https://doi.org/10.33271/nvngu/2023-6/169

T. Beridze[*1],
orcid.org/0000-0003-2509-3242,
Z. Baranik[2],
orcid.org/0000-0002-9753-4572,
S. Tkachenko[3],
orcid.org/0000-0002-3798-5902,
N. Kutova[1],
orcid.org/0000-0002-6145-0713,
O. Korolenko[1],
orcid.org/0000-0002-0771-4298

1 – Kryvyi Rih National University, Kryvyi Rih, Ukraine
2 – Kyiv National Economics University named after Vadym Hetman, Kyiv, Ukraine
3 – Zaporizhzhia National University, Zaporizhzhia, Ukraine
[*] Corresponding author e-mail: beridzet2016@gmil.com

INVESTMENT PRINCIPLES IN VALUE-TARGET PROCESSES OF ELECTRICITY CONSUMPTION AT IRON ORE ENTERPRISES

Purpose. To establish the influence of investment on cost-target processes of electric consumption of iron ore enterprises by applying economic and mathematical models.

Methodology. As a result of the research, system and critical analysis was applied in the synthesis of formation of economic and analytical indicators and processes of electricity consumption at iron ore enterprises. Methods of comparative analysis, functional-cost, economic-statistical research were used to determine cost-target characteristics when building economic-mathematical models. The general basis of the conducted study is a complex approach.

Findings. The capitalization of relations in Ukraine requires a more careful organization of the practice of investing, in relation to the cost policy of electricity consumption at industrial enterprises in Ukraine. When mining iron ore, optimal matching of the cost of electricity consumption and investment investments, which make it possible to ensure the necessary volumes of production, is of great importance. Due to this, in modern conditions, the necessary digital support of investment processes is of great importance. An economic-mathematical model of the impact of investments on the cost-target problems of electric energy consumption is developed, which allows numerically determining the interrelationship of the selected indicators. The combination of theoretical study with practical implementation made it possible to investigate the conditions under which there is the best ratio of investment investments and the cost of electricity consumption.

Originality. The method of influencing investment on the cost of electricity consumption by iron ore enterprises has received further development. An economic-mathematical model has been constructed that allows the proposed method to be implemented.

Practical value. The analysis of the results of the cost of electricity consumption at iron ore enterprises allows us to estimate the statistical dependence of the cost of electricity consumption on the amount of investment. The conducted analysis made it possible to investigate the dependence of the values of the total average daily costs of consumed electricity, the cost of consumed electricity, the specific cost of electricity consumption on the amount of investment contributions at the enterprises of Kryvyi Rih Iron Ore Combine on the basis of regression models. It is expedient to determine the question of choosing an optimization option on the basis of an analysis of the real economic situation in accordance with the volume and cost of electricity consumption at iron ore enterprises. The practice of applying the proposed research results makes it possible to determine the most optimal option for energy efficiency management.

Keywords: *electric consumption, electric supply, iron ore enterprise, investment investments, regression model*

Introduction. The current state of the state's economy and the corresponding standard of living of the citizens of the country depends not least on the development of the energy industry.

Ukraine is one of the world's largest producers of iron ore raw materials. In 2022, Ukraine produced 63.5 million tons of iron ore raw materials, which is about 5 % of world production. The iron ore industry is an important branch of the Ukrainian economy,

The electricity consumption of enterprises of the iron ore industry of Ukraine is about 10 % of the total electricity consumption in the country. In 2022, enterprises of the iron ore industry consumed about 19.5 billion kilowatt-hours of electricity.

In recent years, Ukrainian enterprises of the iron ore industry have invested significant funds in energy efficiency. These investments made it possible to reduce electricity consumption and increase the energy efficiency of production.

These investments will allow enterprises of the iron ore industry of Ukraine to reduce electricity consumption and increase the energy efficiency of production.

Providing society with the necessary energy resources in general and electricity in particular has a decisive influence on the well-being of the population. Providing enterprises with a justified pricing policy with energy resources is gaining special relevance. One of the areas of effective supply of iron ore enterprises with high-quality energy resources, including electricity, is the application of the investment component. The use of investments makes it possible to provide the full volume of energy carriers to meet the needs of the iron ore industry.

Investments in energy efficiency of enterprises of the iron ore industry of Ukraine have a number of advantages, including reducing electricity consumption and electricity costs; increasing the energy efficiency of production and reducing greenhouse gas emissions; creating jobs in the field of energy saving and energy efficiency.

It is expected that investments in the energy efficiency of enterprises of the iron ore industry of Ukraine will contribute to the further development of the industry and increase its competitiveness.

