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Innovative Potential of Hot Dry Rock Geothermal Technology

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Abstract

This article is devoted to the estimation of hot dry rock geothermal technology innovative potential. In particular, we focus on the application of integrated assessment methodology based on the region's resources estimates, their structure and key performance indicators on the example of the Krasnodar Region located in the Southern part of the Russian Federation. We provide a number of innovative and useful suggestions for the application of the hot dry rock geothermal technology worldwide.

Keywords: renewable energy, hot dry rock technology, innovation, innovation potential

1 Introduction

In spite of the developed network of centralized energy supply and the high level of electrification, there are decentralized energy supply systems on a large part of the territory of the Russian Federation. This is associated with low population density and a weak economic activity in areas which are remote from cities. For the decentralized energy supply systems are quite common case of "harp" power failure, which is caused by, in the first instance, unreliable energy resources supplies. This   indicates the low energy security of a region. Moreover, in order to ensure energy for the population of remote areas diesel power plants are used the most often. This has a very negative impact on the environment [5, 6].

The most promising solution to ensure energy security of regions and to comply with ecological compatibility requirements is a development and commissioning of innovative technologies in the field of energy generation, based on renewable sources of energy (RES) [1, 2, 7, 8].

Russia, similar to other large countries, is fertile in renewable energy sources [10]. Almost every subject of the Russian Federation has 2 or 3 types of resources which are suitable to use. This fact opens courses of development for energy of the future. The priority development of RES has become a significant element of public technical policy in the field of energy in many countries. Production and accumulation of renewable energy will become the most rapidly growing segment of energy market in the next 20 years. According to projections, the world turnover of this market will amount to 198.1 billion dollars by 2015 [4, 5, 6, 9].

Important incentives for transition to RES are benefits provided by the state. In the case of Russia, they are stated in the “Electricity Law” (Federal Energy Act). According to this law the Government of the Russian Federation [6]:

- Provides support for the use of renewable sources of energy and realize stimulation of use of energy efficient technologies in accordance with the budgetary legislation.
- Approves the criteria for the provision of subsidies from the federal budget in order to compensate for the cost of technological connection of power generating facilities with installed potential, which is not more than 25 MW, recognized functioning on the basis of renewable sources of energy.
- Defines the mechanism for promoting the use of renewable energy through the sale of electrical energy on the electricity wholesale market, produced by qualified electricity generating facilities functioning on their basis.

Despite the existence of legislative support, the share of renewable energy sources for electricity production less than 1 % in Russia at present, that is substantially lower than figures of industrial countries. If electricity production is considered as an economic system, then one of the reasons for the current situation is a weak understanding of the RES innovative potential magnitude and the lack of resources coordination for its implementation.

As is well known, in any economic system development of innovative potential plays a significant role. Innovative potential is a factor, providing an economic system growth due to innovations. In this case, innovations constitute a system of activities in research, development, exploitation and depletion of productive-economic and socio-organizational potential underlying innovations, which serves as the innovation basis [3, 6, 8, 9].

The innovative potential is defined by the complex of material, technical, personnel, financial and other types of resources, which can be used for the implementation of innovative activities. Besides, the innovative potential is a characteristic degree of region readiness to introduce innovations and includes a set of opportunities for the region to implement the innovation activity.

The structure of the innovative potential includes three components: a resource one, a functional and an efficient one. The resource component of the innovative potential describes promising possibilities of using specific types of resources in accordance with forecast expectations. The functional component includes an informational, infrastructural, managerial and organizational constituents, which determine the ability of the system to attract resources for the creation and dissemination of innovations. Furthermore, it is responsible for the production of innovative product and the resumption of the innovation process cycle. The efficient component reflects the net result of the implementation existing means (in the form of a new product, obtained from the realization of the innovation process). It is also the target feature of the innovative potential. The close relationship between resource, functional and effective components of innovation potential determine the need to identify their optimum relationship [4, 7, 8].

Further, the question about evaluation of the innovation potential for geothermal technology in the Krasnodar region is considered in the article. The geothermal technology refers to renewable sources of energy and represents developing of energy contained in hot rocks, high temperature of which is supported by depth conductive thermal flow.

