Theoretical Preconditions for Business Processes Management of Energy Efficiency in Mining Enterprises

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ABSTRACT
The article justifies the need for further development of the scientific approach to evaluation and selection of energy-saving technologies for the open-cast mining of iron ore deposits, which is important for the mining industry of Ukraine. A structural diagram of the theory of energy saving is proposed. Its key principle is to solve the problem of energy efficiency improvement that is achieved by means of certain technological and organizational methods in case of provision of minimum specific energy and economic costs for mining. The fundamental basis of the theory is a group of relatively independent of each other key regularities. Based on the considered theory of energy saving by energy intensity proposed the criterion for evaluating the feasibility of using known technologies and organization of open mining works. The calculation formula which allows to evaluate adequate options of business processes management at mining enterprises by energy equivalent is presented to solve the problem of energy efficiency improvement.
Further development of the theory energy saving and management business processes in the context of evaluation and selection of energy-saving technologies for the open development of iron ore deposits is important for the stable functioning of the mining industry in Ukraine.
Keywords: *energy saving, energy intensity, business processes, mining industry, management, open-pit*

1. INTRODUCTION

Mining industry is one of the most energy-intensive sectors of the national economy of Ukraine. About 70% of minerals in our country are extracted using energy of explosives. Considerable specific energy consumption is the use of electric and thermal energy. The level of energy consumption is determined by the properties of the rocks, the technological capabilities of the equipment used and organization of mining production. When performing various technological processes, the combination of these factors manifests itself in different ways. Therefore, it is necessary in each case to allocate those that affect the energy intensity of this technological process [8]. Therefore the problem of energy conservation must be addressing using a systematic scientific approach, by considering the main technological processes in a single organized complex. Only in this case we can identify the main areas of production improvement that have the goal of saving energy.
The complexity of the scientific and practical solution of energy saving issues is also the lack of specialized means of measuring energy consumption to relevant technological processes [9]. The instrument-making industry still does not issue reliable certified devices for controlling total and specific energy consumption for drilling rigs, excavators, crushers, lifting transport equipment and other unit aggregates [10]. Existing self-writing devices are quite complex in operation and envisage the involvement of competent personnel for the receipt and processing of data.
Under these conditions, their use in mining enterprises the theoretical preconditions for increasing the efficiency of the process of managing energy saving is an urgent problem.

2. ANALYSIS OF RECENT RESEARCH AND PUBLICATIONS

Scientists and practicians are working hard on energy saving management in all areas [7]. The idea and scientific approaches to the application of energy indicators of evaluation of mining production are laid down in the works of Yu.I. Anistratova, A.A Vernadsky, S.A. Goncharova, N.G. Dombrovsky, G.P. Demidyuk, V.G. Kravets , V.V. Rzhevsky, I.A. Tangaeva, O.E. Fersman, and other well-known scholars [1-3, 6]. The performed researches represent the scientific fundamentals of the theory of energy saving (minimization of energy consumption) in the development of deposits in an open way. Regarding mining, to date, a considerable amount of research has been carried out in this direction. Many of them are profoundly creative and presented in the form of scientific articles or separate sections in the monographs [11].

In the theory and practice of energy management, monitoring and planning systems are used in Western Europe, the USA, Japan (Pooley John, 2005; Jones Phil, 2004), the purpose of the creation and operation of Monitoring and Targeting Systems, in addition to operational management of the efficiency of the use of fuel and energy resources, is also monitoring of the real results achieved in implementing energy saving projects at a certain management object [4].

