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SUBSTANTIATION OF THE WAYS TO USE LIGNITE CONCERNING THE INTEGRATED DEVELOPMENT OF LIGNITE DEPOSITS OF UKRAINE

Purpose. To substantiate the ways of the integrated lignite use as well as its derivatives by power, metallurgical, chemical, and construction industries of Ukraine to support the competitiveness of the country market.

Methodology. The following research techniques were applied to solve the problems: mathematical modeling method was used to determine volumes of lignite extraction and to identify the intensity of inflows to opening mine workings while forming the operating area of an open pit; the method of graphic-analytical and mining and geometrical analysis was used to optimize parameters of open-pit mining operations in the process of their deepening; the method of techno-economic analysis of variants was used to select efficient schemes to extract productive lignite levels under complicated mining and geological conditions; and the method of economic modeling was used to determine investment attractiveness of lignite derivatives.

Findings. Current state of mining enterprises extracting lignite has been analyzed to determine economically viable techniques for its processing. Investment attractiveness has been evaluated concerning ammonia production with the use of a technique of financial and mathematical expenses. Recommendations have been provided as for the future research on lignite mining and processing for the construction of the integral processing enterprise.

Originality. Both attractiveness and profitability of ammonia production on the basis of technique of financial and mathematical expenses have been evaluated since ammonia is the most efficient lignite derivative. The studies have shown that IRR of lignite-based ammonia production is over 10 %. Estimation of technical and economic parameters of ammonia production as the basic product makes it possible to recommend lignite and the associated reserves of coal clay as the raw material to generate synthesis gas instead of natural gas used by chemical industry of Ukraine. Calculations on the adopted scheme of a deposit mining have shown that it is possible to produce the cheapest crude hydrocarbons in terms of equivalent to a ton of equivalent fuel in the Ukrainian energy market. The obtained cost values of the equivalent fuel ton are more than 5 times lower compared with natural gas.

Practical value. The research results concerning the substantiation of a rational scheme to open and develop productive levels and economic and mathematical modeling of ammonia production make it possible to recommend lignite as crude hydrocarbons for chemical industry which will favor the revival of lignite industry in Ukraine. Construction of a processing complex for ammonia production on the basis of Novo-Dmytrivka deposit with 2.7 to 3.8 million tons of annual output will help decrease the country's dependence on import natural gas; increase pumping up the budgets and funds of all levels by the projected amount of no less than UAH 5 billion a year; provide the local communities with new jobs; attract almost USD 5–6 billion of investment; and develop marginal product within the related industries.

Keywords: *lignite, opening and developing of deposits, complicated hydrogeological conditions, economic and mathematical modeling, lignite processing, gasification, ammonia, production profitability*

Statement of the problem. Lignite reserves of Ukraine are significant making more than 3.5 billion tons of balance reserves and 8.6 billion tons of prospected ones. The reserves have been extracted since the 1940s–1950s on the basis of German mining and hoisting equipment delivered in the "line of special supply". From the period up to the start of the 2000s, lignite mining volumes made 12 million tons a year [1]. The product was used as raw material for the lignite briquettes applied mainly as domestic fuel and, partially, for Kirovohrad thermal plant and as chemical raw material to be processed by Semenivka mineral wax plant (SMWP).

Ukrainian lignite reserves are mainly concentrated within the Dnieper lignite basin and within certain deposits in Kharkiv and Poltava Regions (Novo-Dmytrivka and Sula-Udai deposits, respectively); moreover, reserves of the former are recorded by the Government's Balance of Revenues and Expenditures of Ukraine [1].

The Dnieper lignite basin is in the center of Ukraine; in the form of a broad band it stretches northwest-southeast crossing Zhytomyr, Vinnytsia, Kyiv, Cherkasy, Kirovohrad, Dnipropetrovsk, Zaporizhzhia, and Mykolaiv Regions. Total length of the basin is 650 km and its width is 70–175 km. Its area is 10 million hectares to be 16.5 % of the total territory of Ukraine [1].

Almost 200 deposits are known within the basin. The Government's Balance of Revenues and Expenditures of Ukraine has recorded 27 deposits including one deposit in Zhytomyr Region, 7 deposits in Cherkasy Region, 12 deposits in Kirovohrad Region, and 7 deposits in Dnipropetrovsk Region. 11 of them are suitable for open-pit mining [1].