Investments represent an important economic category, which is characterized by a decisive position in the implementation of structural transformations in the economy, adequate to market forms of management. The current crisis situation in Ukraine has practically stopped the investment process. Therefore, the search for ways to stabilize the economy should be aimed at intensifying investment functioning, which will allow one to orient, first of all, industrial enterprises to fundamental structural changes. This directly does not bypass such a key problem as the ratio between the cost of electricity consumption and the amount of investment deposits. Naturally, the solution to this problem involves ensuring significant or constantly increasing production efficiency in general and iron ore enterprises separately. Therefore, the decisive feature of the modern investment cost-target strategy regarding the processes of electricity consumption at iron ore enterprises should be the optimal balance of the cost and volumes of electricity consumption; this will allow stabilizing the production process. The analysis also shows that currently capital investments are mainly concentrated in the field of the main production of the industrial enterprise. Therefore, the current investment strategy should be focused on primarily meeting the development needs of those industries that form the basis of the state' economy; this fully applies to iron ore enterprises. At the moment, the situation in Ukraine has a sectoral investment structure, which cannot be recognized as the best, because it inextricably follows the imperfect, to a certain extent, sectoral structure of the entire economy of the state. The constant increase in energy prices leads to a decrease in the level of production and inhibition of the overall socio-economic development of the state. To overcome this situation, the development of market relations is of primary importance, first of all in the field of energy supply. At present, the development of the direction of increasing the efficiency of investment activities regarding increasing the impact of investment contributions for the balance of value-target processes of electricity consumption at iron ore enterprises is becoming particularly relevant.

Literature review. Solving economic issues of enterprise cost management is always relevant in any market conditions – both during economic growth and during financial crises. Solving the interrelationship of economic indicators ultimately determines the optimal solution to the problem of applying investment principles in cost-target processes of electricity consumption in general and at iron ore enterprises separately. Solutions to these problems are studied in the works of many scientists – researchers. In particular, in the work by O. V. Kosynska, ways of optimizing electricity supply are defined as a means of increasing the profitability of enterprises [1]. The article by G. V. Popovych deserves attention; it considers the optimization of electricity consumption as a factor of increasing competitiveness [2]. Works by Ya. D. Kachmarik, P. O. Kutsik, R. L. Lupak, I. Ya. Kachmarik [3] and O. S. Beshta [4], quite thoroughly investigate the issue of the cost of electricity consumption of the enterprise and the ways of their optimization. The development of modern information technologies became the basis and expanded the possibilities of using the digital economy in solving optimization problems. Thus, the works by scientists Ya. V. Leonov, V. Yu. Gerasimenko are devoted to the analysis of the activities of enterprises in the conditions of costs by means of their economic and mathematical modeling [5]. It is also necessary to single out the publication of the scientist O. S. Omelnychenko, the main purpose of which is research and study on the theoretical and practical principles of cost management, determination of directions for their optimization [6]. Scientists E. O. Boyko and G. S. Ryzhkova studied in detail the list of typical investment projects to improve energy efficiency. Strategic ways of investing in renewable energy sources have been identified. Alternative energy financing programs in Ukraine were considered [7]. S. P. Sivitska identified obstacles to increasing the use of renewable energy sources in Ukraine and investments in their development. The strategic directions of investing in alternative energy in the context of the development of the national economy have been determined [8]. Y. O. Hernego and O. O. Lyakhova [9] described a retrospective study on the trend of financing the development of alternative energy sources worldwide. Attention is focused on the constant growth of investments in this direction and the corresponding efficiency in relation to investments. The applied nature of research by experts from international organizations working in Ukraine, as well as representatives of specialized banking institutions, is shown. In particular, the European Bank for Reconstruction and Development (EBRD) implements the Alternative Energy Financing Program in Ukraine (USELF), which is based on attracting entrepreneurs to participate in the implementation of sustainable energy development projects [10, 11].

Unsolved aspects of the problem. Without detracting from modern scientific and applied achievements in solving the problem of investment in industrial production, it should be noted that the problem of investment foundations in the cost-target processes of electricity consumption of iron ore enterprises based on economic and mathematical modeling has not been resolved.

The purpose of the article is to study the influence of investment on the cost-target processes of electricity consumption of iron ore enterprises by applying economic and mathematical models.

The results. Let us have a group of joint enterprises, the operation of which is considered for some time. Let us define the following characteristics of the functioning of enterprises: Q_{ik} – average daily electricity consumption, kW/h; C_{ik} – average daily cost of consumed electricity, hryvnias; i – company number, ($i = 1, 2, \ldots, m$); k – year of operation of the enterprise, ($k = 1, 2, \ldots, n$); m – the number of enterprises in the group; n – the number of years during which the functioning of enterprises is considered.

