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Article

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INTEGRATED USE OF LIGNITE RESOURCES TO PROVIDE FUEL FOR THE ENERGY SECTOR OF UKRAINE IN THE WAR AND POST-WAR PERIODS

The object of research is technological processes for the complex development of lignite resources, including extraction, processing and the possibility of further use of derived products in the energy sector. The problem solved in the work is related to the underestimation of the complex use of lignite resources of Ukraine to provide fuel for the energy sector, which is suffering significant damage as a result of military operations.

In the course of research, the current state, prospects for the development and use of lignite as an energy resource at thermal power plants (TPP) were analyzed. Using the example of the Myronivka lignite deposit, new technological solutions for its complex development are proposed, which include the following stages:

– development of technological schemes for conducting mining operations with the possibility of selective extraction of minerals;

– identification of promising areas of lignite processing technologies with the involvement of carbonaceous clays;

– calculation of technical and economic indicators, social and economic efficiency of field exploitation.

It is proposed to determine the rational parameters of the overburden zones during the extraction of at least two minerals in the deposit with the use of internal dumping of overburden rocks in the produced space. In order to minimize the impact of field waterlogging, various options for draining the quarry field will be considered based on three-dimensional modeling.

Based on the methodology of expected operating costs, a preliminary economic assessment of the attractiveness of the proposed technological solutions was calculated for a conventional mining enterprise. Graphs of the dependence of mining costs and cost on the productivity of the cut and the overburden ratio were constructed, which made it possible to assert the feasibility of comprehensive development of lignite deposits of Ukraine. It has been established that the expansion of lignite raw materials due to accompanying minerals (coal clay) will lead to an increase in production by mass from 30 to 100 %, and in some cases even more.

Keywords: *lignite, integrated development, energy sector, open field development, associated minerals.*

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1. Introduction

In the period from 2013 to 2021, the extraction of almost all fuel and energy minerals decreased significantly. Coal production decreased by more than 60 %, and oil and natural gas production decreased by 0.5 million tons (23 %) and 1.6 billion m^3 (more than 5 %), respectively, compared to 2013 [1]. The reasons for the decline in production are complex. First, there are technological barriers, namely the depletion of deposits and problems with extracting reserves due to the depth of the deposits. Secondly, regulatory – the absence, at that time, of control over «dormant licenses», high rental rates. Thirdly, economic – unprofitability of coal mining. In addition, most of the balance reserves of natural gas and oil and gas condensate (86 % and 84 %) are already developed. Therefore, Ukraine is characterized by a high dependence on imports for all main types of combustible minerals and not only for the energy sector, but also for metallurgy, chemical and construction industries.

It should be noted that the situation worsened with the beginning of the heating season in 2021. According to the National Energy Company (NEC) «Ukrenergo» in October 2021, 22 power units of Ukrainian thermal power plants (TPP) did not work due to an emergency shutdown and a lack of coal [2]. Since the beginning of the war, the production of natural gas has decreased by 7 %, and the shortage of hard coal at TPPs and combined heat and power plants (CHPPs) of the country is from 10 to 50 thousand tons per day.

At the same time, in the bowels of Ukraine there are significant deposits of lignite of the Neogene age, which lie close to the surface. Occurrence at a depth of 20 to 150 m (on average 70–90 m) determines its extraction in the most economically advantageous way – open mining

operations (cuts). Lignite, unlike hard coal, belongs to a young type of solid combustible mineral and has different technical indicators and chemical properties. Therefore, in Ukraine it was not classified as an energy fuel for thermal power plants and thermal power plants.

As of 2022, the promising deposits of the Oleksandriya geological district are not developed, and in other districts some are in the stage of search and detailed exploration. As it is known, the criterion for the expediency of extracting a mineral by an open method is the so-called marginal coefficient of overburden (economically expedient), which shows at what volume of excavation of the mining mass the cost per ton of raw material extraction will be equal to or lower than its commercial value on the market [3]. Therefore, involvement in the extraction of associated minerals directly affects the economy of the mining enterprise and the expediency of exploitation of the deposit.

Previously, during the second half of the 20th century, about 10 million tons of lignite were processed into household fuel briquettes, and lignite wax and humate reagents and preparations were obtained at the one-of-a-kind enterprise – «Semenivka Mountain Wax Plant». Even then, domestic experts noted that the use of Ukrainian lignite as a chemical raw material is more profitable than burning it at thermal power plants/thermal power plants, boiler houses, and in households. German specialized enterprises and scientific institutions also have such conclusions.

