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Prospects for Development of Geothermal Energy in Lviv Region

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Abstract

The data of geological exploration works carried out in Lviv region allow us to speak about the significant energy potential of geothermal waters in this region. At present, six bore-wells have been discovered in which the temperature of geothermal waters reaches 120^{o}C at a depth of more than 3000 m. However, today the energy potential of geothermal waters of Lviv region is not used for both technical and economic reasons. This article, analyze the most common schemes for the use of geothermal resources based on the experience of countries with developed geothermal energy For geothermal systems with parameters typical of Lviv region, the greatest effect can be achieved by using doublet systems, which consist of two wells: suction and injection, and the resulting heat energy can be used to heat a wide group of consumers.

Keywords: geothermal energy; geothermal waters; energy potential; doublet type systems; heat supply system.

1. Introduction

The difficult situation in Ukraine's energy sector is forcing more and more people to turn to alternative energy sources. According to the Energy Strategy of Ukraine, the share of renewable energy sources in the structure of electricity production by 2025 should be 13% [1]. It should be noted that the first place among renewable energy sources in Ukraine is occupied by solar energy, and it can be used to generate both electricity and heat [2], [3]. In recent years, wind energy has been increasingly used in Ukraine to generate electricity. High-power windmills are created, the quantity and quality of such engines grows annually, and serial production is established. However, as of 2021 in Ukraine, solar power plants have the largest capacity, which is 6351 MW, while the capacity of wind farms is 1593 MW. Biomass is an important component of renewable energy sources in Ukraine. Wastes from the woodworking industry, agriculture, and household waste are suitable for the production of artificial gases, the use of which allows reducing or avoiding the consumption of natural gas [4], [5]. Another area of renewable energy is the use of geothermal energy of the Earth's interior. The main advantage of geothermal energy, compared to solar or wind energy, is that this energy source can be used to produce heat or electricity, regardless of time of day, seasonal fluctuations or climate change [6]. At present, Ukraine has signed memoranda with foreign countries, in particular, China and Iceland, on cooperation in the field of geothermal energy and research of geothermal potential of Ukraine. However, the development of geothermal energy in Ukraine is carried out only at the research and industrial stage. As the Energy Strategy of Ukraine envisages that as of 2025 the use of geothermal energy will be equivalent to 1 million tons oil equivalent, and by 2030 will increase to 1.5 million tons oil equivalent, and will be 1.6% of total energy consumption [1], the development of this energy source is relevant. Indisputable factors in the development of geothermal energy sources are the growing role of renewable energy, reducing fossil fuel reserves, Ukraine's dependence on supplies of coal, natural gas and petroleum products from abroad, as well as reducing the negative impact on the environment.

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2. Aim of work

The aim of the work is to assess the prospects for the use of energy potential of geothermal waters of Lviv region and conduct a comparative description of the feasibility of using different schemes of heat use of geothermal waters with parameters typical of geothermal waters of the region.

3. Analysis of recent research

Geothermal energy sources are classified according to various parameters, the main of which are the depth of heat generation and the method of using geothermal energy. Depending on the depth of heat generation, geothermal systems are divided into deep (high-potential) and surface (low-potential) [6], [7].

High-potential geothermal energy of deep systems is obtained from thermal waters, which are located at a depth of 3000 to 5000 m and have a temperature of up to 300 °C. Thermal waters of such systems are characterized by stability of the regime, relative ease of extraction and large areas of distribution, which allows the use of these waters in heat supply systems for heat generation (geothermal water with a temperature of 40 to 100–150 °C) and electricity generation (geothermal water with a temperature 150–300 °C). In such cases, water from aquifers or fault zones is pumped to the surface where its energy potential is used and pumped back into the aquifer. Obtaining electricity from geothermal sources that have relatively low temperatures of 90–200 °C is associated with significant technical difficulties, primarily due to the unacceptably large size of turbines operating in the vacuum zone. In such cases, binary (double-circuit) installations with low-boiling working bodies (for example, freon or isobutane) are used, in which the classical Rankine cycle is realized. However, the equipment of such installations remains too expensive.

Sources of low-potential geothermal energy of surface systems can be groundwater with a low temperature of 20-60^{o}C or soil surface layers up to 400 m deep. To select geothermal energy, ground heat exchangers are used, which can be vertical with a depth of 400 m or horizontal with a depth of laying up to 10 m. Low-potential geothermal energy can be used only indirectly, because it is first necessary to increase the temperature of the coolant in heat exchangers of different types. The heat obtained in heat exchangers is used in local and district heating networks, in heating and cooling systems of buildings and for drying agricultural products. Heated water can also be used in industrial facilities, such as leather production, greenhouses or commercial fish farming.

In some cases, geothermal energy is taken at depths of 400–1000 m and at temperatures above 60 °C. In this case, geothermal systems are called medium depth systems.