Let the size of the sum of investments, which are invested every year in the operation of the analyzed group of enterprises, be specified

$$x_k \ (k = 1, 2, \ldots, n). \qquad (1)$$

Thus, the total average daily consumption of electricity for all enterprises in the group per year can be represented by the formula

$$Q_k = \sum_{i=1}^{m} Q_{ik}. \qquad (2)$$

Taking into account (1 and 2), it can be assumed that there is a relationship between the total average daily consumption of electricity for all enterprises in the group and the amount of investments, i. e.

$$Q_k = \varphi_1(x_k). \qquad (3)$$

The total average daily cost of consumed electricity for all enterprises in the group per year can be represented by the formula

$$C_k = \sum_{i=1}^{m} C_{ik}. \qquad (4)$$

Taking into account (1 and 4), it can be assumed that there is a relationship between the total average daily cost of electricity consumed by all enterprises of the group for a year and the volume of investments, i. e.

$$C_k = \varphi_2(x_k). \qquad (5)$$

According to the designations, the specific average daily cost of electricity consumed by the enterprise for the y^{th} year is calculated using the formula

$$c_{ik} = \frac{C_{ik}}{Q_{ik}}. \qquad (6)$$

In turn, the total specific cost of consumed electricity of the entire group of enterprises for the i^{th} year is calculated according to the formula

$$c_k = \frac{C_k}{Q_k}. \qquad (7)$$

Thus, according to formulas (1 and 7), there should be a relationship between the total specific cost of electricity consumed by the entire group of enterprises for the i^{th} year and the amount of investments invested in the i^{th} year of operation of the analyzed group of enterprises, i. e.

$$c_k = \varphi_3(x_k). \qquad (8)$$

Formulas (3, 5 and 8) are determined by statistical data that characterize the functioning of the group of enterprises under analysis. The structural analysis of formulas (3, 5 and 8) allows us to draw a conclusion when choosing the dependence of the simplest form, i. e.

$$y_k = \sum_{l=0}^{p} a_l \cdot x_k^l, \quad (k = 1, 2, \ldots, n), \qquad (9)$$

where are a_l, $(l = 0, 1, ..., p)$ parameters that are based on statistical material.

The structure of formula (9) makes it possible to optimize the general dependencies (3, 5 and 8) of the entire group of enterprises on the amount of provided investments by finding the extremum of function (9).

To find the values of the parameters included in formula (9), we will use the method of least squares (LSM) [14]. Since the number of parameters included in formula (9) is less than the number of equations $p < n$, the system of equations

$$\begin{cases} \sum_{l=0}^{p} a_l \cdot x_1^l = y_1 \\ \dots \\ \sum_{l=0}^{p} a_l \cdot x_n^l = y_n \end{cases} \qquad (10)$$

is incompatible. Therefore, to solve (10), we will use the MNC, that is, we will minimize the total discrepancy of the right and left parts of the equations of this system. To do this, we will form the function of the total discrepancy in the form of the sum of the squares of the discrepancies of each of the equations

$$F(a_0, ..., a_p) = \sum_{k=1}^{n} \left(\sum_{l=0}^{p} a_l \cdot x_k^l - y_k \right)^2. \qquad (11)$$

Function (11) is non-negative and is equal to zero when the right and left parts of the equations of the system to be solved coincide. Thus, in order to solve the incompatible system of equations (10), it is enough to minimize the total residual function (11). Given that the function (9) is linear with respect to the parameters sought, this allows us to reduce the problem of minimization (11) to the solution of a system of linear algebraic equations. The simple form of the function (9) allows solving the minimization problem (11) by equating the partial derivatives of the function (11) to zero, i. e.

$$\frac{\partial F(a_0, \dots, a_p)}{\partial a_l} = 0, \quad (l = 0, \dots, p). \qquad (12)$$

Since the function (9) is linear with respect to the parameters, then (11) is a quadratic function, which determines the linearity of the system of equations (12). Indeed, substituting (11) into (12), we have a system of linear algebraic equations with respect to the parameters $a_0, a_1, ..., a_p$

$$\begin{cases} a_0 + \overline{x} \cdot a_1 + \dots + \overline{x^p} \cdot a_p = \overline{y} \\ \dots \\ \overline{x^p} \cdot a_0 + \overline{x^{p+1}} \cdot a_1 + \dots + \overline{x^{p+k}} \cdot a_p = \overline{y \cdot x^p} \end{cases}, \qquad (13)$$

where $\overline{x^j} = \frac{1}{n} \sum_{k=1}^{n} x_k^j$, $(j = 1, ..., p)$; $\overline{y \cdot x^i} = \frac{1}{n} \sum_{k=1}^{n} y_k x_k^i$, $(i = 0, ..., p)$.

The system of equations (13) can be solved using Kramer's formulas.

The found values of the parameters allow us to write the formula (9) in the form

$$y = \sum_{l=0}^{p} \hat{a}_l \cdot x^l, \qquad (14)$$

where $\hat{a}_l, (l = 0, \dots, p)$ are parameters found by solving the system of equations (13).