A good example of the use of lignite is the Federal Republic of Germany (FRG), where more than 125 million tons per year are currently mined (Fig. 1), mainly as a fuel for the energy industry [4]. At the same time, almost a fifth of the entire electricity generation in the country or more than 100 TWh per year is produced (Fig. 2) [5].

The global significance of the use of lignite is confirmed by German experts, who note that this type of fuel remains in demand in the energy industry until the moment of full transition to renewable energy sources [6].

It is worth noting that similar processes regarding the revitalization of the role of lignite are taking place not only in the flagship of European industry, but also in other EU countries. In particular, in Greece, russia's invasion of Ukraine forced the government to return to the use of lignite. This led to the opening of the Ptolemaida 5 Lignite TPP with a capacity of 660 MW, which is of strategic importance. At the same time, the cost of lignite in the electricity price policy structure for Ptolemaida 5 will be 30 EUR (32.16 USD) per megawatt-hour (MWh), compared to 45 EUR (48.25 USD) for the old lignite stations. The new plant will emit one ton of carbon dioxide (CO_2) per MWh, compared to 1.4 tons for older TPPs.

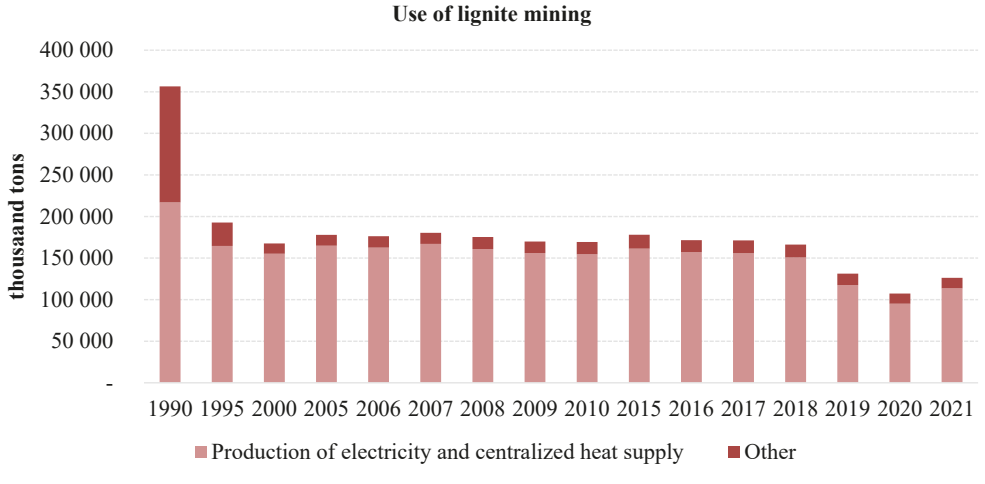

Fig. 1. Schedule of use of lignite mined in the Federal Republic of Germany for electricity generation and provision of centralized heat supply by year

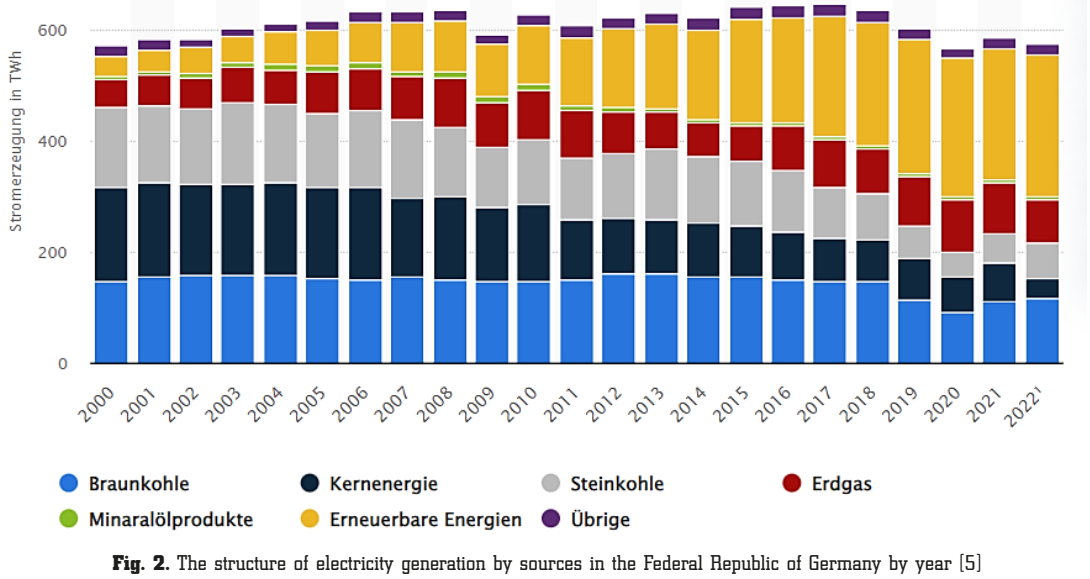

Fig. 2. The structure of electricity generation by sources in the Federal Republic of Germany by year [5]