The main characteristic of hot dry rock geothermal energy is geothermal gradient, reflecting the increase in temperature of rocks with respect to increasing depth in the Earth's interior. On the territory of the Russian Federation, this value varies from 0.39^0C/100m to 6.86^0C/ 100m, which is sufficient to obtain rocks with temperature 100^0C between 3500 meters and 4500 meters depth. Due to such an enormous heat potential it is possible to supply every house in areas with decentralized energy with electricity using the geothermal energy.

At present, construction of geothermal binary cycle plants is in progress, that is low-boiling working body in a circuit with a turbine is used for electricity generation. This way of a heat extraction from the Earth has a number of shortcomings: contamination of the heat-carrier, the need for an underground explosion and the high cost of the drilling and provision of the necessary facilities for more the one drillholes. Hot dry rock geothermal technology is deprived of given drawbacks. However, in comparison with geothermal power stations (GeoTPS) it has a lower surface of heat exchange, and, consequently, less installed potential. Additionally, the construction of petrothermal power station (PetroTPS) may be in any terrain regardless of groundwater availability.

Realization of the innovative potential of hot dry rock geothermal technology makes it possible to solve the following tasks:

- to enhance the reliability of autonomous power systems;
- to reduce harmful emissions into the environment from fuel and energy complex;
- to accelerate economic growth in sectors of the economy related to the RES;
- to ensure the availability of heat and electricity for people from remote areas;
- to release fuel energy resources.

The considered hot dry rock geothermal technology implies the construction of PetroTPS with installed capacity of 1000 KW at the territory of the Krasnodar region, which would be supported in both the private and public order. PetroTPS has a year-round operation mode and stops only for regular overhauls, for this period it is expected to use the available diesel station.

2 Classification of methods for evaluating innovative potential

In the modern economic literature, there is no unified approach to assessment of the innovative potential. In less detail all considered methods for assessing potential can be systematized in groups in accordance with the three approaches: a resource one, a structural and an efficient one.

Table 1 provides a systematization of considered methods for evaluating innovative potential is given with indication of the fundamental framework for the assessment.

Table 1: Systematization of methods for assessing innovative potential

	Resource-based approach	**Structural approach**	**Efficient approach**
Criteria	The level of financial sustainability	The analysis of constituents: a resource one, an internal and an efficient one.	Indicators of efficiency of resources use
	Sufficiency of financial and economic resources	The analysis of structure of the funding sources	An input of balanced performance indicators
	The assessment of dominant resource components	The structure of indicators forming an innovative potential	An integrated assessment of innovative potential

Source: Own results

The resource-based approach to evaluating of innovative potential involves analysis of the adequacy of resources determining potential for innovative activities. In many scientific works the financial resource is contemplated as a key one, still the analysis of only financial sources does not allow to evaluate the other types of resources, because only the availability of opportunities for investments does not determine the ability to build up an innovative potential in the region [5, 6, 8].

The structural approach that is the most frequently encountered in the scientific literature is based on calculating indicators of structural components of innovative potential and the evaluation of their changes. A set of structural components (technological, manufacturing, personnel, etc.) is segregated and then a set of comparative indicators of their change is assembled. An advantage of this approach is the universality, complexity and the ability to take into account key performance indicators of a specific region [1, 6, 9].

The productive approach consists in obtaining assessments about an attainment of planned targets as a result of realization of the innovative potential. A special feature of this approach is the orientation toward the achievement of performance indicators for innovation activities in the region and development of innovative potential. One disadvantage of this approach is the difficulty to determine what factors and to what extent have influenced on the use of innovative potential.

In order to evaluate the innovative potential of hot dry rock geothermal technology it is proposed to apply an integrated methodology, which is based on the strategic planning and forecasting the results of innovation activity. A step-by-step diagram of determination the innovative potential is shown in Table 2.

Table 2: Procedures (a 5-step process) for evaluating the innovative potential

Defining the objective of an innovation strategy (an implementation of the innovative potential through creating high-tech products and services)
Execution of SWOT analysis and evaluation factors and phenomena that affect the implementation innovative potential. Identifying internal and external factors contributing or inhibiting to the achievement of strategic objectives
Defining the gears for the implementation of the innovation strategy
Indicators of assessment the achievement of objectives (payback period of innovation, specific weight of innovation products in total volume product output)
Forecasting results of the implementation of the innovation strategy

Source: Own results

3 Assessment of innovative potential of hot dry rock geothermal technology for the Krasnodar region

Electricity supply of the Krasnodar region consumers is provided by own sources only for 34%, approximately 66% of electricity comes from neighboring regions. The bulk of the heat energy production is supplied by boilers. The average level of boilers deterioration is 67 %, in the individual municipal entities it reaches 93% [6]. Consequently, electrical and thermal energy produced by hot dry rock geothermal technology will be in high demand in the market because of a lower price.