To establish the adequacy of the found model (14), it seems appropriate to apply the Chaddock scale [14]. According to the Chaddock scale, we have:

if $R = 0$, then there is no correlation;
if $0.01 \le R \le 0.19$, then the statistical relationship is very weak;
if $0.2 \le R \le 0.49$, then the statistical relationship is weak;
if $0.5 \le R \le 0.69$, then the statistical relationship is average;
if $0.7 \le R \le 0.99$, then the statistical relationship is strong.

It should also be emphasized that if the regression coefficient has a positive sign (+), then the relationship is increasing, and, conversely, with a negative sign (–), the relationship is decreasing.

To find the extreme value of the consumed electricity of the entire group of enterprises from the value of the amount of provided investments, it is necessary to calculate the derivative of the amount of provided investments and, equating it to zero, solve the obtained equation, i. e.

$$\frac{dy}{dx} = \sum_{l=1}^{p} l \cdot \hat{a}_l \cdot x^{l-1} = 0. \qquad (15)$$

Next, using the sufficient condition for the extremum of function (14), we find the extreme values of one of the functions (3, 5 and 8) of the entire group of enterprises. The found value allows you to answer the question about the optimal value of the amount of provided investments for each of the three considered functions, limited to the other two functions.

On the example of the mines of PJSC "Kryvyi Rih Iron Ore Combine" (KZRK) the optimization of consumed electricity was studied depending on the amount of provided investments. Table 1 presents the results of calculating the average daily electricity consumption by KZRK mines and the total average daily electricity consumption by all mines at the same time for the specified year

Fig. 1 shows the field of correlations between the total average daily electricity consumption and the amount of investments, as well as an approximation of real data. To find the approximation, we will use MNK. First, we choose the structure of the dependence of average daily electricity consumption on the amount of provided investments in the form of a third-order polynomial

$$Q(x) = a_0 + a_1 \cdot x + a_2 \cdot x^2 + a_3 \cdot x^3. \qquad (16)$$

The choice of such a polynomial can be explained by the need to study the function at its extremum. Next, we compile the functionality that needs to be minimized by parameters

$$F\left(a_0, a_1, a_2, a_3\right) = \sum_{k=1}^{6} \left(\sum_{l=0}^{3} a_l \cdot x_k^l - Q_k \right)^2. \qquad (17)$$

Next, we calculate the partial derivatives on the parameters, which we equate to zero

$$\frac{\partial F(a_0, \dots, a_3)}{\partial a_l} = 0, \quad (l = 0, \dots, 3). \qquad (18)$$

As a result, we get a system of four linear algebraic equations with four unknowns

$$\begin{cases} a_0 + \overline{x} \cdot a_1 + \overline{x^2} \cdot a_2 + \overline{x^3} \cdot a_3 = \overline{Q} \\ \overline{x} \cdot a_0 + \overline{x^2} \cdot a_1 + \overline{x^3} \cdot a_2 + \overline{x^4} \cdot a_3 = \overline{x \cdot Q} \\ \overline{x^2} \cdot a_0 + \overline{x^3} \cdot a_1 + \overline{x^4} \cdot a_2 + \overline{x^5} \cdot a_3 = \overline{x^2 \cdot Q} \\ \overline{x^3} \cdot a_0 + \overline{x^4} \cdot a_1 + \overline{x^5} \cdot a_2 + \overline{x^6} \cdot a_3 = \overline{x^3 \cdot Q} \end{cases}. \qquad (19)$$

To solve the system of equations (19), we add the appropriate determinants

$$\Delta = \begin{vmatrix} 1 & \overline{x} & \overline{x^2} & \overline{x^3} \\ \overline{x} & \overline{x^2} & \overline{x^3} & \overline{x^4} \\ \overline{x^2} & \overline{x^3} & \overline{x^4} & \overline{x^5} \\ \overline{x^3} & \overline{x^4} & \overline{x^5} & \overline{x^6} \end{vmatrix}; \quad \Delta_1 = \begin{vmatrix} \overline{Q} & \overline{x} & \overline{x^2} & \overline{x^3} \\ \overline{x \cdot Q} & \overline{x^2} & \overline{x^3} & \overline{x^4} \\ \overline{x^2 \cdot Q} & \overline{x^3} & \overline{x^4} & \overline{x^5} \\ \overline{x^3 \cdot Q} & \overline{x^4} & \overline{x^5} & \overline{x^6} \end{vmatrix};$$

$$\Delta_2 = \begin{vmatrix} 1 & \overline{Q} & \overline{x^2} & \overline{x^3} \\ \overline{x} & \overline{x \cdot Q} & \overline{x^3} & \overline{x^4} \\ \overline{x^2} & \overline{x^2 \cdot Q} & \overline{x^4} & \overline{x^5} \\ \overline{x^3} & \overline{x^3 \cdot Q} & \overline{x^5} & \overline{x^6} \end{vmatrix}; \quad \Delta_3 = \begin{vmatrix} 1 & \overline{x} & \overline{Q} & \overline{x^3} \\ \overline{x} & \overline{x^2} & \overline{x \cdot Q} & \overline{x^4} \\ \overline{x^2} & \overline{x^3} & \overline{x^2 \cdot Q} & \overline{x^5} \\ \overline{x^3} & \overline{x^4} & \overline{x^3 \cdot Q} & \overline{x^6} \end{vmatrix};$$