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It should be noted that the current prices in Ukraine operating on the intraday market (IDM) and the day-ahead market (DAM) are at the level of 67–84 USD/MWh. In the same period in neighboring countries – 152 EUR/MWh (Poland) or 167 EUR/MWh (Hungary).

Lignite is considered not only as a primary energy carrier in Germany, where in recent years there has been a program with the general business goal of developing new technologies for the production of basic substances for the chemical industry from lignite along the entire value chain (lignite chemical park). German specialists claim that lignite is a raw material that is the basis for the production of unique chemical products (lignite wax), fuel and lubricants, as well as synthesis gas and its derivatives, with special attention to the responsible use of raw material from an economic and ecological point of view.

According to preliminary estimates, the cost of obtaining a ton of conventional fuel may decrease by more than 20–30 % if associated minerals, namely carbonaceous clays, are involved in the extraction of lignite. In the case of involvement in the extraction of other minerals [7], it is possible to achieve the lowest cost price with an increase in synergy. In this regard, the joint mining of coal and related minerals (coal clays, sandstones, loams and clays, water resources), especially in conditions of fuel shortage, is an urgent problem for the sustainable development of Ukraine, and the provision of fuel for the energy sector in the conditions of resistance to aggression from the Russian side.

Previously, at the operating enterprises of the state holding «Olexandriavugillya» it was virtually impossible to extract various raw materials. At the lignite sections operating at that time, mining operations were carried out by powerful rotary and chain excavators with a working height of ledge up to 40 m, and all the rock from the outcrop, in a single stream, was directly stored in the created space by conveyor transport [8]. Therefore, even if there was a need for sand or loams and clays, it was technically impossible to selectively extract this resource.

It should be noted that during the development of project documentation for the development of lignite deposits as the main mineral, only lignite was considered within the established seam contour within the quarry field, taking into account the quality, mainly according to the ash content. The possibilities of mining carbonaceous clay and other minerals were not considered, and lignite, the layers of which were smaller than those accepted by the deposit before mining, or which went beyond the limits of the mining contour (quarry field) were written off as unsuitable for mining. Also, the use of mining machines of the previous generation led to the loss of conditioned coal due to the impossibility of selective mining. At the same time, in the EU countries and in particular in Germany, the issue of coal mining with minimal losses is relevant not only in the development of the field development project, but also in the current sections [9].

Specialists from the Freiburg Mining Academy constantly carry out research work on optimizing the technology of mining operations, so coal losses at German enterprises are minimal. Moreover, since there are several layers of industrial coal with different quality indicators in the German deposits, the possibility of selective development of deposits depending on the directions of their processing is used during their extraction. Optimization of mining technology in Germany makes it possible to develop even those deposits that were previously mined.

Moreover, mining companies in Germany are also faced with the issue of dewatering of lignite deposits. For example, on some high-capacity sections, water inflows into the pits significantly exceed the volume of Ukrainian deposits and reach the level of 5000 m^3 per hour or even more [10]. That is why the Federal Republic of Germany has developed technical solutions to reduce the inflow of water into the cut. This is, first of all, the construction of waterproof walls to a depth of up to 100 meters from the side of the groundwater inflow. In addition, German specialists not only provide technical solutions for the drainage of the quarry field, but also plan in advance how groundwater flows will be formed after decommissioning the mining enterprise, and how the water body (lake) will be located and its configuration in former mine workings [11].

The experience gained in the implementation of project-scientific developments with the use of fundamentally new equipment and technologies allowed the team of authors to perform several research works on the substantiation of parameters for the development of lignite deposits located close to each other by a joint venture based on the Novo-Dmytrivka deposit. A number of fundamental works on the justification of the involvement in the development of associated minerals of non-ore deposits of Ukraine have also been performed [12, 13]. However, only the technologies of opening, preparation and processing of lignite layers were studied, and the extraction and use of carbonaceous clays and various associated rocks with the justification of technologies and parameters of their separate use as additional raw materials were not considered. But their varieties are high-tech, high-quality raw materials. For example, under the leadership of prof. Yu. Razumny, with the participation of O. Bielov, as part of the feasibility study, the technology for the production of lignite wax (a component of lignite), which is scarce for Ukraine and the world, was developed and the feasibility of its production in the amount of 7.5 thousand tons/year was established, which provided an annual gross income of 10.5 million EUR (in 2000 prices) with a payback period of 7.5 years. As for other accompanying minerals, the technologies of their complex extraction with quality and volume assurance during the development of various types of powerful lignite beds have not been studied enough.