Decisive factors in the exploration, development and operation of geothermal energy sources are a clear definition of the nature and characteristics of the system being developed. Decisions are made on the basis of analysis of geological and geophysical information, temperature, pressure, and chemical composition of formation fluids. In addition, decisions on how to use geothermal energy should be based on the experience of countries where such technologies are already operating successfully. Today, the world leader in the use of geothermal energy is the United States, where the capacity of geothermal plants is 3.6 GW. The top five countries with the highest level of geothermal energy use are the Philippines, Indonesia, Turkey and New Zealand.

Ukraine has significant potential for geothermal energy. Potential geothermal resources approved by the Ministry of Ecology and Natural Resources of Ukraine are 27.3 million m^3 per day of thermalenergy water, and their thermal potential, taking into account the characteristics of thermal waters as a heat carrier – 84 million Gcal / year. The annual technically achievable energy potential of geothermal energy in Ukraine is equivalent to 12 million tons of conventional fuel, and its use saves about 10 billion m3 of natural gas. The main indicators of geothermal resources of the most promising regions of Ukraine are given in Table 1.

Table 1. Forecast resources of geothermal energy in Ukraine for energy [6].

Area, deposit	Depth interval, km	The average temperature of rocks, °C	Area of deposits, km^2	Geological reserves of thermal energy	Possible capacity of GeoTES, thousand MW
Zakarpattia	3 – 6	210 – 250	50 – 130	8.5	5.8
Prykarpattia	4 – 7	200	600	6.7	4.6
Crimea	4 – 7	200 – 220	300 – 500	15.3	10.5
Eastern Ukrainian regions	5 – 7	185 – 217	660 – 2800	70.0	48.0
Total				100	70

Areas of priority development of geothermal resources are the Kerch Peninsula (Crimea), Lviv and Zakarpattia regions, some deposits in Kharkiv, Poltava and Donetsk regions (see Table 2). The Carpathian geothermal region is characterized by a high geothermal gradient and correspondingly high temperatures of rocks compared to other regions of Ukraine. The temperature of rocks in wells drilled in the Carpathians at a depth of 4 km reaches 210 °C. According to the Institute of Renewable Energy of NASU, the total technically achievable energy potential of unconventional and renewable energy sources in the Carpathian region is 5.16 million tons of conventional fuel, including the potential of geothermal energy – 597 thousand tons of conventional fuel.

Table 2. Predicted thermalenergy potential of geothermal energy of thermal deposits in promising regions [8].

	Transcarpathian region	Ivano-Frankivsk region	Lviv region	Poltava region	Sumy region	Kharkiv region	Chernivtsi region	Chernihiv region
The expected temperature of the coolant at the outlet, °C	85 – 90	65 – 90	90 – 130	120 – 130	80 – 100	85	77	70 – 100
Technically available equivalent savings of natural gas, billion, m^3	0.4	0.3	0.4	0.3	0.2	0.3	0.1	0.2

As can be seen from Table 2, Lviv region has significant geothermal energy potential. As in other cities of Ukraine, data on geothermal resources are usually obtained from the study of wells during oil and gas exploration. Thus, the chief hydrogeologist of SE "Zakhidukrgeologiya" Petro Chaly noted that during the search for oil and gas within the Lviv region, 5 – 6 wells with high temperatures geothermal waters were found and confirmed. They are located at a depth of 3000 meters and have an isotherm of 120 degrees. Also, conclusions about the geothermal waters of Lviv region can be made on the basis of exploration work carried out by SE "Zakhidukrgeologiya". In particular, it can be argued that within the Mostyska district of Lviv region there is groundwater with a temperature of 90 – 100 °C at a depth of more than 3000 m, and the geothermal gradient in the Lviv region is 2 – 3 °C per 100 m depth. The main indicators of canned wells on the basis of the data of SE "Zakhidukrgeologiya" are given in Table 3.

Table 3. The main indicators of wells in Mostyska district of Lviv region.

Number of bore-well	Depth of the bore-well, m	The temperature in the mouth of the bore-well	Debit, l/s	Water mineralization, mg/l	Type of water by mineralization	Ph
1	3358	49.6	2.8	6467	Hydrocarbonate-sodium	8.5
2	3616	90 – 95	9.8	48607	Chloride-Calcium	6.7
3	3550	128	0.35	6760	Chloride-Calcium	6.0

According to the international classification of geothermal energy sources, geothermal waters of Lviv region are classified as low-temperature, as the temperature of the aquifer at a depth of 1000 m is below 150 °C. Geothermal water with a temperature below 150 °C is not appropriate for being used in the production of electricity, namely in the development of large geothermal thermal power plants with a unit capacity of 10 – 50 MW. One of the important factors of this decision is the economic efficiency of GeoTES. Thus, the construction of power plants and drilling wells cost about 2 – 5 million euros per 1 MW of electric power, while the average cost of energy is 0.04 – 0.10 euros per kWh. In addition, the thermal waters of Lviv region have a high mineralization of more than 30 g/dm^3, as well as high hydrogen sulfide content.