German researcher (J. Kals, p. 182-184) highlights the following typical strategies that can be applied to strategic modeling of energy saving in an enterprise [5]:

- passive strategy - there is no systematic planning, management of energy saving is not considered as a separate object of influence. The task of forming energy policy and applying international energy-saving standards are not relevant to the enterprise, but rather are auxiliary in finding ways to survive in an environment of increased competition;
- a strategy for maximizing profits in the short run - the introduction of energy saving measures with a relatively short payback period and high returns [12]. The strategy focuses on solutions that have already shown their effectiveness, are more standardized and tested, and their implementation does not lead to additional problems in the form of additional training of employees, increasing the efficiency of the introduction of new technologies. Low profit measures are not considered;
- the strategy of maximizing profits in the long run involves a serious understanding of the market for energy prices and technology development, the management takes into account energy-saving projects with long payback periods. Appropriate measures (for example, the introduction of new power plants or heat exchangers) may have a few decades of implementation;
- the strategy of realization of all investment-attractive measures considers the purpose of application of the whole set of possible measures in the field of optimization of energy consumption, having a positive economic effect both in the short-term and long-term perspective;
- the maximal strategy assumes that even entire enterprise can undergo changes in the interests of energy conservation and climate protection. The enterprise joins both applied research in the field of energy efficiency, which has a long payback period, and to fundamental research, for example, in the field of alternative energy.

However, until now insufficiently studied unproductive energy losses are not sufficiently studied, the energy of human labor, energy invested (materialized) into materials and equipment is not fully taken into account, and the evaluation of expenses from environmental damage in the energy equivalent [13]. In addition, there is a lack of monographic research that presents a thorough study of the problem of energy saving management in general concerning the technology of mining. Therefore, the need for further development of the energy conservation theory is very significant and constantly increasing [14]. This explains the existence this area of a number of poorly developed, debatable and even controversial issues. The purpose of the study is to create a scientific approach to evaluation and selection of energy-saving technologies for the open development of iron ore deposits, which is important for the further stable functioning of the mining industry.

3. RESEARCH METHODS

It is a well-known fact that theory is a system of the organized knowledge. The generalization of the performed research allowed us to form the structure of the theory of energy saving (minimization of energy consumption) in the development of deposits in an open way (Fig. 1).

The main element of the theory is the principle that organically unites all its elements into comprehensive whole. The key principle of the theory of energy saving is formulated as follows: energy saving with open development is achieved by technological and organizational methods that provide a minimum integral indicator of energy efficiency, representing the amount of specific energy consumption in monetary terms (eZs) and specific reduced economic costs (Zs = (EnK + C) / Q) for this technology. It provides an opportunity to reveal ways of further development of the theory of energy conservation.

The core of the theory is a group of relatively independent basic principles. They express the essential, stable, repetitive and necessary connections between phenomena covered by the theory of energy conservation. It includes:

1. The specific energy inputs of the drilling and boring works (e_{dbw}) are directly proportional to the coefficient of rock strength (f), rock density (y), specific time expenditures for performing auxiliary operations for drilling (t_t), price of the machine (Z_{pm}), the price of BP (Z_{bp}) and inversely proportional the diameter of the charge (D), the capacity of the excavator bucket (Ee), which is applied to the load of the exploded rocks, the specific energy of the explosion(ε), the height of the working ledge (H_l), the effectiveness of the means of dust extinguishing (η). It follows from this regularity that the expediency of reducing the time for performing auxiliary operations during drilling, increasing the diameter of the charge and the height of the ledge, the use of VR with high specific energy explosion with a decrease in its price.
2. Specific energy inputs for excavation and transport operations (e_{ET}) are in direct proportion to the coefficient of rock strength and density, the average diameter of the piece (d_{ar}), the coefficient of the vehicle's container (k_v), the length (L), the bias (i) and the main resistance of

the movement (ω_c), the prices of the excavator (Z_{ex}), the prices of vehicles and communications (Z_v) and the inverse proportionality of the coefficient of roughness in the collapse (k_r), the capacity of the excavator bucket, the carrying capacity of the vehicle (q_v) and the height of the ledge. It follows the conclusion that it is expediency of use of powerful cargo-transport equipment, decrease the average diameter of the piece, rational slope way, implementation of measures to reduce traffic resistance and increasing the height of the bench.