In order to solve the mentioned problem, it is necessary to carry out a study to determine the reserves of lignite and related minerals in the areas of the Myronivka lignite deposit of the Oleksandriya geological and industrial district. At the same time, special attention should be paid to the reserves of the main and related raw materials, which are outside the boundaries of the quarry field, which was considered earlier during the study of the Myronivka deposit. This will make it possible to expand the fuel (raw material) base of Ukraine at the expense of its own capacities and reduce dependence on the import of coal and, if necessary, hydrocarbon raw materials for the chemical industry in order to obtain highly liquid products.

It should be noted that technology options for the complex development of a lignite deposit using modern high-performance equipment will be based on reducing energy, material and metal consumption, reducing the negative impact on the environment, rational use of subsoil and land areas, increasing labor productivity and capital return.

Therefore, *the aim of the study* is to evaluate technological solutions for the extraction and processing of

lignite and related minerals to ensure the integrated use of subsoil resources, taking into account the requirements and needs of the energy sector.

In order to achieve the set aim, it is necessary to solve the following research problems:

– analysis of promising mining technologies and determination of directions for lignite processing with the involvement of associated minerals;
– economic assessment of the attractiveness of obtaining derivatives of lignite processing with the involvement of fuel in the energy complex;
– development of recommendations for the comprehensive development of lignite resources with the establishment of budgetary and social efficiency of their use.

2. Materials and Methods

The object of research is technological processes for the complex development of lignite resources, including extraction, processing and the possibility of further use of derived products in the energy sector.

The following methods were used when performing the work:

– technical and economic analysis – to substantiate the choice of optimal options for technological schemes for the development of lignite deposits;
– scientific generalization – for the processing and analysis of information sources regarding the study of promising areas of lignite processing;
– economic assessment of the dynamics of design and planning indicators (forecast of cash flows, discounting of monetary estimates, normalized cost of electricity or Levelized Cost of Energy) – to justify the technical and economic parameters of open pit mining of lignite depending on the volumes and overburden coefficient of the deposit.

3. Results and Discussion

3.1. Proposals and technological solutions regarding the possibility of complex development of lignite deposits of Ukraine. In order to solve the first task of the research and in order to solve the issue of expanding the fuel base of the energy sector of the country, the authors of the work propose to create digital 3D models of lignite deposits with a display of the configuration of the layers of the main and associated minerals. At the same time, available minerals are calculated both in the quarry field and outside it, taking into account the debit of water by areas.

In the future, it is necessary to establish the volumes and quality indicators not only of lignite reserves, but also of associated minerals in areas of the deposit, which is considered with gradation according to the economic feasibility of their extraction and the possibility of modeling repayment (extraction) with given conditions. Further volumes of production (repayment) of the established indicators of mineral reserves will be substantiated taking into account modern economic, social, ecological factors and taking into account the state of the real fuel balance of the country.

Taking into account the experience of open mining, the research is based on the approach that the separate (selective) development of complex-structured lignite deposits with soft rocks can be implemented at the minimum necessary level with gradual development of deposits. As the main option, a mining scheme using equipment consisting of compact rotary or chain excavators and belt conveyors with the organization of intermediate warehouses of developed rocks or, if necessary, man-made deposits for future use can be considered. An alternative to considering such technologies are milling combines and single-bucket excavators with a bucket capacity of up to 50 m^3 in a complex with dump trucks with a load capacity of up to 360 tons. Protection of the earth's surface from violations by external dumps is possible when creating temporary dumps both near the quarry field and on its surface, followed by moving them into the created space.

The substantiation of the novelty of the technological schemes of complex industrial development of the deposit will necessarily be based on the evaluation of possible options for the use of the extracted carbonaceous mass (different ratios of coal and carbonaceous clay) depending on its quality indicators. The use of the mining enterprise's products is possible both at existing enterprises of the energy sector and at industrial facilities of potential consumers of lignite processing products and mineral resources. The proposal to build a new processing complex near the deposit will be considered, taking into account the logistics of raw material delivery. In order to rationally use the subsoil and reduce the cost of the main products, qualitative and quantitative characteristics of underground water will be established in order to develop proposals for their use in the national economy.