Mining conditions of the basin deposits are complicated due to the availability of semi-stable rocks and several water-bearing levels including artesian ones (percarbonic whose thickness is up to 50 m; overcarbonic one whose thickness is up to 60 m, and inter-coal one). The coal seams occur in the formation of loose sandy and clay rocks, which predetermines significant water content of sites complicating open-pit mining operations. Aquifers of percarbonic sands are of high filtration properties (filtration coefficient is 5 to 25 m per day); dewatering wells drain them quite successfully. On the contrary, overcarbonic sands are of low filtration, which involves additional research concerning drainage of productive coal levels.

At different times, *Burugol* Group, later transformed into integrated works, and *Aleksandriaugol* SHC (used to be the State Association) were the main operators to extract and process lignite in Ukraine. After structural subdivisions of *Aleksandriaugol* were lend leased, *Energougol* ltd became the key enterprise of the industry. The attempts to restart lignite mining by the efforts of *Burugol* SE and *Trest Aleksandriarazrez* failed. Currently, lignite is mined limitedly at Mokra Kalihirka deposit (Cherkasy Region) by *Enerhetychna investytsiina kompania* ltd. Reserves of the deposit are insignificant (7.8 million tons of $A + B + C_1$ grades). Previously, it was owned by *Aleksandriaugol* SHC where an open-pit coal mine was built in 1988–1997; its annual output was planned to be 300 thousand tons. Due to the lack of financing, the construction was ceased in 1998 and the site was put out of commission to "a" group.

Ultimately, the complicated situation in the industry resulted from underfunding and progressive wear of capital assets and influence of other factors caused actual liquidation of lignite industry.

In addition to the Dnieper basin where lignite has been mined for more than 100 years, the deposits of Northwest Donbas should be mentioned (Fig. 1). Novo-Dmytrivka deposit is the largest one among them. Its industrial reserves are more than 394 million tons with $A + B + C_1$ categories. Maximum thickness of coal levels is 74 m. In Barvinkove, Bakaleia, Izium, and Sloviansk Districts of Kharkiv and Donetsk Regions, there are located such deposits as Bantysh, Berek, and Stepky. They are of a synclinal structure having a number of associated minerals (i.e. diatomites, sulphur, mercury, building sand, glass sand, coal clay, zink, and others).

In this context, such deposits should be developed with applying a technology of integrated use of mineral reserves, stipulating the seams dewatering in proportion to their development; and taking into consideration the problems of rational use of land disturbed by open-pit mining [2, 3]. Precisely this program will help extract and process lignite involving minimum capital and operational costs [4, 5].

Analysis of the recent research and publications. The analyzed recent scientific papers, concerning open-pit methods, confirm that opening of deep lignite open pits and their developing are rather expedient procedures. Basing upon the carried-out research, opening schemes for open-pit field of Novo-Dmytrivka lignite deposit have been proposed; a criterion of efficiency to open deep watered deposit which is thought as minimum term of its putting into operation has been determined; basic methodological ideas regarding the formation of a system to open lignite deposits involving typical features of deep open pits operation in Ukraine have been substantiated [1, 6]. At the same time, problems of future use of lignite derivatives in mining and metallurgical, chemical, and power industries remain unsolved.

In turn, economic and mathematical evaluation of lignite mining cost under the complicated mining and geological conditions was performed taking into consideration mining and loading facilities [7]. The expediency of the integrated use of coal clay and lignite to reduce overburden coefficient has been substantiated [8]. Recommendations to save time required for lignite opening and accelerate its putting into operation have been given [9].

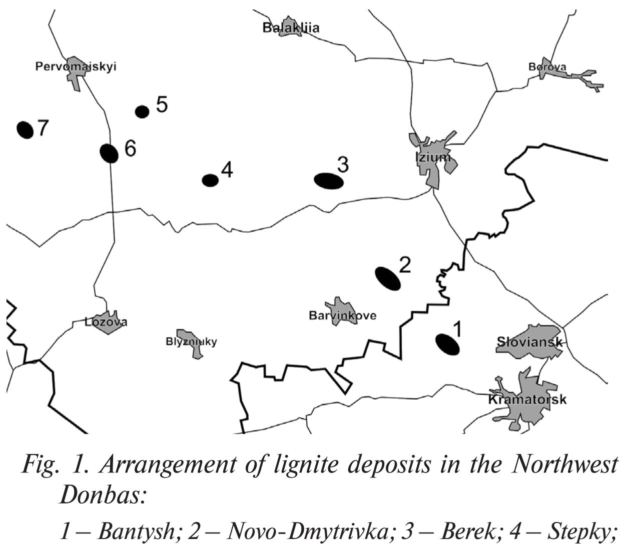

Fig. 1. Arrangement of lignite deposits in the Northwest Donbas:

1 – Bantysh; 2 – Novo-Dmytrivka; 3 – Berek; 4 – Stepky; 5 – Lozovenky; 6 – Biliaevka; 7 — Myronivka

The improved efficiency of reclamation on lignite deposits is rather important. It can be achieved while using specific transport facilities to hoist mineral to the surface instead of transport inclines [10]. The method has been substantiated from the viewpoint of economic effect without considering an economic component. However, the problems of further lignite processing with the separation of an economically sound marketable product are understudied.

It is necessary to mention the arrangement of lignite deposits in the Northwest Donbas located relatively close to a central processing area within Novo-Dmytrivka industrial site. Communication between the deposits and processing complex is possible by means of different types of transport used (Table 1).

As it follows from Table 1, Bantysh deposit is in the most favorable transport condition since it is possible to use highways and operating railway there. However, it should be noted that rail transportation of rocks will be followed by strict loading-unloading rules involving the construction of special service points. Operating highways also have their traffic standards to be kept. Thus, while scheduling future shipments, one should be focused on the construction of a new detached highway for high-capacity dumpers. In this context, traffic volume will be halved.

Together with the use of operating highways and railway, it is also possible to be geared to the use of pipeline transport where coal is transferred with the help of water energy or use of self-propelled transport which involves further studies.

Unsolved aspects of the problem. The above-listed papers emphasize the improvement of technological schemes for overburden extraction and mineral rock hoisting. However, insufficient attention is paid to the problem of integrated use of lignite and associated minerals.

Closure of enterprises mining lignite and processing it into fuel briquettes is indicative of low demand for the fuel type to compare with coal and natural gas. Nevertheless, in the near future, consequences of a conflict in Eastern Ukraine and the aggravated relations with the Russian Federation will make us consider lignite, which

Table 1

Distances of lignite transportation to the spot of its processing into marketable product within industrial site of Novo-Dmytrivka deposit, km

Deposit	New routes to facilities	Access to available routes	Available routes		Interconnection of the routes	Total length of the highway	
			Highways	Railway		Highway	Railway
Bantysh	16.0	0.8 0.8	8.8 30.4	20.0	0.8 0.8	10.4 32.0	20.0
Berek	19.2	0.8	22.4	–	0.8	24.0	–
Stepky	24.8	9.6	34.2	–	0.8	43.8	–

Ukraine is rich in, as an alternative energy carrier. Apart from its use for domestic needs, lignite may also be used to generate thermal energy by heating plants and thermal plants [11], to produce montan wax and humic products [12], engine fuel [13], methanol, ammonia and other end-products [14].

At the same time, looking for ways to utilize or apply industrial wastes (coal clay, ash, slag, and others) while extracting and using lignite remains an important problem. Nevertheless, the waste should be considered as the raw material for the resource-saving production of construction materials, sulphur, and aluminium for Ukrainian industries [15]. Besides, production of ammonia, being one of the most economically viable lignite derivatives, remains to be the critical problem.

Objectives of the article. The objective of the paper is to substantiate the ways for the integrated lignite use as well as the use of its derivatives in the context of power, metallurgical, chemical, and construction industries of Ukraine to support competitiveness of the country market.

Presentation of the main research. Depending upon configuration of a lignite deposit, its parameters, and occurrence of productive levels, different opening and mining methods are applied. It is worth distinguishing the following conditions, on which the order of development activities depends: internal conditions (thickness of seams and their angles; thickness of overburden rocks and their strength; the deposit watering; and highwall slope stability) and external ones (capacity of the open pit and the extracted mineral sales; salary level; type of ownership of the enterprise; purchase and use of highly productive mining and hoisting as well as transportation facilities; and profitability of the extraction) [16].