Table 1

Results of calculations of average daily electricity consumption for mines of PJSC KZRK [12, 13]

KZRK mines		Ternivska	Hvardiiska	Home	October	Summarized	Investments
No.	Years	Average daily consumption of e/e. kW,h (Q)					UAH
1	2013	1863	1027	3096	1512	7498	459,715
2	2014	1725	1725	1725	1725	6900	1,917,945
3	2015	1587	1026	3278	1662	7553	3,376,174
4	2016	1566	876	3342	1403	7187	2,128,345
5	2017	1545	717	3405	1143	6810	880,515
6	2018	1425	736	3018	948	6127	704,229
7	2019	1305	754	2631	752	5442	639,562
8	2020	1147	748	2572	739	5206	580,143
9	2021	1097	684	2365	706	4852	540,324

$$\Delta_4 = \begin{vmatrix} 1 & \overline{x} & \overline{x^2} & \overline{Q} \\ \overline{x} & \overline{x^2} & \overline{x^3} & \overline{x \cdot Q} \\ \overline{x^2} & \overline{x^3} & \overline{x^4} & \overline{x^2 \cdot Q} \\ \overline{x^3} & \overline{x^4} & \overline{x^5} & \overline{x^3 \cdot Q} \end{vmatrix}.$$

According to the data in Table 1, we find the coefficients of the system of equations (19)

$$\overline{x} = 1.58 \cdot 10^6; \quad \overline{x^2} = 3.51 \cdot 10^{15}; \quad \overline{x^3} = 9.38 \cdot 10^{21};$$
$$\overline{x^4} = 2.74 \cdot 10^{27}; \quad \overline{x^5} = 8.48 \cdot 10^{33}; \quad \overline{x^6} = 2.71 \cdot 10^{41};$$
$$\overline{Q} = 7.01 \cdot 10^3; \quad \overline{x \cdot Q} = 1.13 \cdot 10^{10}; \quad \overline{x^2 \cdot Q} = 2.57 \cdot 10^{19};$$
$$\overline{x^3 \cdot Q} = 6.94 \cdot 10^{25}.$$

We get

$$a_0 = 9{,}514; \quad a_1 = -6.4 \cdot 10^{-3}; \quad a_2 = 3.8 \cdot 10^{-9}; \quad a_3 = -6.2 \cdot 10^{-16}. \tag{20}$$

Taking into account (22), equation (16) takes the form

$$Q(x) = -6.2 \cdot 10^{-16} \cdot x^3 + 3.8 \cdot 10^{-9} \cdot x^2 - 6.4 \cdot 10^{-3} \cdot x + 9{,}514; \quad R = 0.81. \tag{21}$$

According to the Chaddock scale, the value of the regression coefficient indicates a strong statistical relationship.

In accordance with the given task, it is necessary to find the optimal value of the investment amount, at which the average daily electricity consumption will have the largest value. For this, it is necessary to find the largest value of the function (21). Let us use the derivative of function (16), which we equate to zero

$$Q'(x) = (a_0 + a_1 \cdot x + a_2 \cdot x^2 + a_3 \cdot x^3)' = a_1 + 2 \cdot a_2 \cdot x + 3 \cdot a_3 \cdot x^2 = 0. \tag{22}$$

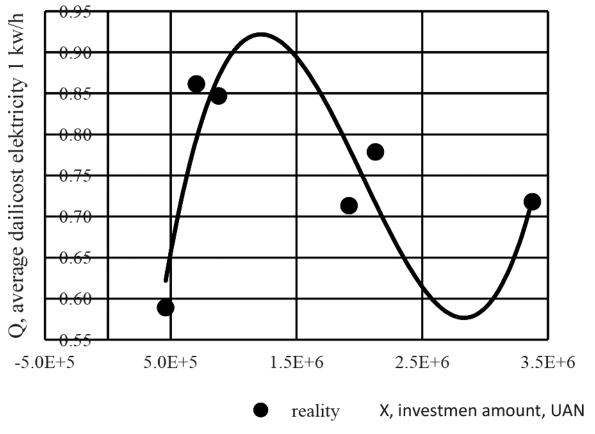

Fig. 1. Field of correlations of average daily electricity consumption and sums of investments, as well as approximation of the field of correlations

After substituting parameter values (20), we get

$$x_1 = 1.187 \cdot 10^6; \quad x_2 = 2.899 \cdot 10^6.$$

To find the maximum of function (20), we use the second-order derivative of function (16)

$$Q''(x) = 2 \cdot a_2 + 6 \cdot a_3 \cdot x.$$

Because

$$Q''(x_2) = -2.436 \cdot 10^{-9} < 0,$$

then at

$$x_2 = 2.899 \cdot 10^6$$

function (21) reaches a maximum.

