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RISK CONSIDERATIONS IN THE STUDY OF INVESTMENT ATTRACTIVENESS OF GEOTHERMAL ENERGY OBJECTS

(Представлено членом редакційної колегії д-ром геол. наук, проф. В.А. Михайловим)

Background. *The article explores a comprehensive approach to risk assessment affecting the investment attractiveness of projects in the field of geothermal energy. This involves the combination of various objective prerequisites, opportunities, and limitations arising during the process of attracting investments in the development of geothermal energy, which can create conditions for the rational and effective use of available resources (natural, human, informational, technological, capital, etc.). Special attention is given to local, regional, and techno-environmental risk factors.*

Methods. *The study utilizes methods that combine financial and economic analysis, risk assessment, technical expertise, examination of the regulatory and legal environment, and market conditions. The core of the research involves the calculation of financial indicators such as Net Present Value (NPV), Internal Rate of Return (IRR), Discounted Cash Flows (DCF), and payback period, which help assess the potential profitability of a project. The technical assessment includes environmental expertise and an analysis of the sustainability of geothermal resource use, particularly the depth of deposits and temperature potential. At the same time, it is crucial to study the regulatory framework concerning subsoil use and tariff regulation. This approach ensures the validity of investment decisions and minimizes risks.*

Results. *During the study, the authors proposed an improved method for assessing investment risks in geothermal energy, taking into account a comprehensive analysis of the interconnection between local, regional, and techno-environmental factors. A method for ranking risks based on their impact on project effectiveness was also developed, along with recommendations for their minimization. The proposed methods improve the accuracy of forecasting and the justification of investment decisions in this field.*

Conclusions. *It is analytically substantiated that the Levelized Cost of Energy (LCOE) with risk adjustments allows for accounting for all possible losses and uncertainties, just as NPV evaluates financial attractiveness and helps determine whether investing is worthwhile. It is also determined that considering regional and local risks provides a more realistic assessment of investing in geothermal energy. Promising areas for future research in this field include the development of more precise risk assessment models using modern digital technologies, such as machine learning and big data. Moreover, improving methods of environmental monitoring and developing effective strategies for minimizing technogenic risks is important. Research on the impact of climate change on the stability of geothermal resources, as well as improving the legislative and regulatory framework to stimulate investment in the sector, can contribute to the sustainable development of geothermal energy.*

Keywords: *geothermal energy, subsoil use, investment attractiveness, risks, renewable energy, environmental safety, risk management, development prospects.*

Background

Fundamental and applied works on determining the investment attractiveness of renewable energy facilities, including geothermal energy as a component of it, have been carried out both in Ukraine and worldwide for a long time. Theories of investment and the evaluation of the effectiveness of investment projects are dedicated to the works of authors (Tatarenko, & Poruchnyk, 2000; Suprun, & Yukhymchuk, 2009; Chorna, Smirnova, & Buhrimenko, 2017; Karpov, & Horbachenko, 2013). The analysis of strategic investment directions in renewable energy in the context of national economic development has been conducted in the works (Drach, 2023; Sivitska, 2014; Dyachuk et al., 2019). Structural analysis of the costs for implementing a wind power plant investment project is presented in the works (Hlushchenko, 2023; Ivanchhenko, & Tuchynskyi 2007; Stehly, Tyler, Duffy, & Patrick, 2021). Separate studies focus on modeling and analyzing the cost of electricity from renewable sources (Tochenyi, Reztsov, & Tuchynskyi, 2010). Research on the investment attractiveness of mineral resources and the evaluation of risks has been presented in the works of many authors [Mykhailov et al., 2023; Rudko, Karli, & Tolkunov, 2022; Kumar, 2022; Lukawski, Silverman, & Tester, 2016; Savchuk, 2024; Zurian, Levchenko, & Pidtilok, 2015).

Research on the efficiency of using the thermal potential of the environment and the upper layers of the Earth's crust in Ukraine is described in the works (Morozov, 2019). Active research is underway to study the physical features and energy efficiency of using water from underground horizons, with a focus on technical, economic, and ecological analysis of implementing geothermal systems of this type (Zurian, 2023a; Zurian, 2023b).