3. The specific energy inputs for the dump formation (e_O) are directly proportional to the density of the rocks, the average diameter of the piece, the distance from the quarry to the dump (L_o), the norm for the placement of overburden (Cp), the cost of the bulk equipment (Zo) and the inverse capacity of the working body the drowning machine (Eo), the coefficient of loosening, compensating the slope of the working platform (k), the probability of servicing locomotive warehouses in the dump (Ro). Main conclusions: thoroughly substantiate the location of the dumps and the calendar placement of empty rocks; use the maximum value of the compensating slope of the work area in the dump when used for laying rocks of mobile equipment; strive to increase the value of Ro.

4. The specific energy intensity of the excavator-transport complex (e_{ETK}) is directly proportional to the age of dump trucks (t_a), the number of excavators operating on one ledge ($n_{ек}$) and inversely proportional to the most probable value of the coefficient of time use of mining equipment (P_{rv}), the coefficient of loading of slaughter and boom excavators (k_s), which takes into account the relative intensity of the adjacent processes - loading, transportation and unloading, a certain probability of deviation of load time, unloading and the interval between the approaches of transport vehicles, the number of vehicles, the organization of their movement. The theory of energy conservation includes the laws of varying degrees of community, revealing its principles and the nature of these phenomena. Not revealing the nature of the laws of the second and third levels, we note only the decoding of the initial values: n - the frequency of rotation of the drill rod; t_{co} - duration of the working cycle of the excavator; E_E^O - the capacity of the bucket excavator; B - width of the mooring step; L_s - the length of the rolling stock (train); $m_б$ - mass of bulldozer; α_b- angle of rotation of the bulldozer's lever; $h_б$ - height of the bulldozer blade; Tr - duration of the flight; t_{tu} - load time of the transport unit; t_o - the duration of the exchange of a transport unit in the face; N_{tu} - number of transport units; M_e - the number of excavators in the face; t_c - ordinal time of working change; N_a - the number of dump trucks serviced by one excavator; q_{vr} - specific consumption of VR; e_{iw} - ideal work of explosion; q_C - specific allocation that clogs the atmosphere with substances in the explosion; L_q - the stability of the bit; R_i - criterion of fission; d_{avr} - average size of blocks in the array; ν - Poisson volumetric deformation coefficient; k_v - coefficient of excavation; υ_{cp} - average speed of the vehicle; e_k - Specific consumption of electricity by the conveyor line; α- angle of inclination of the conveyor; Q_f - actual production of the conveyor; Q_t - the theoretical performance of the conveyor; k_v - coefficient of increase of prisms drawing at work of a bulldozer under a slope; $\alpha_к$ - slope of the working platform for the bulldozer; e_{pn} - Specific energy consumption of the loader during the set of rocks; $E_н$ - capacity of the loader bucket; $\rho_п$ - coefficient of simple equipment; M- number of failures (non-working equipment changes); T_c- net calendar time; N_{cp} - average number of used excavators; Z_e- the price of the equipment; Z_m - the price of the material; Z_{tc} - the price of transport communications; Z_{oc} - costs for environmental protection measures; E_{oe} - the amount of own energy spent for a certain time on the main production processes; E_{AB} - the amount expressed in materials and equipment energy expended for the time considered; $E_л$ - the amount of human energy spent in the same time; E_{oc} - costs and losses from land use and environmental pollution, expressed in terms of energy equivalent; Q_f - quantity of finished goods produced during the same period.

Presented generalized theoretical conclusions reflect the main content of scientific approaches to solving the problem of energy saving management in deep quarries.