As a result, we get

$$x_{0opt} = 2.899 \cdot 10^6, \quad Q0opt^3_{\max}. \tag{23}$$

At the same time, the values of the average daily cost of consumed electricity and the average daily cost of specific electricity consumption are, respectively

$$C(x_{0opt}) = 4.591 \cdot 10^3; \quad c(x_{0opt}) = 0.571.$$

Table 2 presents the results of calculating the average daily cost of electricity consumption by KZRK mines and the total average daily cost of electricity consumption by all mines at the same time for the specified years.

Fig. 2 shows the field of correlations between the total average daily cost of electricity consumption and invested amounts of investments for the same years, as well as an approximation of real data. The approximation was carried out by a polynomial of the third order, according to the method described above, which has the form

$$C(x) = 1.13 \cdot 10^{-15} \cdot x^3 - 6.8 \cdot 10^{-9} \cdot x^2 + 0.0118 \cdot x. \tag{24}$$

At the same time, the regression coefficient was

$$R = 0.998. \tag{25}$$

According to the Chaddock scale, the value of the regression coefficient (25) indicates a strong statistical relationship.

According to the given task, it is necessary to find the optimal value of the amount of investment, at which the average daily cost of consumed electricity will have the smallest value. For this, it is necessary to find the smallest value of the function (24).

As a result, according to the method described above, we will get

$$x_{1opt} = 2.743 \cdot 10^6, \quad C1opt^3_{\min}.$$

At the same time, the values of the average daily electricity consumption and the average daily value of specific electricity consumption are, respectively

$$Q(x_{1opt}) = 9.673 \cdot 10^3; \quad c(x_{1opt}) = 0.572.$$

Table 3 presents the results of calculating the average daily specific cost of electricity consumption by KZRK mines and

Table 2

The results of calculating the average daily cost of electricity for the mines of PJSC KZRK [12, 13]

KZRK mines		Ternivska	Hvardiiska	Home	October	Summarized	Investments
No.	Years	Average daily cost of e/e, UAH (C)					UAH
1	2013	1207	701	1778	731	4417	459,715
2	2014	1255	549	2062	1055	4921	1,917,945
3	2015	1303	397	2345	1378	5423	3,376,174
4	2016	1207	357	2667	1365	5596	2,128,345
5	2017	1110	316	2989	1352	5767	880,515
6	2018	1076	342	2831	1029	5278	704,229
7	2019	1042	367	2672	705	4786	639,562
8	2020	1229	754	3774	935	6692	580,143
9	2021	1026	498	2683	823	5\030	540,324

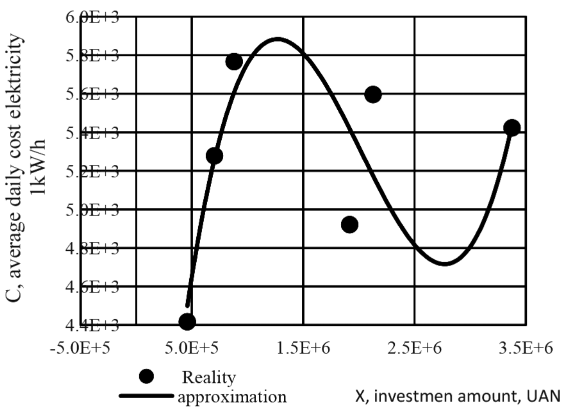

Fig. 2. Field of correlations of the average daily cost of electricity consumption and sums of investments, as well as approximation of the field of correlations

the total average daily specific cost of electricity consumption by all mines at the same time for the specified years, as well as the amount of investments made in the corresponding years.

Fig. 3 shows the field of correlations between the total average daily specific consumption of electricity and provided investments for the same years, as well as the approximation of real data.

The approximation was carried out using a polynomial of the third order, according to the method described above, which has the form

$$c(x) = 1.72216 \cdot 10^{-19} \cdot x^3 - 1.04568 \cdot 10^{-12} \cdot x^2 + + 1.78099 \cdot 10^{-6} \cdot x. \quad (26)$$

The regression coefficient of formula (24) was the value

$$R = 0.998. \quad (27)$$

According to the Chaddock scale, the value of the regression coefficient (27) indicates a strong statistical relationship.

According to the given task, it is necessary to find the optimal value of the amount of investment, at which the average daily specific cost of consumed electricity will have the smallest value. For this, it is necessary to find the smallest value of the function (26). Using the method described above, we find

$$x_{2opt} = 2.83 \cdot 10^6, \quad C2opt_{\min}.$$

At the same time, the values of the average daily electricity consumption and the average daily cost of electricity consumption are, respectively

$$Q(x_{2opt}) = 9.838 \cdot 10^3; \quad C(x_{2opt}) = 6.458 \cdot 10^3. \quad (28)$$

Thus, three options for optimizing electricity consumption are considered, depending on the amount of investments.