Therefore, it is expedient to consider options for using low-temperature geothermal waters of Lviv region for heat generation, in particular for heat supply systems of settlements.

4. Research results

Depending on the mineralization and chemical composition of geothermal waters, there are three ways to use them in heat supply systems: with preliminary water treatment, with the use of intermediate heat exchangers and with direct supply of thermal water to the heat supply system. Schemes of geothermal heat supply systems also depend on the temperature of geothermal water, the nature of possible consumption of geothermal heat, conditions of discharge of waste geothermal water, availability of drinking water source, mutual location of thermal intake, type of consumer and distance between source of drinking water and discharge place [9]. According to these indicators, there are two main schemes of geothermal water connection to heating systems: open heat supply system with dependent connection of the heating system, closed heat supply system with independent connection of the heating system.

In an open heat supply system with dependent connection of the heating system, the heat of geothermal waters is used directly. This system has the simplest design, operating conditions and capital costs, as it does not require an intermediate heat exchanger, allows you to fully use the temperature potential of geothermal water and save tap water. However, the direct use of geothermal water in the form of hot water is possible only if its chemical composition meets the sanitary requirements for drinking water.

If the quality of geothermal water does not meet the sanitary requirements for drinking water, then there are two options for its use: either its preliminary treatment, or the use of intermediate heat exchangers. Preliminary treatment of geothermal water includes processes of chemical purification of water to reduce its corrosion activity and removal of substances that cause the formation of scale on the inner surfaces of pipelines and heaters. In this case, aggressive gases (O2, SO2, etc.), salts (CaSO4, SaSO3, etc.) are removed from geothermal water, or corrosion inhibitors (e.g. silicate sodium) and anti-scale agents (e.g. sodium hexametaphosphate) are introduced. Purified geothermal water can be used directly in the heat supply system.

Closed heat supply system with independent connection of the heating system is used at high aggressiveness and salinity of geothermal waters. In this case, intermediate heat exchangers are installed between geothermal water and heat carriers of heating and hot water supply systems, the constructions of which allow heating the heat carrier due to the heat of geothermal waters. In this case, the heat supply system consists of two closed circuits: the geothermal water circuit and the heat consumer circuit.

As the geothermal waters of the Lviv basin are highly mineralized, their direct use in heat supply systems is impossible. For wide introduction of geothermal systems it is necessary to use modern technologies of purification of mineralized geothermal waters or to apply schemes of heat supply with intermediate heat exchangers. The optimal solution for the use of geothermal waters, which are explored in the Lviv region, will be a system of the type "doublet" (Fig. 1). In this scheme, geothermal water from deep aquifers is transported to the earth's surface through a receiving (production) well and fed to the peak boiler room for heating, and then to heat exchangers of heating and hot water systems to heat their coolants. After giving off its heat, geothermal water is pumped back into aquifers through an injection well. Thus, the system of the "doublet" type allows creating the closed cycle of artificial circulation of thermal waters at its use for needs of systems of heat supply. Two wells from the depths of carbon deposits can provide from 0.4 to 4.5 MW of thermal energy.

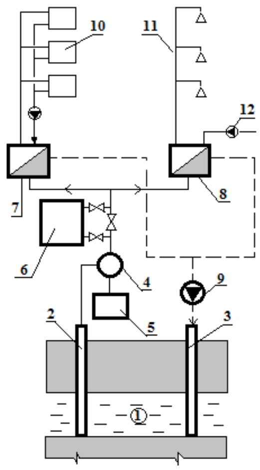

Fig. 1. Geothermal heat supply scheme with doublet system:
1 – flow of geothermal waters; 2 – receiving well; 3 – injection well; 4 – gas sludge cleaner; 5 – system of utilization of gases and sludges; 6 – peak boiler room; 7 – heat exchanger of the heating system; 8 – heat exchanger of hot water supply system; 9 – discharge pump; 10 – heating system; 11 – hot water supply system; 12 – booster pump of cold water supply system.

The peak boiler house in this scheme is switched on when the outside air temperature decreases, when the heat energy potential of geothermal water is insufficient to cover the heat load of consumers. With the help of the peak boiler house, geothermal water is heated to the required temperature according to the temperature schedule and supplied to intermediate heat exchangers of heat energy consumers. When the outside air temperature rises, the peak boiler room is switched off and the geothermal water is supplied directly to the intermediate heat exchangers of the consumers.

Figure 2 shows the dependence of the amount of thermal energy that can be obtained during the year from 1 km^2 of surface depending on the formation temperature, which in turn depends on the depth of wells and the local temperature gradient. For such well parameters as reservoir diameter of 500 mm, energy recovery factor 10% and well operation period of 50 years, it was determined that for a 1 MW installation during its year-round operation the drilling site area should be approximately 2 km^2.