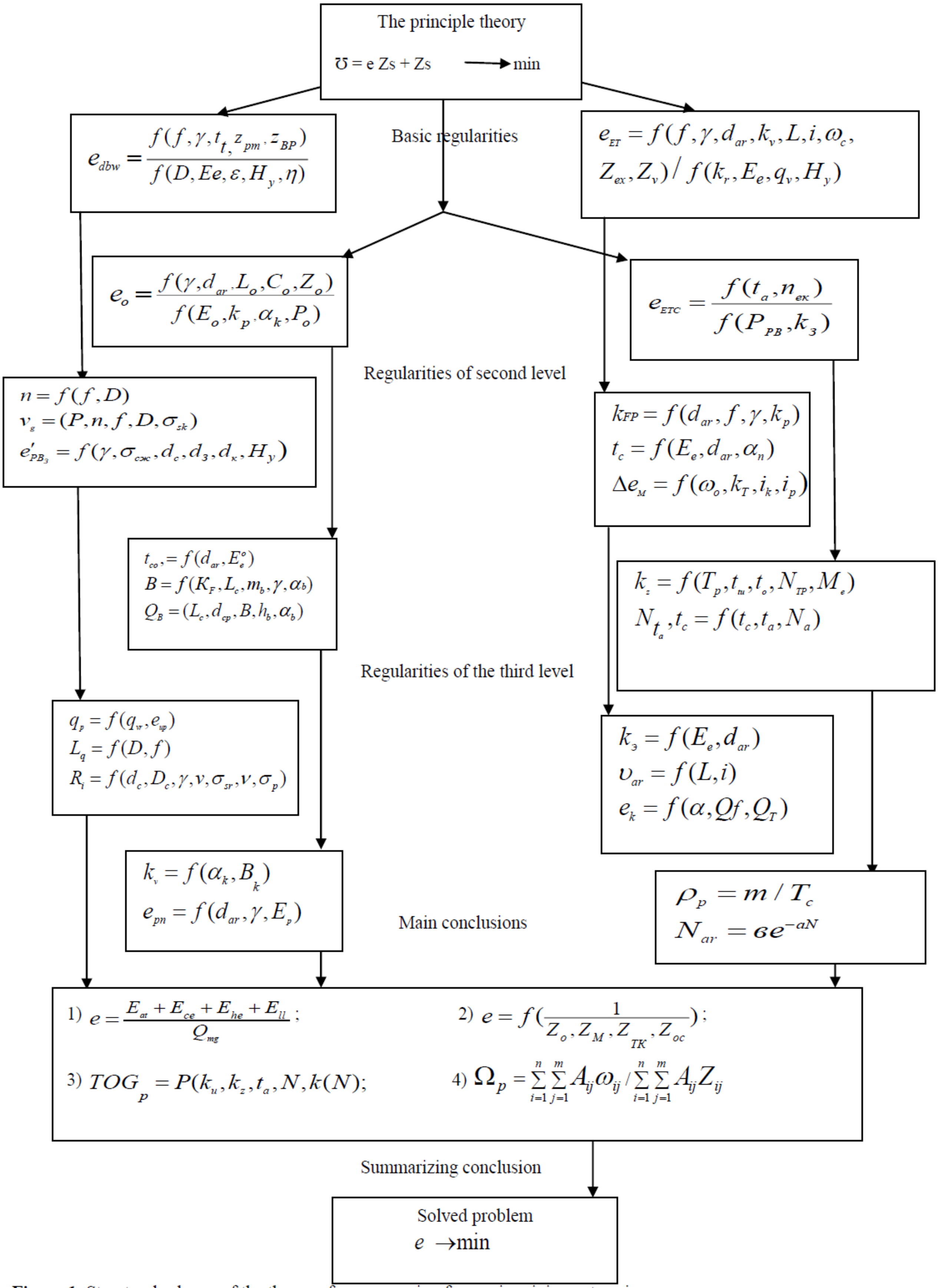

Figure 1. Structural scheme of the theory of energy saving for use in mining enterprises

4. RESEARCH RESULTS

The main task of modern mining science is to improve the technology of production in order to increase the productivity of social work or reduce the cost of units of commodity products. Increasing of the efficiency of mining production is possible only with the availability of reliable indicators of the cost of social work.