Various methods for mining lignite were considered taking into consideration mining and hydrogeological conditions of the Dnieper and the Donets basins. The first of them is the use of cyclic equipment (i.e. shovel excavators together with ground transportation facilities). The following involves the use of heavy-duty rotary excavators together with belt conveyors and overburden spreaders as well as rock mass transportation with the help of transport and dumping bridges. The alternative with continuous and cyclic equipment application while separating areas of their activities combined with the use of hydraulic excavators to dewater the open-pit field depending upon the mining deepening is also possible [17]. Each of the alternatives should take into consideration specific features of the deposit.

The analysis of the alternatives concerning lignite deposit opening and developing has shown that the prime cost of the mineral ton depends significantly on expenditures related to overburden operations. In the context of similar overburden rock volume-lignite ratio, cost for the deposit opening should be minimized.

Practices of the Dnieper surface mines have helped conclude that the use of transport-and-dumping or transport system as well as the use of cyclic facilities for immediate overburden dumping and seam mining is the most economically expedient for the conditions of flat deposits. The combined opening system applied by

Kostiantynivka surface mine of the Dnieper basin is the most representative one (Fig. 2).

Fig. 2 explains a scheme to open and develop flat deposits where it was foreseen to mine upper front bench by means of multi-bucket rotary excavator EPc-1120 with the separation into two subbenches and loading on a belt conveyor. The lower front bench is mined with the help of the equipment system consisting of a rotary excavator ЭР-5250 and overburden spreader ОШР-7000/190; overburden is piled within the inside dump. Three draglines of ЭШ 6/45, ЭШ 10/70 and ЭШ 11/70 types mine lower share of the main bench with further reexcavation of dumps. The complicated transportless schedule is applied. In this context, the mining operations had to be performed by means of Э-2503 and ЭКГ-5А excavators with the following truck loading.

Efficiency of the method is based upon the fact that certain overburden share is transported from the working bench using the shortest path through the working trench; then the rock is disposed into the worked-out area of the open pit. As for the mineral, it is delivered to the surface by means of trucks; it is warehoused and then moved to consumers. It should be noted that over the years owing to the lack of the repeat investment the efficiency of the method will increase. The fact will help the equipment operate with the rated capacity during the whole period of the surface mine life. If the technique is selected, then optimum cost of both opening and mining operations will be provided.

In view of possible inflows into the openings as well as watering of productive lignite levels it is required to make a prognosis of underground water regime with the consideration of the specific features of mining and hydrogeological conditions of the deposits [18, 19]. Numerical modeling of filtration is the popular approach to adequate forecasting.

Estimation of regularities of hydrodynamic regime of underground water is based upon the solution of the basic problem of the scheduled unsteady filtration

$$\frac{\partial}{\partial x}\left(T_x\frac{\partial H}{\partial x}\right)+\frac{\partial}{\partial y}\left(T_y\frac{\partial H}{\partial y}\right)+Q_w-\varepsilon=n_f\frac{\partial H}{\partial t},$$

where H is underground water level; T_x, and T_y are the water-bearing level on linear coordinates x and y; n_f is the fissuration factor of rock masses; Q_w is intensity of flows into the mine workings; ε is infiltration intensity; t is time.

Under the complicated hydrogeological conditions with the numerous variable parameters, it is expedient to perform filtration calculations involving numerical models where equations are solved by means of finite-difference methods based upon explicit and implicit schemes.

When the efficient method concerning both opening and developing of lignite deposits is substantiated, a problem to study its use and process in the context of different industries remains to be topical.

Briquetting. In the 1950–1980 ss, four processing complexes of *Aleksandriaugol* PA/SHC produced almost 4 million tons of briquettes among 10–12 million tons of the total annual output. Selection of the product was based on the following factors: cheapness of rough lignite mining in terms of 30–40 m depth of overburden operations and significant thickness of the coal seams; deficit of household fuel in rural regions of Ukraine and Moldova; and import of German equipment and methods in the “line of specific deliveries”.