The results of recent publications confirm the promising direction of research into the technical, economic efficiency, and profitability of implementing geothermal energy projects, including the use of low-potential thermal energy from the upper layers of the Earth for heating, cooling, hot water supply, and meeting technological needs of consumers. At the same time, the problem of economic-mathematical modeling for assessing the economic attractiveness of heat supply technologies based on the use of geothermal energy, taking into account all possible risks of using this type of renewable energy, remains relevant.

Problem Statement. The analysis of scientific publications and practical experience in the application of methods for evaluating investment efficiency, taking into account risks, will contribute to enhancing the level of scientific research on the prospects of geothermal energy development and the investment attractiveness of relevant projects.

Results

The investment attractiveness of geothermal energy objects is the combination of various objective preconditions, opportunities, and limitations that arise in the process of attracting investments in the development of geothermal energy, which can create conditions for the rational and effective use of available resources (natural resources, human resources, information resources, technologies, capital, etc.). The main criteria for the investment attractiveness of geothermal energy objects should be the values of Net Present Value (NPV), Internal Rate of Return (IRR), Capital Expenditure volumes (CAPEX), payback period, and the levelized cost of energy (LCOE). Corresponding calculations are carried out taking into account the current and forecast market conditions, the characteristics of the investment regime, as well as geological, technological, ecological, economic, and political risks (Fig. 1).

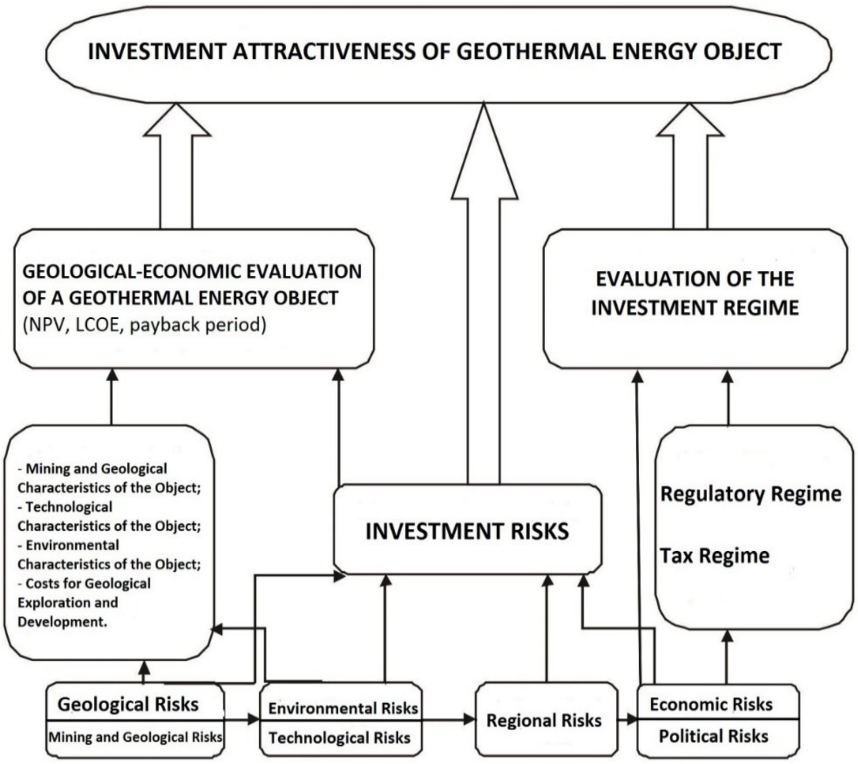

Fig. 1. Investment Attractiveness of Geothermal Energy Projects

It is proposed to conditionally divide the main factors of the investment attractiveness of geothermal energy objects into two major groups. Thus, the factors related directly to the underground water extraction objects for thermal energy purposes are local (geological, mining-geological, technological, techno-economic, and ecological), while those related to the region in which the implementation of the projects is planned are regional (regulatory, economic, geographical, and natural-geographical) (Table 1).

