	28.8	31.3

Table 4. Exergy indicators of GHSS

Parameters and factors	Kaliningrad region		Yakutia		Kamchatka		Vologda region	Pskov region	Kostroma region	Yaroslavl	
	Devonian	Cambrian	Vilyuisk	Devonian	Field 1	Field 2	Devonian	Town of Palkino	Town of Bui	Village of Medyagino	Town of Rybinsk
Annual heat generation, GJ/y	146.0	172.0	130.0	102.0	105.0	115.0	370.0	116.0	201.2	87.3	17.6
Annual fossil fuel saving, thousands of t of f.o.e.	6.26	7.39	5.58	4.4	4.5	4.94	15.9	4.97	8.65	3.75	0.76
Annual power consumption, GWh	14.9	12.6	4.35	8.95	3.68	1.61	31.0	11.0	18.1	7.93	1.71
Nominal fuel consumption, th of t of f.o.e*	5.07	4.3	1.48	3.04	1.25	0.547	10.5	3.73	6.17	2.69	0.58
Specific energy consumption per 1 GJ, kWh	102.4	73.5	33.5	87.4	35.2	14.0	83.9	94.8	90.2	90.6	97.4
Annual electric boiler plant heat generation, thousands of t of f.o.e.**	1.83	1.55	0.535	1.1	0.45	0.198	3.8	1.35	2.23	0.97	0.21

* Nominal fuel consumption required for power generation for GHSS use.

** Annual electric boiler plant heat generation at the expense of GHSS use.

Table 5: Economic indicators of GHSS

Parameters and factors	Kaliningrad region		Yakutia		Kamchatka		Vologda region	Pskov region	Kostroma region	Yaroslavl	
	Devonian	Cambrian	Vilyuisk	Devonian	Field 1	Town of Bui	Devonian	Township of Palkino	Town of Bui	Village of Medyagino	Town of Rybinsk
Capital expenditures on GHSS, million of USD	2.40	2.81	3.66	2.77	2.15	1.39	9.9	1.12	2.49	1.25	0.89
Annual operating costs,million of USD	1.02	0.89	0.747	0.842	0.468	0.315	3.39	0.41	1.25	0.373	0.29
Annual disbursement of loan and payment of interest rate, thousands of USD	228	257	335	254	166	127	-	-	240	88	-
Average cost per 1 GJ, USD	6.99	5.17	7.28	8.25	6.36	4.97	9.16	3.53	6.22	7.74	16.48
Capital expenditures on alternative fuel-fired plant (AFFP), million of USD *	3.0	3.0	5.93	3.95	3.95	3.95	12.1	1.62	4.09	2.18	0.92
Cost per 1 GJ generated by AFFP, USD	7.46	7.46	11.51	10.73	10.64	10.64	10.73	4.18	7.77	9.45	18.26
Commercial efficiency	1.21	1.63	1.58	1.30	1.67	2.14	1.17	1.18	1.25	1.22	1.11
Net present value (NPV),million of USD	2.98	11.32	10.07	3.54	9.08	14.90	4.60	0.75	5.30	2.48	0.09

* Capital expenditures intended for the construction of an alternative fuel-fired plant