In the late 20th century and in the early 21st century, the briquetting turned out to be unprofitable to compare with natural gas due to considerable energy-consuming costs with minimum cost of the end product as well as

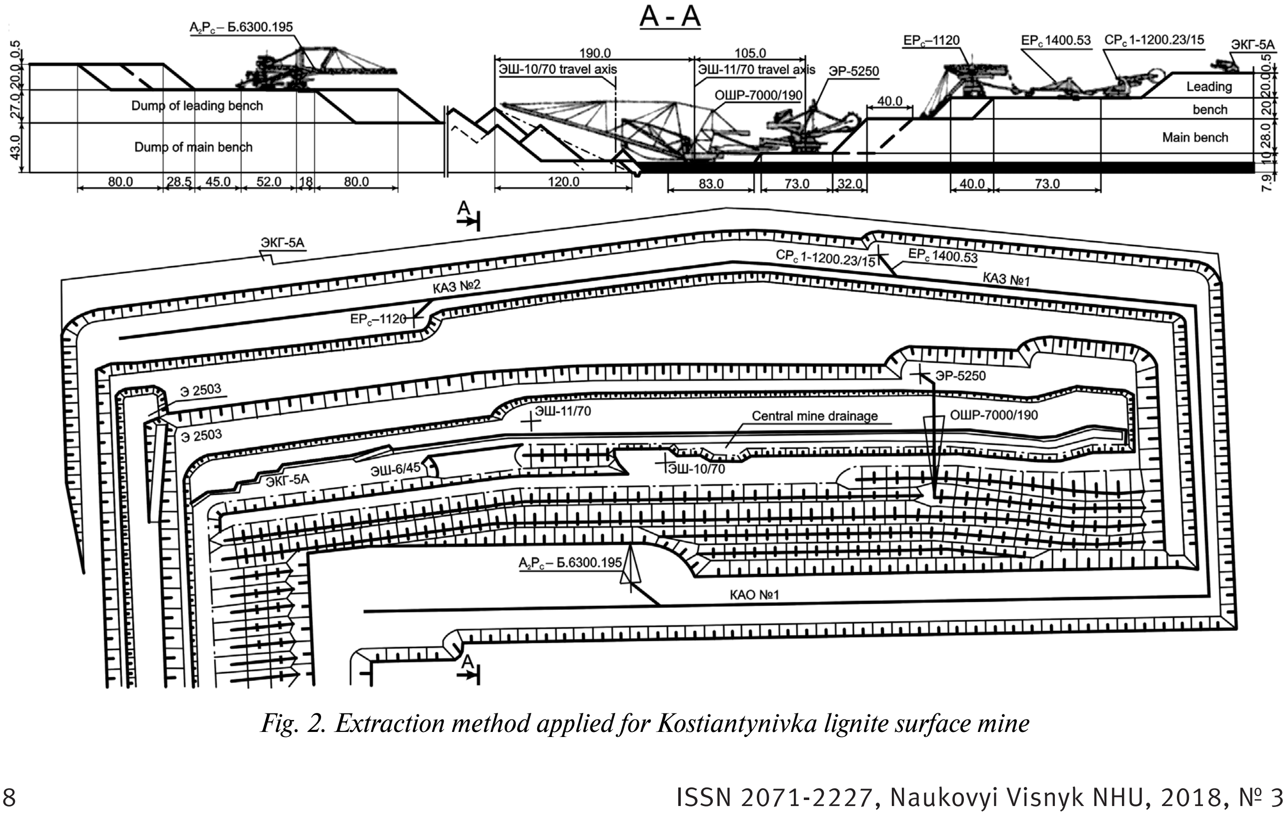

Fig. 2. Extraction method applied for Kostiantynivka lignite surface mine

under the worsening mining and geological characteristics of mining enterprises. Moreover, mining enterprises in Donbas could satisfy completely the national demands in solid fuel. However, rather high level of accidents (i. e. methane explosions, fires, and others) resulting in drastic social and economic consequences is a fundamental disadvantage of the mining technique [20]. In the context of economic changes, which have occurred in the country, the method to produce montan wax, used by Semenivka plant, turned out to be unprofitable. Nevertheless, ballast humates are still profitable.

Since Ukrainian lignite cannot correspond to the fuel parameters by the key consumers of coal product (i. e. thermal stations and thermal plants of power supply system of Ukraine) it is wise to consider it as the raw material for methods aimed at the production of a product with new properties. Currently, three types of techniques of solid fossil fuel (SFFs) are available.