Before making a decision regarding the implementation of a geothermal energy project, the potential subsoil user attempts to analyze as much available information as possible (geological, economic, regulatory) in order to assess the level of investment potential and investment risk. Therefore, the issue of accounting for risks when studying the investment attractiveness of geothermal energy projects is the focus of this research.

Today, several traditional methods for calculating risks that affect the investment attractiveness of geothermal energy projects exist. These methods are based on economic, geological, technological, and environmental analysis. For example, the scenario analysis method (Shelikhov, & Masalska, 2015). Today, technological forecasting has become an essential tool for decision-making, at least at the strategic level for management bodies at all levels. However, besides decisions related to the development of the organization, scenario analysis can also be used to address issues related to the investment attractiveness of geothermal energy projects. For instance, this method allows for the consideration of different project development scenarios depending on changes in key risk factors (such as fluctuations in reservoir temperature, initial well flow rates, and electricity prices). For each scenario, possible financial outcomes and risk levels are assessed.

Another applicable method is the Monte Carlo method, which is used to model uncertainties by performing random trials multiple times within the defined parameters (geological, technological, economic). This allows for the estimation of the probability of achieving certain economic indicators (NPV, IRR). Using the sensitivity analysis method, one can determine which factors have the greatest impact on the project's effectiveness. This is done by changing the values of specific parameters (for example, extraction costs, electricity tariffs) and assessing their influence on financial results.

Table 1

The main factors of the investment attractiveness of geothermal energy objects

Factors Related to the Geothermal Energy Object	Factors Related to the Location of Project Implementation
Geological: - Features of the object's structure, composition of rocks, type and characteristics of the deposit, water volume, etc. **Mining-Geological:** - Depth of the water-bearing horizon, initial formation pressure and temperature, initial well flow rate and filtration parameters, operating depression, extraction coefficient, etc. **Technological:** - Chemical composition, presence of accompanying components, extraction and product preparation technologies, extraction coefficient of useful components, etc. **Techno-Economic:** - Methods and systems of operation, production cost, capital and operational expenses, profit size, profitability level of the object's operation, risk capital (cost of geological exploration works), etc. **Ecological:** - Economic value of areas being alienated, possible environmental consequences from breaching the integrity of subsoil, water regime, etc., and costs for minimizing the negative ecological impacts of the object's operation.	**Regulatory:** - Organizational and legal regime of subsoil use, its state (public) regulation, - Stability of the political system; stability and predictability of the state's investment policy, general and mining legislation, conditions under which investors can carry out exploration, development, and extraction of minerals (concessions, production-sharing agreements, joint ventures, service contracts), export rights for extracted products, etc. **Economic:** - Product price, demand and consumption levels in local and external markets, tax regime, availability of sales markets, level of competition, etc. **Natural-Geographical:** - Geographical, geomorphological, and climatic conditions of the area, type of terrain, availability of infrastructure (proximity to transport infrastructure, processing plants, communication routes, availability of electricity and water resources), availability of workforce, etc.

It is also possible to forecast and systematize the main risks (geological, techno-economic, environmental, political) and assess their potential impact on the investment attractiveness of the project using risk factor analysis. Among classic methods, the discounted cash flow method can be mentioned. Although this method is mostly used for evaluating the financial efficiency of a project, it can also be used for accounting for risks by adjusting the discount rate. The higher the level of risk, the higher the discount rate applied to adjust future cash flows.

Furthermore, considering that modern geothermal projects increasingly use GIS technologies and underground reservoir modeling for more accurate assessments of geological and hydrothermal risks, traditional methods place the main emphasis on financial calculations, geological analysis, and technological factors. However, today, with the development of digital technologies, machine learning, big data, and digital modeling methods are increasingly being applied to more accurately assess risks and the investment attractiveness of geothermal projects.