Upon completion of the research, it is possible to develop a sketch project for the created technology of extraction of lignite and related minerals of the deposits, ready for implementation and for consideration by potential investors as an object of future business.

The established indicators of the productivity of the lignite pit with the accompanying extraction of carbonaceous clays and other resources will become the basis for the future development of the enterprise's technological line for obtaining various products that will be in demand on the market.

The next stage of the study provides for the determination of the characteristics of the main extraction-loading and transport equipment, and the quality indicators of the extracted raw materials in the warehouse of the mining enterprise are established. When developing the technology for conducting mining operations and extraction of solid minerals, technical decisions regarding the use of water resources, determining the level of chemical and mechanical pollution, carrying out a technical and economic assessment of possible options and providing proposals for the most rational use of groundwater will be taken into account.

After the mining technology is developed, the feasibility of processing lignite and related minerals will be substantiated.

The final task will be the calculation of technical and economic indicators, social and budgetary efficiency of exploitation of the field sites in comparison with past project data (if available). When comparing the technological solutions of the development systems of the deposit, the load on the atmospheric air will be calculated based on the emissions of greenhouse gases, as well as other pollutants. On the basis of this, recommendations will be developed regarding the further implementation of the created technology and the order of development of the field sites according to the performed ranking.

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As an example, it is possible to consider a lignite deposit on which a mining enterprise existed in the past, namely, the Kostyantynivka lignite cut. Currently, the section, due to bankruptcy, is effectively liquidated as an industrial facility. At the same time, it does not belong to the register of liquidated mining enterprises or those that are in the stage of liquidation. Therefore, in fact, on the territory of the former mining enterprise, the reclamation of disturbed areas is not carried out, and the abandoned mine workings are flooded and pose a direct threat to the lives of the residents of the territorial community. The beginning of the reclamation of this section is not foreseen, because there are existing problems with financing such unremunerative works. By analogy with other similar sections, it is necessary to attract more than 10–12 million USD for reclamation works. That is, such a sum of money can be compared with the construction of a new modern mining enterprise with a moderate capacity. This area will also be considered from the point of view of resumption of mineral extraction, and for the territories disturbed by mining operations, appropriate calculations and recommendations will be provided for their return to the use of the territorial community.

Today, lignite is almost not used in Ukraine, unlike the countries of Central and Eastern Europe (275 million tons in 2021) [14] and the USA (47.4 million tons in 2021) (Fig. 3) [15].

This attitude towards lignite arose only because this type of solid fuel belongs to the lower rank of coalification and has its own technological features, as well as sufficient reserves of hard coal at that time. Nevertheless, lignite reserves, in terms of conventional fuel, amount to hundreds of millions of tons. At the same time, the involvement of balance and off-balance reserves of lignite of Ukraine will allow to significantly reduce the share of imported energy resources. Existing technologies for the development and processing of lignite do not allow its use as fuel for existing thermal power plants due to their non-design quality characteristics. The expected advantages of the technological solutions that will be developed by the authors of the work, over the existing ones, consist in the involvement of the fuel and raw material bases of the country in areas of deposits that were previously considered unpromising for extraction by open mining operations (cuts) due to the involvement of associated minerals, including recommendations for their processing for receiving new products.

The development of lignite deposits of Ukraine is significantly underestimated, taking into account price parameters and world trends in the use of this raw material. For example, world experience shows that the production cost of ordinary lignite can be at the level of 30–50 USD according to t.c.f. in it. For comparison, as of the end of 2022 and the beginning of 2023, the cost of natural gas for industry is in the order of 450–550 USD/t.c.f. or higher by almost 10 times relative to the cost of lignite mining.

For example, obtaining a concentrate with qualitative characteristics similar to the energy coal of the gas group allows the use of this fuel in virtually all coal-fired power plants of Ukraine, except for those operating on anthracite. And the use of lignite raw materials as a substitute for natural gas to obtain synthesis gas is possible at nitrogen industry enterprises after installing the appropriate gasifiers.

Given that, according to preliminary estimates, the volume of carbonaceous clays in the lignite deposits of Dniprobas can be from 30 % to 100 % of the lignite reserves, and in some cases even more, as, for example, in the Nova Dmytrivka deposit, the reserves of carbonaceous clays amount to 624 million tons.