1. Techniques to upgrade coal products to meet the demands of thermal stations and thermal plants, residential users as well as the cement sector and metallurgical industry while upgrading derivatives (i. e. processing and briquetting, pulverized coal fuel and coal-water one). The idea of the techniques is as follows: when SFF is being processed, no changes take place at the molecular level of organic matter. Macromolecule of coal cannot be destructed; transformation is the change in certain physical properties of coal.

2. Techniques to manufacture a product with new consumer properties making it possible to produce derivatives of radically different price range while using thermal action (i. e. coking, semi-coking, gasification and generation of such synthetic gas derivatives as methanol, ammonia, motor fuels and others as well as hydrogenation). The type of techniques differs in various destruction degrees of the organic matter and its transformation. As a rule, physical influence on the organic coal mass is applied to destruct its molecules. At the start, labile links are involved and then carbon-carbon line is added. Semi-coking and coking combine irreversible processes of decomposition of a matter, being heated, with the recovery of low-molecular products and condensation with the formation of solid high-carbon matters. As contrasted with coking process, gasification procedure results in complete destruction of organic matter. Gasification products (i. e. CO and H_2) can be used to synthesize various organic compounds. Hydrogenization of coal macromolecules and their modification take place in the process of hydrogenization making it possible to generate a matter with new physical and chemical characteristics.

3. Non-fuel technologies to produce montan wax, humate products, and adsorbents.

The techniques are based on the possibility to recover different components from coal matter depending on their solvability in various solvents to obtain substances of non-fuel application. That also concerns the production of montan wax, a product known in coal chemistry as bitumen or bitumoid, and humic acid sulphates. Production of the adsorbents belongs to intermediate techniques of types two and three.

Bitumens are extracted by means of their infusion from peat and coal using low-boiling organic solvents.

Generally, humic acids or their sulphates are extracted with the help of one-percent water solution of NaOH.

Sorbents are produced while heating in the process of alkaline activation with the availability of alkaline metal hydroxide within lignite frame.

As a rule, techniques of group three are applicable for coal of low metamorphism intensity belonging to lignite grade.

According to volumes and cost of extraction of a ton of fuel equivalent, one should point up group two, namely, generation of end-product (i. e. ammonia) and, conceivably, methanol as the most profitable processing line of lignite. Partially, lignite may be limitedly used as fuel for municipal thermal plants as well as raw material for the techniques of type three.

Currently, chemical enterprises of Ukraine are facing a problem connected with natural gas value resulting in noncompetitiveness of the national ammoniacals and, consequently, in the decreased production of ammonia and fertilizers. In this connection, preliminary technical-and-economic modeling of lignite-based ammonia production profitability has been performed. Informational materials (reports) posted on Web-portal of the National Energy Technology Laboratory (NETL) part of the U.S. Department of Energy (DOE) national laboratory system, TU Bergakademie Freiberg, Institute of Energy Process Engineering and Chemical Engineering and others are the source of basic parameters of an enterprise engaged in lignite gasification and ammonia synthesis; besides, they are adopted to a grade of lignite being considered [21]. Fig. 3 demonstrates the typical structural chart for ammonia production.

Use of a method of financial-mathematical averaged cost (FMAC). To discuss certain projects (variants), a procedure, being well-reputed while estimating the expediency of lignite industry and power industry progress on the basis of lignite use, applied in Germany and represented in the "Master Plan (General Plan) of lignite industry development in Ukraine", has been adopted. According to the procedure, common, internationally recognized methods of the dynamic economic business

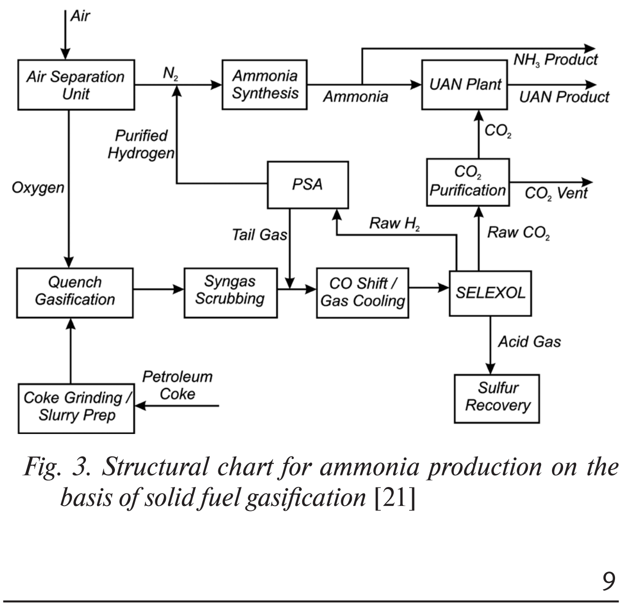

Fig. 3. Structural chart for ammonia production on the basis of solid fuel gasification [21]