Each of the traditional methods for assessing risks in the field of geothermal energy has certain drawbacks. The general problems inherent in these approaches include a high degree of uncertainty in the initial data, limited consideration of interdependencies between risks, insufficient adaptation to changing conditions, high subjectivity of assessments, complexity in calculations and resource intensity, as well as inadequate consideration of environmental risks and the impact of an unstable regulatory environment.

Thus, none of the traditional methods are perfect. The best results are achieved through their combination and the use of modern digital technologies. To improve the accuracy of risk assessment, it is necessary to consider the multidimensional relationships between factors and to continuously update data in light of real changes in the geothermal energy sector.

Given the above, it can be argued that modern approaches to risk assessment in the field of geothermal energy should focus on improving forecasting accuracy, accounting for interrelationships between risks, and adapting to changing conditions. In our opinion, key methods that could improve risk assessment include:

1. ***The use of artificial intelligence and machine learning***. This approach allows for the analysis of large volumes of data to identify hidden dependencies between risk factors. Automatic training of models based on historical data on geothermal projects can enhance the accuracy of forecasting geological, technological, and financial risks. For example, neural network algorithms can predict the likelihood of seismic tremors, fluid leaks, or decreased well flow rates based on geological and hydrothermal data. Deep learning can help determine optimal field development parameters with minimal risks.

2. ***The use of geographic information systems (GIS) and reservoir digital modeling***. This approach allows the creation of detailed 3D models of geothermal systems for more accurate forecasting of reservoir behavior and visualization of risks associated with fluid movement, seismic processes, potential leaks, and other environmental threats. For example, GIS systems help combine geological, climatic, and economic data to create integrated risk maps, while underground reservoir modeling can predict the longevity of geothermal wells and potential operational problems.

3. ***The use of Bayesian networks for assessing complex risks***. This approach allows for considering the interrelationships between various risk factors (e.g., the dependence between changes in formation pressure and the risk of hot water breakthrough into other horizons), as well as performing dynamic updates to forecasts as new data arrives. For instance, Bayesian models can assess how changes in reservoir temperature will affect the longevity of wells and the economic feasibility of the project.

4. ***Integration of environmental and social factors into risk analysis***. This enables more accurate consideration of the impacts of geothermal projects on the environment and local communities, as well as the assessment of effects on the ecosystem.

The authors have proposed a comprehensive approach to assessing risks that impact the investment attractiveness of geothermal energy projects. Special attention is paid to local, regional, and techno-environmental risk factors. Local risks include geological (features of the object's structure, rock composition, resource volume, etc.), mining-geological (deposit depth, temperature regime, filtration parameters), technological (chemical composition, extraction technologies), techno-economic (production costs, profitability level), and environmental aspects (disruption of subsoil integrity, costs for minimizing environmental impacts).

Among regional factors, political (state regulation, stability of investment policy), economic (tax regime, competition level), and natural-geographical (infrastructure conditions, resource availability) factors are considered. Additionally, techno-environmental risks are analyzed, including the potential for thermal water leakage, contamination of aquifers, seismic risks, and ground surface deformations.

In the course of the study, the authors proposed an improved methodology for assessing investment risks in geothermal energy, which considers a comprehensive analysis of the interconnection between local, regional, and techno-environmental factors.

A generalized mathematical model of the economic attractiveness of geothermal energy projects is proposed, based on the discounted cash flow method, determination of production cost considering the life cycle of the energy installation, calculation of the normalized production price of energy products, and capital expenditure indicators, taking into account risk.

One of the most important indicators of the effectiveness of an investment project is the Net Present Value (NPV). This indicator represents the sum of all cash flows discounted to the present moment (as of the date of the investment project evaluation): The net present value is calculated using the formula.

The equation for calculating NPV considering risks is proposed to be written in the following form:

$$NPV = \sum_{t=0}^{n} \frac{S_t}{(1+i)^t}, \quad (1)$$

Where S_t – the net cash flow in period t, i.e., the sum of all revenues minus the sum of all expenses for that period; i – the discount rate for one period (usually a year).