Table 3: Technical and economic indicators of PetroTPS for the Krasnodar region

Indicators	Values
The installed electrical power, MW	1
The installed thermal power, MW	2.22
Investments, million roubles.	164.85
Total annual costs, million roubles.	11.097
Cost of heat energy released to consumers, rub. /Gcal	460.28
Cost of electricity released to consumer, kopecks /kwh	62 ,3

Source: Own results

Technology part of the project at the initial stage is determined to a large degree by drilling technology. Out of all examined boring tools a drilling rig BC-

01 developed by Russian scientists has proved to be the most suitable. The modern drilling rig BC-01 allows to reduce the time of drilling (when speed of work of the rig is 30 m/h , time needed for drilling of two 10 km depth wells amounts approximately 1 months) to retrench the cost of establishing a Hot dry rock geothermal circulation system; to reduce the cost of electricity and heat received at Hot dry rock geothermal stations. The calculation of technical and economic indicators for PetroTPS is listed in Table 3.

Comparative evaluation of competitiveness parameters for Hot dry rock geothermal technology is shown in table 4.

Table 4: Comparative assessment of competitiveness indicators for PetroTPS in the Krasnodar region

Indicators	Technology Solutions	
	Hot dry rock geothermal plant	Diesel power plant
Parametric		
- plant-use factor, %	0.75	0.8
- The number of working hours of power plants in a year, h	6570	7008
- Useful life, years	30	25
Economic		
- Capital investment, million roubles. /1 MW of installed potential	164.85	10.2
-Payback period, years	5, 17	3
- Cost of electrical energy, rub. /kwh	0.62	9

Source: Own results

Our calculations of the integral competitiveness indicator yield that technology solution for utilization of heat of the Earth is more competitive in the Krasnodar region than technological solution applied in diesel systems, which means that the construction of hot dry rock geothermal plants in Krasnodar region is feasible and cost-effective.

According to the evaluation method of innovative potential considered above the basic goals indicators have been determined. They are the payback period of innovation and the specific weight of innovation production in the total volume.

According to table 4 the payback period of construction PetroTPS in the Krasnodar region is 5 years and 2 months. The specific weight of innovation production in the total volume is determined from the calculation of the proportion of electrical and thermal energy generated through the use of alternative sources of energy. Without taking into account hydroplant with capacity more than 25 MW [it is approximately 0.9% in 2013 year] the relative weight of the heat energy, received from RES, is approximately 3%. At present extent of RES use in the energy supply of the Krasnodar region is not greater than 2% [6].

Forecast outcomes from introduction of Hot dry rock geothermal technology in the Krasnodar region:

- A solution to the problem with shortage of energy resources and the high dependence of the province on energy prices
- Supplying consumers with an uninterrupted power supply
- Cost reduction of electrical and thermal energy [gaining of profit for energy companies]
- Releasing of fuel resources and, accordingly, reducing of specific fuel consumption by the population, which at the moment is approximately 1.24, tons of fuel equivalent [tfe] /per person
- Positive environmental effect
- On the expiry of the payback period, it is possible that the fare for electrical and thermal energy will be below than the established fare for the region.

4 Main conclusions

Currently, geothermal technologies are one of the most promising areas of developing of renewable energy in the world as well as in the Russian Federation where they are gaining wider recognition and use. There are technologies of hot dry rock geothermal energy that constitute one of the most important aspects of geothermal technologies. This sub-section of geothermal technologies represents technologies of energy development, contained in hot rocks, which is a new and promising method of using the renewable sources of energy.

Our paper evaluated the hot dry rock geothermal technology innovative potential for the Krasnodar region in Southern Russia. Based on the comprehensive estimation procedure of the Krasnodar region’s resources, their structure and compiling of performance indicators, estimated figures of hot dry rock geothermal technology innovative potential for the Krasnodar region were listed and evaluated.

The results of our study provide an opportunity to foster the development of hot dry rock geothermal energy both in Krasnodar regions and in various regions in the world as an important factor of the economy modernization, which is associated with the development of innovative industries, a new job places creation, an improvement of social conditions and environment.

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