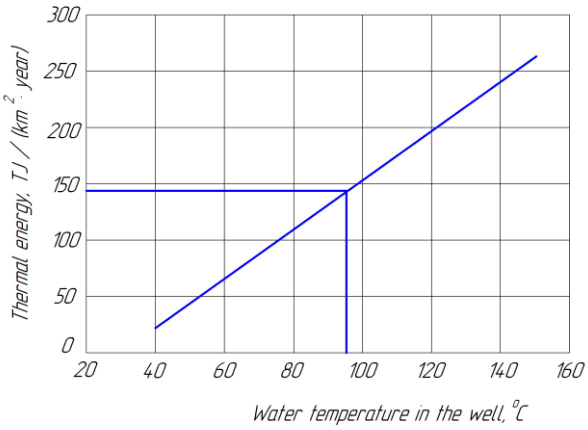

Fig.2. Dependence of the amount of thermal energy that can be obtained from 1 km^2 of surface depending on the formation temperature

When developing geothermal heat supply systems of Lviv region, it is necessary to ensure the maximum value of the coefficient of efficiency of thermal water intake, which is defined as:

$$\eta_{geo} = \frac{Q_{actual\ annual}}{Q_{\max\ annual}}, \qquad (1)$$

where $Q_{actual\ annual}$ is the thermal potential of the bore-well, which is actually used during the year; $Q_{\max\ annual}$ is the maximum amount of heat that can be obtained during the year-round operation of the bore-well at its estimated debit.

The value of the coefficient of efficiency of the use of thermal water intake η_{geo} depends on the type of consumer of thermal energy and is within the following limits: for the heating system 0.05 – 0.34; for the ventilation system 0.15 – 0.45; for hot water supply system 0.7 – 0.92. To achieve high values of the efficiency of the use of thermal water intake η_{geo} it is advisable to use combined geothermal heating systems, in which heating systems are combined with consumers who use geothermal heat all year round.

In the Lviv region there are a large number of canned gas, oil and oil and gas wells that can be used for geothermal energy production. The use of geothermal well resources in the Western region is also economically feasible given the existing production base, as there is a possibility to reorient existing exploration and oil and gas companies, which are operating at incomplete capacity due to depletion of exploited fields. In addition, to stimulate the development of geothermal energy in Ukraine, it is necessary to make changes to the current regulatory framework, which currently provides for double taxation of such systems. Thus, for the use of groundwater for geothermal energy purposes, it is necessary to obtain permits under both water legislation and subsoil legislation [10]. It should also be noted that a well-established regulatory framework will protect the interests of investors, establish clear rules of use, guarantee the rights of users, determine pricing mechanisms, and regulate tax and environmental issues.

5. Conclusion

This article analyzes the feasibility of using the thermal potential of geothermal waters of Lviv region. At the initial stage of development of this renewable energy source, it is advisable to use a closed heating system with independent connection of the heating system with installations of the "doublet" type. Such systems allow providing thermal energy to the heating and hot water supply system at the expense of geothermal waters of Lviv region. Due to the high mineralization and high corrosion activity of geothermal waters, it is necessary to resolve the issue of their pre-treatment before use in heat supply systems. In addition, to increase the efficiency of thermal water intake, it is advisable to use combined geothermal heating systems, in which heating systems are combined with consumers who use geothermal heat all year round. The review is only preliminary, because for informed decision-making it is necessary to have a much larger and more reliable body of information, including data for all operating and canned wells in the Lviv region. Therefore, further research should focus on temperature, species reservoir rocks and their permeability, pressure, flow rate and chemical composition of geothermal waters.

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Перспективи розвитку геотермальної енергетики Львівщини

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Анотація

Дані геологорозвідувальних робіт, які проводилися у Львівській області, дозволяють говорити про значний енергетичний потенціал геотермальних вод у цьому регіоні. На цей час виявлено 6 свердловин, в яких на глибині понад 3000 м температура геотермальних вод досягає 120°C. Проте на сьогоднішній день енергетичний потенціал геотермальних вод Львівщини не використовується як з технічних так і економічних причин. В даній статті, опираючись на досвід країн з розвинутою геотермальною енергетикою, зроблено аналіз найпоширеніших схем використання геотермальних ресурсів. Для геотермальних систем з параметрами, які характерні Львівщині, найбільшого ефекту можна досягнути при використанні систем типу «дублет», які складаються з двох свердловин: всмоктуючої та нагнітальної, а отриману теплову енергію використовувати для теплопостачання широкої групи споживачів.

Ключові слова: геотермальна енергетика; геотермальні води; енергетичний потенціал; системи типу «дублет»; система теплопостачання.