In the first case, formula (23) determines the optimization of the investment amount by maximizing the average daily electricity consumption.

In the second case, formula (25) determines the optimization of the investment amount by minimizing the average daily cost of electricity consumption.

And, finally, in the third case, formula (28) determines the optimization of the investment amount by minimizing the average daily specific cost of electricity consumption. investments in KZRK mines and determine the optimal amount of investment for each of the types of costs.

Conclusions. Investment activity in Ukraine in the conditions of market relations requires the use of modern methods of economic management, which are based on the digital economy. One of the important issues is the study on the impact of investment contributions on the electricity consumption of the enterprise, the solution of which is impossible without the use of economic and mathematical modeling based on the construction of regression models. A structural-analytical model for solving the optimization problem of cost-target investment direction regarding electricity consumption at industrial enterprises is proposed. Alternative solutions to the selected problem were studied. The analytical solution became the basis of the research on the applied practical direction.

Table 3

The results of calculating the average daily specific cost of electricity consumption at the mines of PJSC KZRK [12, 13]

KZRK mines		Ternivska	Hvardiiska	Home	October	Summarized	Investments
No.	Years	Average daily cost of e/e, UAH (C)					UAH
1	2013	0.648	0.683	0.574	0.484	0.589	459,715
2	2014	0.728	0.318	1.195	0.617	0.713	1,917,945
3	2015	0.821	0.387	0.715	0.829	0.718	3,376,174
4	2016	0.771	0.408	0.798	0.973	0.779	2,128,345
5	2017	0.718	0.441	0.878	1.183	0.847	880,515
6	2018	0.755	0.465	0.938	1.085	0.861	704,229
7	2019	0.7985	0.4867	1.0156	0.9375	0.8795	639,562
8	2020	1.0715	1.0080	1.4673	1.2652	1.2854	580,143
9	2021	0.935	0.728	1.134	1.168	0.991	540,324

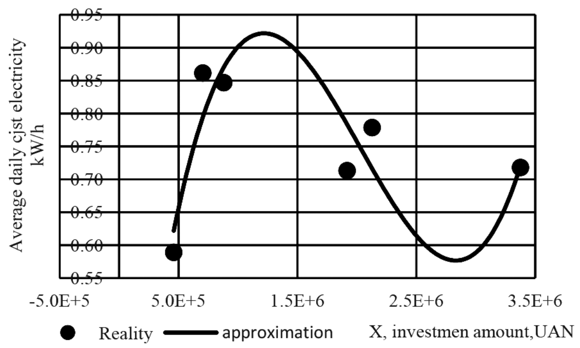

Fig. 3. Field of correlations between the total average daily specific value electricity consumption and the amount of investments, as well as approximation of the field of correlations

Practical purposefulness made it possible to highlight the directions of implementation of the received optimization solutions. The question of choosing an option to optimize the amount of provided investment from three options can most likely be determined by the real economic situation with electricity consumption at enterprises of the iron ore industry in general and PJSC "Kryvyi Rih Iron Ore Combine" separately. Thus, the analysis made it possible to investigate the dependence of the values of the total average daily costs of consumed electricity (Q), the cost of consumed electricity (C), the specific cost of electricity consumption (c) on the amount of provided investments. Investments will be made by enterprises of the iron ore industry of Ukraine to reduce electricity consumption and increase the energy efficiency of production.

References.