3.2. Preliminary economic evaluation of the proposed technological solutions. The economic effect of the introduction of the proposed technological solutions has a large number of components and is determined depending on the current fiscal year, and the need for related minerals and other input prerequisites. In addition, investments in production when calculated per unit of production can be in a wide range and are calculated for each deposit separately depending on the parameters of the mining enterprise under consideration. For example, for a conventional mining enterprise, graphs of dependences of expected operating costs (OPEX) on extraction and cost forecast on the productivity of the cut and the overburden coefficient (K_{over} were constructed (Fig. 4, 5)).

Based on the above data, it can be seen that the cost of lignite mining by an open-pit mining enterprise or cut mainly depends on its productivity. For example, if the configuration of the quarry field allows mining from 1.5 to 2.25 million tons per year, and the productivity of the cut is below 1.5 million tons, then already at the level of 1.25 million tons, the production cost exceeds 20 USD per ton and vice versa, when the design capacity is reached, it decreases by more than 50 % to the level of 13–14 USD/t.

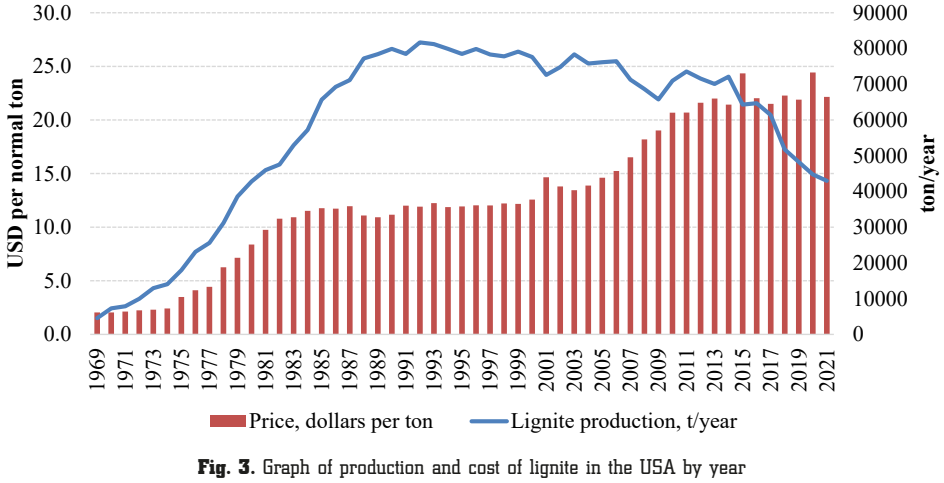

Fig. 3. Graph of production and cost of lignite in the USA by year

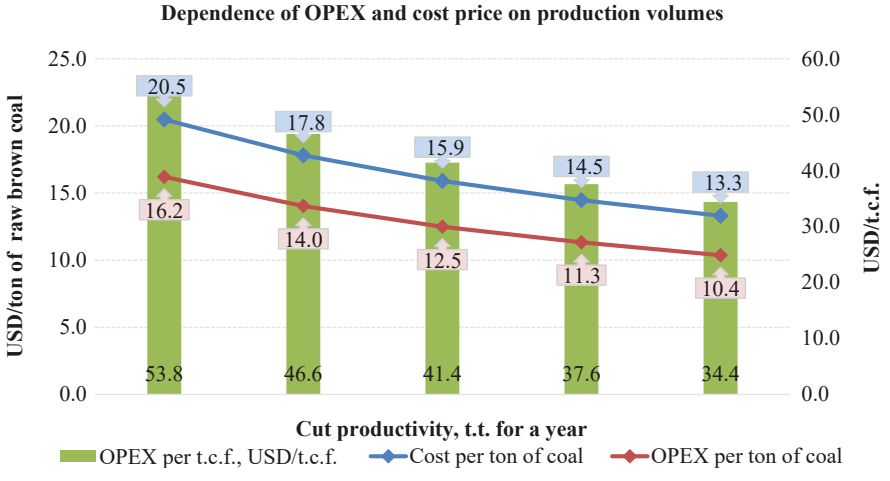

Fig. 4. Graph of dependence of expected operating costs and cost of extraction on the cut productivity