Efficiency is derived from the word "effect". The term "effect" is borrowed from the economic science in the terminology of the natural sciences, where it has long been widely used as a phenomenon (in physics, the Doppler effect, in technical terminology, the Joule-Thompson effect, etc.) or as a result of something (a hydroscopic effect in mechanics). Analyzing the use of the term "effect" in natural sciences, one can notice that in all cases it has the same meaning. Namely, characterizing the change of the state of any object or system, caused by the action of an internal or external cause. Obviously, a similar content in the concept of "effect" must be invested also in the process of mining production, which is a continuous or discrete change in the states of productive forces and industrial relations. Any change that occurs in the production process can be called the effect of production or the effect of labor. It is important to distinguish positive effects, when the changes are useful, and negative ones, when the changes are negative. All changes that take place in the production process have not only qualitative, but also quantitative certainty. That is, they can be evaluated by means of use of various quantitative indicators (parameters, characteristics, coefficients, etc.). Numerous production effects can be quantified by means of changing of relevant indicators. And since production figures are partial and general, then the corresponding effects of production can also be divided into partial and general. It should be noted that the concept of "general indicator", as well as the concept of "general effect", is conditional. The production process is rather complex and multifaceted. Its occurrence causes all sorts of changes that makes their comprehensive evaluation with one common indicator impossible, not to mention that we do not have any idea about some changes at all or even only guess that they exist. Therefore, by means of choosing this or that general production index, more or less we will approach the absolute value.

Absolute magnitude of the effect does not reflect the scale of production and production costs, and therefore, does not say anything about the price at which this effect is obtained. In other words, the absolute magnitude of the effect reflects only the quantitative evaluation of the results of production, but does not contain their qualitative characteristics. To obtain such a characteristic, it is necessary to compare the absolute magnitude of the effect with the cost of its receipt. Just this characteristic is the measure of the efficiency (effectiveness) of production. Consequently, in quantitative terms, efficiency, in contrast to the effect, is relative and its dynamics is not associated with any changes in the production process. Growth of production efficiency is possible only under the following conditions: increasing the effect at constant costs, reducing costs when achieving the same effect, increasing the effect at a slower rate of growth of costs. If the results and costs of production change in the same direction at the same pace, then the level of production efficiency remains unchanged.

In evaluating the efficiency of production, numerous indicators and criteria are used. Indicator in general is a qualitative sign or quantitative parameter characterizing the state of an object, phenomenon or process. Unlike the indicator, the criterion is a measure of the state of an object, phenomenon or process, that is, it represents distinctive features or conditions on the basis of which the evaluation, determination or selection of something is carried out. The criterion is not adequate to the indicator that forms its basis. Their difference lies in the role they play. If any indicator, including criterion, is a characteristic of the state of an object, phenomenon or process, then the criterion serves as a measure of this status evaluation, that is, the measure of evaluation, the level of the criterion, determining the boundaries or directions of its changes. Such evaluation is carried out by comparing the level of the criterion to the acceptable level adopted for the basis of evaluation or with the permissible limits by changes in the levels of the criterion, as well as with the levels of the criterion for other objects, phenomena or processes from a given set of population, or same for other states of the same object [9].

In general terms, we denote the level of the criterion through $X_к$. Then the criteria can be expressed through this indicator with the following possible conditions:

$X_к = a$;

$X_к < a$;

$X_к > a$; ,

$a < X_к < b$; (1)

$X_к = max$;

$X_к = min$;

where, a and b are the maximum permissible levels of the criterion.

Economic performance, efficiency and optimality criteria, as well as relevant benchmarks, can be general and partial. In the generalizing criterion, the criterion indicator comprehensively takes into account the change in all parameters and indicators that affect the level of efficiency. Partial criteria are based on partial criterion indicators that do not take into account some parameters and indicators that, in specific conditions of evaluation of the level of efficiency, are not subject to change, and, consequently, do not affect the level of efficiency.

The value of a criterion in any optimality criterion can be represented in the form of an ordered chain inequality:

$X_1 < X_2 < \ldots < X_n$, (2)

where, X1, X2 ... .Xn - the value of the criterion for the variants.