Very often, the discount rate (NPV) is calculated using the NBU's (National Bank of Ukraine) discount rate. The NBU's discount rate ranged from 10 % to 25 % in 2022–2024. As of January 25, 2025, it stood at 14.5 % (National, 2024).

The authors suggest applying a risk premium to the discount rate depending on the probability of an unwanted loss/hazard occurring (Table 2).

Table 2

Risk premium to the discount rate based on the probability of unwanted loss/hazard occurrence

Risk	Risk Premium to Discount Rate (%)		
	Probability of Unwanted Loss/Hazard	Probability of Unwanted Loss/Hazard	Probability of Unwanted Loss/Hazard
	From 0 % to 30 %	From 30 % to 70 %	From 70 % to 100 %
Geological Risk	1 %–3 %	3 %–7 %	7 %–10 %
Mining-Geological Risks	1 %–3 %	3 %–7 %	7 %–10 %
Technological Risks	1 %–3 %	3 %–7 %	7 %–10 %
Economic Risks	1 %–3 %	3 %–7 %	7 %–10 %
Environmental Risks	1 %–3 %	3 %–7 %	7 %–10 %
Political Risks	1 %–3 %	3 %–7 %	7 %–10 %
Regional Risks	1 %–3 %	3 %–7 %	7 %–10 %

This table reflects the potential risk premium applied to the discount rate, depending on the probability (0% to 30%) of experiencing undesirable losses or hazards. The risk premium will vary based on the likelihood of each specific risk occurring, impacting the overall investment evaluation of geothermal energy projects. The actual risk premium values for each risk type should be filled in based on the project-specific risk assessment and factors.

In this article, it is proposed to account for the risk factor in the NPV calculation by adding a "total risk component" in addition to the NBU base interest rate, depending on the factors and evaluation criteria according to Tables 1 and 2.

To account for the risks associated with the implementation of geothermal energy projects, the authors propose calculating the risk premium added to the discount rate using the following equation:

$$r_{c.r.} = r_{ref} + r_{geo} + r_{\min} + r_{tech} + r_{ecom} + r_{enw} + r_{pol} + r_{reg}, \quad (2)$$

where: $r_{c.r.}$ – discount rate considering risk; r_{ref} – NBU base interest rate; r_{geo} – geological risk (probability of insufficient flow rate, temperature drop); r_{min} – mining-geological risks (pressure, depth, resource extraction); r_{tech} – technological risks (equipment efficiency, availability of supporting components); r_{econ} – economic risks (competition, energy prices, taxes); r_{env} – environmental risks (pollution, thermal water leakage, seismic risks); r_{pol} – political risks (regulatory changes, legislative stability); r_{reg} – regional risks (infrastructure remoteness, transportation costs).

Thus, the equation for calculating NPV considering risks is proposed to be written in the following form:

$$NPV = \sum_{t=0}^{n} \frac{S_t}{(1+(i+r_{c.r.})^t} \quad (3)$$

An important component of evaluating the investment attractiveness of geothermal energy projects is the calculation of the Levelized Cost of Energy (LCOE), which takes into account all key parameters.

$$LCOE = \frac{\sum_{t=0}^{n} \frac{C_t + O_t + R_t + E_t}{(1+r)^t}}{\sum_{t=0}^{n} \frac{E_t}{(1+r)^t}}, \quad (4)$$

where C_t – capital costs for construction and well drilling in year t; O_t – operational and technical costs in year t (maintenance, extraction, energy preparation); R_t – costs for risk management and environmental measures; E_t – amount of energy produced in year t; r – discount rate; n – total lifetime of the installation (years).

The discount rate is usually taken as the NBU (National Bank of Ukraine) rate.

An integrated risk factor coefficient R_f is also used, which includes risks that impact the economic attractiveness of the geothermal energy project. This indicator is used when considering risk in the normalized production price.