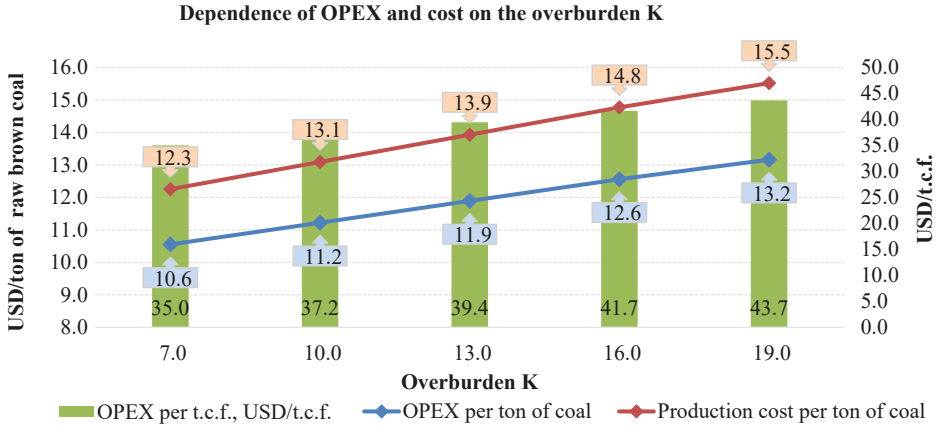

Fig. 5. Graph of dependence of expected operating costs and cost of extraction on the overburden coefficient of the deposit

The given example indicates that the dependence of the mining enterprise on the overburden coefficient is less sensitive. So, with the growth of $K_{over.}$ by 2 times from 9–10 to 19 m^3/t, the cost price increases by less than a third under the condition of the same productivity of the mineral. All this indicates that a thorough study of the mining and geological conditions is required in advance of the development of the deposit or its section. At the same time, the choice of the optimal scheme of conducting mining operations and mining equipment is a key task and a guarantee of the future economic condition of the mining enterprise. This factor is decisive, taking into account the fact that currently Ukrainian lignite deposits have a linear coefficient of overburden of 9–10 m^3/t per ton and higher.

Analyzing the structure of costs for lignite mining (Fig. 6), it is worth noting that about 40 % of the total costs belong to the article electrical energy, which is spent on draining the cut and on the provision of mining machines and equipment. Taking into account that conventional fuel in lignite has a rather low cost and the presence of an additional accompanying mineral (coal clay); the extraction of two minerals together makes it possible to reduce the specific norms of costs for the mining enterprise. Secondly, the obtained additional cheap energy carrier can be used for the production of own electricity for the needs of the mining enterprise.

Thus, shown in Fig. 4, 5, the approximate values of the cost price and OPEX for the extraction of ordinary lignite can be further reduced to the level of the purchase of electrical energy from the outside. If you look more broadly, when producing your own electrical energy, it is advisable, in order to increase the fuel utilization rate, to also receive thermal energy, which should be directed to the drying of dry coal. Such a technological scheme, where in a single technological chain both the extraction of wet mining mass and its drying, allows obtaining finished products in the form of dry coal or commercial briquettes with a moisture content of 20 % and a calorific value of more than 4000 kcal/kg.

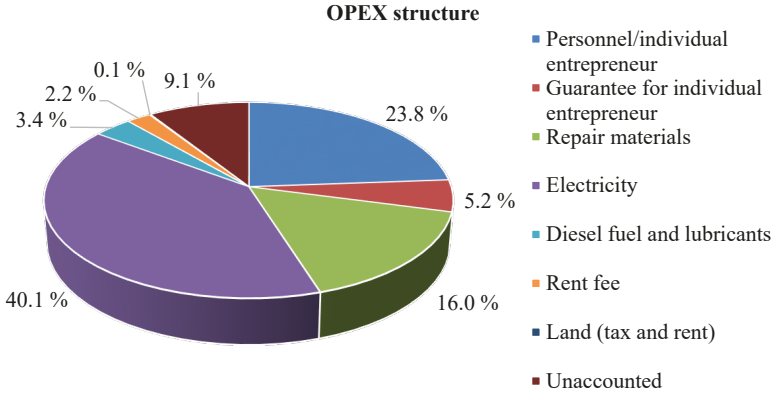

Fig. 6. Diagram of the OPEX structure of ordinary lignite mining

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For a clear preliminary economic assessment and attractiveness of the project on the integrated use of lignite resources, it is recommended to compare the prices of primary energy carriers operating on the fuel market. For the basis of the price of ordinary lignite, the price of similar fuel in the USA and Germany or at the level of 20 USD can be taken or about 70 USD per ton of conventional fuel (t.c.f.).

Accordingly, comparing with the current prices for hard coal and natural gas for different groups of consumers, it can be stated that the cost of lignite is 2 times lower than: natural gas sold for the needs of the population, 7 times the exchange price; hard coal supplied by import is 2.5–3.0 times (Fig. 7).