From the theory of inequalities, we will use some of their properties, which can be formulated in relation to expression (2) as follows:

1 - the meaning of the inequality will not change if all its members multiply by the same positive number a:

$aX_1 < aX_2 < \ldots < aX_n$; (3)

2 - the meaning of the inequality will not change if all its members multiply by the same negative number (-a) and change the signs of the inequality to the opposite:

$-aX_1 > -aX_2 > \ldots > -aX_n$; (4)

3 - the meaning of the inequalities will not change if all its members add or subtract from them a constant number "a":

$X_1 + a < X_2 + a < \ldots < X_n + a$; (5)

$X_1 - a < X_2 - a < \ldots < X_n - a$. (6)

On the basis of the above properties of inequalities, we formulate the basic properties of the criterion of optimality:

- the content of the criterion will not change if, from the criterion, exclude general factors and constituents, which are constant values for all considered variants;
- the content of the criterion will not change if the criterion is multiplied by (-1) and change the sign of the optimality criterion to the opposite (max on min and vice versa).

These properties of the optimality criterion can greatly simplify the generalizing criterion of optimality by its transformation into partial criteria. The choice and justification of the evaluation criterion is a very important point in scientific research.

The assessment criterion must meet the following requirements [10]:

- to meet the set task;
- be the only one to solve this problem in general;
- be measurable with a physical value;
- to be sensitive to changes in the parameters characterizing the process;
- reflect the interests of the state, of society as a whole.

Optimization of mining production is carried out in three distinct situations:

1 - on active production, which is equipped with equipment, with a certain technological scheme and with the established parameters of the development system;

2 - in the reconstruction of a deep quarry, when it is possible to replace technology or to restore it and change;

3 - during the process of designing a new quarry, when it is possible to compare several variants of relatively close and fundamentally other technologies and quarry options.

In the active iron-ore quarry, the possibilities of optimization are relatively limited by the already existing links of the technological chain of mining production.

In the reconstruction of a deep quarry, the possibilities for optimization are much larger. Here there is an opportunity in the changing mining-geological conditions of the development of the field to use new technology and technology. However, in this case, the change of technology is complicated by the fact that mining equipment already exists in the quarry, the deposit is opened with workings with certain parameters, a structure for the repair and maintenance of certain equipment is created, and there are competent personnel who are well-equipped with the available technology.

The most extensive opportunities for optimization are at the design stage of a quarry. In this case, the greatest effect is provided with a systematic analysis of the whole technology associated with the main parameters of the iron ore quarry.

To determine the efficiency of mining one uses natural and cost indicators that are the subject to quantitative consideration.

The advantages of natural indicators - their reliability, because they are obtained on the basis of quarry and engineering calculations. Natural indices include labor productivity, production capacity of a quarry, coefficients of overturning, coefficient of rock mass, energy intensity, metal intensity, and others like that.

Cost indicators: cost of production, operating costs, capital expenditures, profit, profitability, etc. They are generalizations that can cover virtually any factors affecting mining production [15].

Profit is the most synthetic, universal characteristic of production results (it is assumed that all prices are objectively quantified estimates). However, profit in itself cannot be the goal of social production, its purpose - to create conditions for the realization of this goal.

At present, for many reasons, confidence in the accuracy, correctness of economic indicators has been undermined. In an unstable economy, when inflationary processes are unpredictable, their reliability and comparability are relatively small. In these conditions, in the process of management of crisis phenomena one increasingly seeks for the use of different indicators, focusing on their comparative assessment.

The volatility of cost indicators in open mining operations in recent years is confirmed by corresponding annual reports on the production and economic activity of domestic mining enterprises. The main share in the evaluation of operating expenses for the extraction of 1 ton of ore in modern iron ore quarries is the cost of energy resources. In particular, the indicative distribution of total energy consumption in Ukraine's mining and processing enterprises is as follows: 1 ton of crude ore takes 6,4-8,3 kWh of electricity, 1-3,5 kW of inland carriage of the mine , and the transport of iron ore from the surface of the quarry fields to the enrichment plants is 2-3 kWh. At the same time, the most energy-intensive process of ore processing is enrichment, which consumes about 20% of all energy resources of the plant and is the main consumer of electricity - more than 45% of total costs, and the crushing of mineral raw materials accounts for 30% of the specified costs. At the same time, the depreciation costs for the restoration of technical and operational characteristics of outdated mining equipment in general for ore-mining enterprises of Kryvbas for 2016-2017 vary only from 23.8% to 18.5%, with a tendency to decrease them, which negatively affects the possibility of upgrading the technical and technological base and, accordingly, reducing the significant factors of energy-intensive equipment operation at the level of 70% by the main technological repartition of the extraction and processing of iron ore raw materials. Energy expenditures and expenditures on materials in recent years tend to increase substantially and reach 50% of all operating costs of the ore mining and processing enterprise.