1. Kosyns'ka, O. V. (2011). Cost optimization as a means of increasing the profitability of enterprises. *Formuvannia rynkovykh vidnosyn v Ukraini*, *7*(122), 106-110.
2. Popovych, H. V. (2011). Cost optimization of the enterprise, as an important factor of increasing the competitiveness. *Conference materials. Current problems of modern science.* Retrieved from http://www.rusnauka.com/15_APSN_2011/Economics/14_87797.doc.htm.
3. Kachmaryk, Ya. D., Kutsyk, P. O., Lupak, R. L., & Kachmaryk, I. Ya. (2012). *The economic mechanism of ensuring the competitiveness of a trading enterprise: monograph*. Lviv: Literaturna ahentsiia "Piramida".
4. Beshta, O. S., Kuvaiev, V. M., Mladetskyi, I. K., & Kuvaiev, M. V. (2020). ULPA particle separation model in a spiral classifier. *Naukovyi Visnyk Natsionalnoho Hirnychoho Universytetu*, (1), 31-35. https://doi.org/10.33271/nvngu/2020-1/031.
5. Leonov, Ya. V., & Herasymenko, Yu. S. (2010). The system of cost management as a factor of competitiveness. *Biuleten' mizhnarodnoho nobelivs'koho ekonomichnoho forumu*, *1*(2), 175-183.
6. Omel'nychenko, O. S. (2016). Directions of cost optimization in the management system. *Efektyvna ekonomika,* (4). Retrieved from http://www.economy.nayka.com.ua.
7. Bojko, Ye. O., & Ryzhkova, H. S. (2015). Strategic investment directions of renewable energy sources. *Naukovyi Visnyk Mizhnarodnoho Humanitarnoho Universytetu Seriia: Ekonomika i menedzhment. Zbirnyk naukovykh prats', 14*, 52-56.
8. Sivits'ka, S. P. (2014). Strategic directions of investing in alternative energy in the context of the development of the national economy. *Molodizhnyj ekonomichnyj dajdzhest*, *1*(1), 76-80.
9. Herneho, Yu. O., & Liakhova, O. O. (2021). Financing the development potential of alternative energy in Ukraine. *Efektyvna ekonomika*, (3). Retrieved from http://www.economy.nayka.com.ua.
10. Gernego, Iu., & Dyba, O. (2016). Energy efficiency financing: innovative models and strategies. *PNAP, 18*(3), 79-88.
11. Pryb, K. A. (2021). Investing in the development of renewable energy sources. *Naukovi zapysky NAUKMA. Ekonomichni nauky*, *6*(1), 111-116.
12. State Statistics Service of Ukraine (n.d.). Retrieved from http://www.ukrstat.gov.ua/.
13. SMIDA (n.d.). *Account of information services. Reports of enterprises*. Retrieved from http://smida.gov.ua.
14. Zakharchenko, V. I. (2019). Correct use of the regressional analysis in economic research. *Economic journal Odessa polytechnic university, 4*(10), 68-75.

Інвестиційні засади у вартісно-цільових процесах електроспоживання на залізорудних підприємствах

Т. М. Берідзе[*1], *З. П. Бараник*[2], *С. М. Ткаченко*[3], *Н. Г. Кутова*[1], *О. Б. Короленко*[1]

1 – Криворізький національний університет, м. Кривий Ріг, Україна
2 – Київський національний економічний університет імені Вадима Гетьмана, м. Київ, Україна
3 – Запорізький національний університет, м. Запоріжжя, Україна
[*] Автор-кореспондент e-mail: beridzet2016@ gmail.com

Мета. Встановлення впливу інвестування на вартісно-цільові процеси електроспоживання залізорудних підприємств шляхом застосування економіко-математичних моделей.

Методика. У процесі дослідження був застосований системний і критичний аналіз – при формуванні системи економіко-аналітичних показників і аналізі процесів електроспоживання на залізорудних підприємствах. Методи компаративного аналізу, функціонально-вартісного, економіко-статистичного аналізу для означення вартісно-цільових характеристик при побудові економіко-математичних моделей. Загальним підґрунтям проведеного дослідження є системний підхід.

Результати. Капіталізація відносин в Україні потребує більш ретельного підходу до використання процесів інвестування щодо вартісної політики електроспоживання на залізорудних підприємствах України. При видобутку залізної руди велике значення має оптимальне співвідношення вартості електроспоживання–інвестування, що дозволяє забезпечити необхідні обсяги виробництва продукції. Унаслідок цього, у сучасних умовах велике значення має відповідний цифровий супровід процесів інвестування. Розроблена економіко-математична модель впливу інвестування на вартісно-цільові процеси споживання електричної енергії, що дає можливість чисельно з'ясувати відповідний зв'язок. Поєднання теоретичного дослідження із практичною реалізацією надало можливість дослідити умови, за яких існує оптимальне співвідношення інвестування–вартість електроспоживання.

Наукова новизна. Удосконалена методика визначення впливу інвестування на вартість електроспоживання залізорудними підприємствами. Побудована економіко-математична модель, що дозволяє реалізувати запропоновану методику.

Практична значимість. Аналіз вартості споживання електричної енергії на залізорудних підприємствах дає можливість оцінити статистичну залежність цієї вартості від величини інвестування. Проведений аналіз дозволив дослідити залежність величин загальних середньодобових витрат спожитої електроенергії, вартості спожитої електроенергії, питомої вартості споживання електроенергії від суми інвестиційних вкладів на підприємствах Криворізького залізорудного комбінату на основі регресійних моделей. Питання щодо вибору варіанту оптимізації доцільно визначати на основі аналізу реальної економічної ситуації відповідно до обсягів і вартості споживання електроенергії на залізорудних підприємствах. Практика застосування запропонованих результатів дослідження дозволяє визначити найбільш оптимальний варіант управління енергоефективністю.

Ключові слова: *електроспоживання, електропостачання, залізорудне підприємство, інвестиційні вклади, регресійна модель*

The manuscript was submitted 18.05.23.