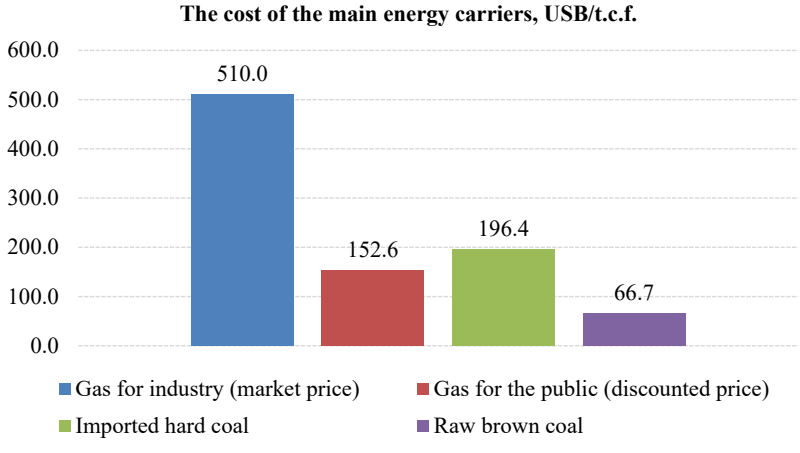

Fig. 7. Dependence of the cost of lignite on other types of energy carriers calculated per t.c.f.

If the production of ordinary lignite is developed by at least 50 % of the level of the 80s with the achievement of volumes of 5 million tons/year and more, or equivalent to the conventional fuel of 1.5 million t.c.f., the annual savings from replacing other fossil fuels will amount to about 100 million USD/year relative to the cost of natural gas prices for the population. Or almost 200 million dollars, when replacing imported hard coal or more than 0.5 billion USD/year, but without taking into account such factors as the cost of transportation and the efficiency of power plants. Taking into account the creation of new jobs at mining and other related enterprises in the amount of at least 1,200–1,300 units and, accordingly, the expansion of the tax base, it can be argued that the additional socio-economic effect will amount to about 30 million USD per year.

Thus, the advantage of the obtained research in comparison with domestic and global analogues lies in the involvement in the open development of off-balance sheet reserves of lignite and other related minerals, which makes it possible to significantly expand the fuel base of Ukraine. Among the limitations of the use of research, the difficulty of restoring the production of lignite resources due to the lack of a single development strategy for the use of fossil fuels in the energy sector should be highlighted. Also, lignite has somewhat lower quality characteristics compared to hard coal, which requires further research on its processing. In order to implement the results in practice, it is necessary to develop a sketch project for the ready technology of lignite extraction, which includes technical and economic modeling of options for technological schemes and can be accepted for consideration by a potential investor.

4. Conclusions

The current state and prospects of integrated development of lignite resources of Ukraine are analyzed. It has been established that the issue of attracting lignite in the energy sector, which is constantly damaged as a result of military operations, is urgent. This is confirmed by the existing global experience of producing electricity from lignite in Germany, the prospects for its use at energy-generating enterprises in Europe, in particular Greece, and the indicators of production in the USA.

Using the example of the Myronivka lignite deposit, technological solutions for its complex development are proposed, the novelty of which is the involvement in the open development of off-balance reserves of lignite and related minerals (coal clays, sandstones, clays, loams, water resources). To solve the task of complex development of the deposit, the following stages are considered:

– development of technological schemes for conducting mining operations based on 3D modeling of sites;

– identification of promising areas of lignite processing with the involvement of carbonaceous clays;

– preliminary calculation of technical and economic indicators, social and economic efficiency of field operation.

A preliminary economic assessment of the attractiveness of obtaining derivatives of lignite processing with the involvement of fuel in the energy complex has been carried out.

For a conventional mining enterprise, graphs of dependences of expected operating costs (OPEX) on extraction and cost forecast on cut productivity and overburden coefficient were constructed. It has been established that with production volumes of 5 million tons/year, annual savings from replacing other fossil fuels will amount to 100 million USD/year. The social effect consists in the creation of new jobs in the amount of at least 1,200–1,300 units.

Technological solutions for the complex development of lignite deposits will be useful for solving the issue of expanding the resource base of the country's energy industry due to the extraction of lower-rank coal and carbonaceous clays. Upon completion of the research, it is advisable to develop a sketch project for the created technology of extraction of lignite and related minerals of the deposit, ready for implementation, with further consideration by potential investors as an object of future business.

Conflict of interest

The authors declare that they have no conflict of interest in relation to this research, whether financial, personal, authorship or otherwise, that could affect the research and its results presented in this paper.

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Data availability

The manuscript has no associated data.

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