5. DISCUSSION OF THE RESULTS

In the choice of the criterion for evaluating the appropriateness of its energy essence noted in his works, A.E. Fersman (defined the energy constants of the crystalline structure of minerals and developed the foundations of geoenergetic theory in 1937), who pointed out that researchers had to deal with a variety of phenomena and factors. This is the reason why in the analysis of natural relationships, one seeks to minimize the variables of independent variables, since all science goes towards the gradual reduction of the number of those primary units or primary properties of matter, which should serve as guiding parameters in the equations. Regarding the physical parameters and properties of minerals, he noted that the most generalizing and determining parameters would be the magnitude of the energy nature.

Significant energy intensity of mining production is evidently confirmed by the production of agglomeration at the Mine-Enrichment Division of Arcelor Mittal Kryviy Rih PJSC. In particular, the main share of energy consumption falls on electricity (70-80%), a little less share falls on diesel fuel (15-26%), and explosives (BP) accounts for only 1-6%. That is, there is a negative change in the specific energy consumption for the three types of energy considered (total energy consumption) when the annual production of agglomeration fluctuates, from which the sharp increase in the specific energy intensity with a sharp decrease in the production of agglomerate is clearly observed. There can be no other reason, because during the analyzed period the physical and chemical properties of rocks in the quarries have not changed significantly and the technology and mining technology have practically changed radically. At the same time, the consumption of diesel fuel and BP did not decrease a lot. Electricity consumption is also steadily increasing as a result of increased tariffs for consumption of 1 kWh by powerful equipment. Also, this can be explained by the fact that installed (connected) power of electric consumers has not changed significantly and production of sinter has decreased. In addition, unforeseen non-productive electricity costs sometimes increase because of the absence of qualitative programs for the introduction of energy saving measures at certain stages of the extraction of the iron ore in quarries. All this confirms the high variability of cost indicators.

It should be noted that energy in our day becomes a factor that limits the steady development of production and successful operation of the company in the short term as a whole, because it is the main constituent factor in the cost price of commodity iron-containing products.

Thus, the objective necessity of further development of the evaluation of the efficiency of technology, further strategic management and the organization of open mines according to the energy intensity indicator (e), which can be determined according to the proposed formula (7), has risen:

$$e=(E_{ae}+E_{ce}+E_{h}+E_{cl})/Q \quad (7)$$

E_{ae} - the amount of actual energy spent at a certain time by the main production processes;

E_{ce} - quantity of energy consumed in the period considered in materials and equipment;

E_{h} - amount of human energy spent for the same time;

E_{cl} - costs and losses from land use and environmental pollution, expressed in terms of energy equivalent;

Q - quantity of manufactured goods for the same period.

The complexity of the scientific and methodological plan consists in determination of the total energy costs for modern mining. That is why scientific research should focus mainly on solving the problem of energy saving management in deep iron ore quarries.

6. CONCLUSION

On the basis of the proposed theoretical work on energy saving problems that takes into account the practice and specificity of energy consumption in open mining operations, the following conclusions can be done:

- the solution of the problem of scientific substantiation of technological methods of reducing of energy consumption in deep iron ore quarries allows further development of the theory of energy saving, which includes basic principles, key regularities, regularities of the second and the third level, main conclusions and general conclusion.
- the improvement of the technology of open mining is possible only if there are reliable measurements of the cost of social work, that is, the corresponding criterion of evaluation. The most general and determining parameters of mining production are energy and economic indicators.
- the assessment of the technology of open mining operations according to the energy indicator should be carried out at the total energy input, which includes the amount of actual energy expended on the main production processes, the energy of human labor, the amount of deflated energy in materials and equipment, costs and losses from land use and environmental pollution, expressed in energy equivalents.

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