The corresponding equation, which accounts for risks in the normalized cost of energy production, looks like this:

$$LCOE^* = LCOE \times (1 + R_f), \quad (5)$$

where R_f – integrated risk factor coefficient:

$$R_f = \omega_1 R_{geo} + \omega_2 R_{\min} + \omega_3 R_{tech} + \omega_4 R_{ecom} + \\ + \omega R_{enw} + \omega_6 R_{pol} + \omega_7 R_{reg}, \quad (6)$$

Each of these components determines the risk by direction: R_{geo} – geological risk (probability of insufficient flow, temperature drop); R_{min} – mining-geological risks (pressure, depth, resource extraction); R_{tech} – technological risks (equipment efficiency, availability of supporting

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components); R_{econ} – economic risks (competition, energy prices, taxes); R_{env} – environmental risks (pollution, thermal water leakage, seismic risks); R_{pol} – political risks (regulatory changes, stability of legislation); R_{reg} – regional risks (distance of infrastructure, transport costs).

Table 3

Risk surcharge in the normalized cost of energy production depending on the probability of undesirable loss/threat occurrence

Risk	Risk Premium to Discount Rate (%)		
	Probability of Unwanted Loss/Hazard From 0 % to 30 %	Probability of Unwanted Loss/Hazard From 30 % to 70 %	Probability of Unwanted Loss/Hazard From 70 % to 100 %
Geological Risk	0,01–0,03	0,03–0,07	0,07–0,1
Mining-Geological Risks	0,01–0,03	0,03–0,07	0,07–0,1
Technological Risks	0,01–0,03	0,03–0,07	0,07–0,1
Economic Risks	0,01–0,03	0,03–0,07	0,07–0,1
Environmental Risks	0,01–0,03	0,03–0,07	0,07–0,1
Political Risks	0,01–0,03	0,03–0,07	0,07–0,1
Regional Risks	0,01–0,03	0,03–0,07	0,07–0,1

Each component is determined by the probability of the risk occurrence P_i and the possible economic impact I_i:

$$R_i = P_i \times I_i, \quad (7)$$

For example, if the probability of contamination of the aquifer Penv = 0.1, and the cost of the consequences (penalties, restoration) Ienv=5 million UAH, then:

$$R_{env} = 0.1 \times 5 = 0.5 \text{ million UAH}$$

The lifetime of the installation is modeled as a function of productivity reduction over time:

$$E_i = E_o \times e^{-\lambda t}, \quad (8)$$

where E_0 – initial capacity of the installation (MW); λ – coefficient of productivity reduction due to reservoir and equipment degradation.

The reduction in productivity affects capital expenditures and the need for modernization:

$$C_e = C_0 + C_{maint}(1 + \beta t), \quad (9)$$

where β – rate of increase in maintenance costs over time.

Thus, the investment efficiency can be evaluated through the Net Present Value (NPV), which is determined by the formula:

$$NPV = \sum_{t=0}^{n} \frac{(\mathrm{R_{evt}} - C_t - O_t - R_t)}{(1+r)^t}, \quad (10)$$

where C_t – capital expenditures for construction and well drilling in year t; O_t – operational and technical costs in year t (maintenance, extraction, energy preparation); R_t – costs for risk management and environmental measures; r – discount rate; n – total lifetime of the installation (years); R_{evt} – revenue from energy sales in year t:

$$R_{evt} = P_e \times E_t, \quad (11)$$

where P_e – price per 1 MWh.

The project can be considered investment-attractive if NPV>0.

The results of a comprehensive analysis of the investment attractiveness of geothermal energy projects, taking risks into account, should provide the potential resource user with the necessary information for making a decision regarding the feasibility of implementing the respective project. On the other hand, such studies are necessary for an adequate assessment of the development prospects of geothermal energy and for improving investment and regulatory frameworks, as well as for the development of relevant state policies.

Discussion and conclusions

The authors propose the category of investment attractiveness for geothermal energy projects. The factors affecting investment attractiveness are identified, which are directly related to the underground water extraction objects for thermal energy needs. These include local factors (geological, mining-geological, technological, techno-economic, and ecological) and those related to the region where the projects are to be implemented – regional factors (regulatory, economic, geographical, and natural-geographical).

The use of NPV and LCOE calculation methods, taking risks into account, is analytically justified for assessing the investment attractiveness of geothermal energy projects. It is proposed to use a risk premium to the discount rate when calculating the NPV of geothermal energy investment projects, depending on the probability of undesirable loss or danger, with possible values of this premium identified.

Considering regional and local risks provides a more realistic evaluation of investment in geothermal energy.

Further research perspectives include the development of more precise risk assessment models using modern digital technologies, including machine learning and big data. Moreover, improving methods of environmental monitoring and developing effective strategies for minimizing technogenic risks is crucial. The results of the evaluation of investment attractiveness of geothermal energy projects may be of interest not only to resource users but also to institutions and organizations studying the prospects for the development of this industry. Enhancing the regulatory and legal framework to stimulate investments in the geothermal energy sector should contribute to the sustainable development of the economy and strengthen energy security.

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ВРАХУВАННЯ РИЗИКУ ПРИ ДОСЛІДЖЕННІ ІНВЕСТИЦІЙНОЇ ПРИВАБЛИВОСТІ ОБ'ЄКТІВ ГЕОТЕРМАЛЬНОЇ ЕНЕРГЕТИКИ

Вступ. ***Розглянуто комплексний підхід до оцінки ризиків, що впливають на інвестиційну привабливість проєктів у сфері геотермальної енергетики, як – сукупності різних об'єктивних передумов, можливостей і обмежень, що виникають у процесі залучення інвестицій у розвиток геотермальної енергетики, здатних створити умови для раціонального та ефективного використання наявних ресурсів (природних, людських, інформаційних, , технологій, капіталу та ін.). Особливу увагу приділено локальним, регіональним та техніко-екологічним чинникам ризику.***

Методи. ***В роботі використано методи, які поєднують фінансово-економічний аналіз, оцінку ризиків, технічну експертизу, вивчення нормативно-правового середовища та ринкових умов. Основу становить розрахунок фінансових показників, таких як чиста приведена вартість (NPV), внутрішня норма рентабельності (IRR), дисконтовані грошові потоки (DCF) та період окупності, що дають змогу оцінити потенційну дохідність проєкту. Технічна оцінка включає екологічну експертизу та аналіз сталості використання геотермального ресурсу, зокрема глибини залягання та температурного потенціалу. Водночас важливим є вивчення нормативно-правової бази щодо використання надр і тарифного регулювання. Такий підхід забезпечує обґрунтованість інвестиційних рішень і мінімізацію ризиків.***

Результат. ***У ході дослідження запропоновано вдосконалену методику оцінки ризиків інвестування в геотермальну енергетику, яка враховує комплексний аналіз взаємозв'язку локальних, регіональних і техніко-екологічних чинників. Також розроблено підхід до ранжування ризиків за ступенем впливу на ефективність проєкту та розроблено рекомендації щодо їх мінімізації. Запропоновані методи дають змогу підвищити точність прогнозування та обґрунтованість інвестиційних рішень у цій сфері.***

Висновки. ***Аналітично обґрунтовано, що LCOE з коригуванням на ризики дозволяє врахувати всі можливі втрати та невизначеності, як NPV оцінює фінансову привабливість та допомагає визначити, чи варто інвестувати, також визначено, що урахування регіональних і локальних ризиків забезпечує більш реалістичну оцінку інвестування в геотермальну енергетику. Перспективними***

напрямами подальших досліджень у цій галузі є розробка більш точних моделей оцінки ризиків із використанням сучасних цифрових технологій, зокрема машинного навчання та великих даних. Також важливим є вдосконалення методів екологічного моніторингу та розробка ефективних стратегій мінімізації техногенних ризиків. Дослідження впливу змін клімату на стабільність геотермальних ресурсів, а також вдосконалення законодавчої та нормативної бази для стимулювання інвестицій у галузь можуть сприяти сталому розвитку геотермальної енергетики.

Ключові слова: ***геотермальна енергетика, надрокористування, інвестиційна привабливість, ризики, відновлювана енергетика, екологічна безпека, управління ризиками, перспективи розвитку.***

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