calculations estimate the variants of the projects development. In this context, both annual costs and revenues are determined or those for the whole operation period of a deposit or those for planning time-frame. The costs and revenues are compared in terms of financial-mathematical averaged cost. They are determined by means of:

- actual value in the context of different cost-accounting interest rates;
- financial-mathematical averaged cost;
- domestic interest rate.

A prerequisite to apply the methods of dynamic economic calculation is as follows: each cost is recorded both for investment and the current production from year to year for the whole period under the study in the form of the payment series. Neither amortization nor loan interest is considered. Potential credit interest rate or capital charges are considered while forecasting cash flows. Amortization charges are not considered as expenditures. Computation of costs and revenues involves annual favorable ratio of income to expenditure as well as favorable ratio of income to expenditure for the whole period.

FMAC is calculated according to the formula, (USD/t)

$$FMAC = \frac{\sum_{i=1}^{n} A_i \times q^{-i}}{\sum_{i=1}^{n} M_i \times q^{-i}},$$

where A_i stands for CAPEX and OPEX payments for the i^{th} period, USD; M_i is sales for the ith period, t; q^{-i} is discount factor for the ith period.

Hence, to estimate investment activity of ammonia production on the basis of Novo-Dmytrivka surface mine, graphs of stress analysis were constructed. The graphs take into consideration financial solvency of the project in the course of its implementation. FMAC involved expenditures connected with mining and processing enterprises (Table 2). Potential capability of the project to preserve the value of investment with their sufficient increase rate provision should also be noted (Fig. 4).

Domestic interest rate, considered according to the FMAC method, is actually the internal rate of return (IRR); i.e. interest rate where net present value (NPV) is equal to zero.

The data from Table 2 demonstrate that to implement the adopted 10 % interest rate of return on invested capital, the cost of a ton of ammonia production should not be less than USD 238. Such calculations involve certain assumptions. Thus, to determine the FMAC-based estimation stability, it is expedient to analyze sensitivity with the following parameters: changes in interest rate on capital; changes in operational cost; and changes in capital investment. A range of changes in the considered parameters is –30 +45 % with 7.5 % step (Fig. 4).

Fig. 4 explains that the project of ammonia production on the basis of *Novo-Dmytrivka* surface mine is the most sensitive to the capital value and the least sensitive to the operational production cost. It means that to improve financial stability of the processing plant it is required to attract capital with the minimum interest rate

Table 2

Unit costs for ammonia production in the context of Novo-Dmytrivka surface mine

Index	Units	Unit costs without discounting	Unit costs (if discount rate is 10 %)
CAPEX	USD/t	53	184
OPEX	USD/t	54	54
$\sum$CAPEX + OPEX	USD/t	107	238

and following optimization of capital investment towards its decrease. Taking into account the fact that the project was considered in terms of constant prices unadjusted for inflation, it is possible to say that the 10 % annual interest rate is the real rate of interest.

Taking into consideration the fact that imported delivery was considered as the major equipment, the possibility to localize the manufacturing of certain share of equipment by means of Ukrainian enterprise may result in 20 % decrease of capital investment or even more.

Conclusions and recommendations for further research. Low prime cost of lignite extraction and availability of various methods make it possible to produce profitably such commodities of organic synthesis as ammonia, methanol, and motor fuels. Despite the high demand in capital investment, in terms of the current prices for a product (i.e. ammonia), the enterprises have more than 10 % of positive IRR (to be the real rate without regard to inflation).

Since industrial-scale lignite extraction is not available in Ukraine and the solid fossil fuels gasification technologies have not been mastered in full, it is proposed to allot the first launching stage for certain shares of Novo-Dmytrivka deposit for the accelerated start of lignite mining and its processing at the experimental-industrial enterprise.

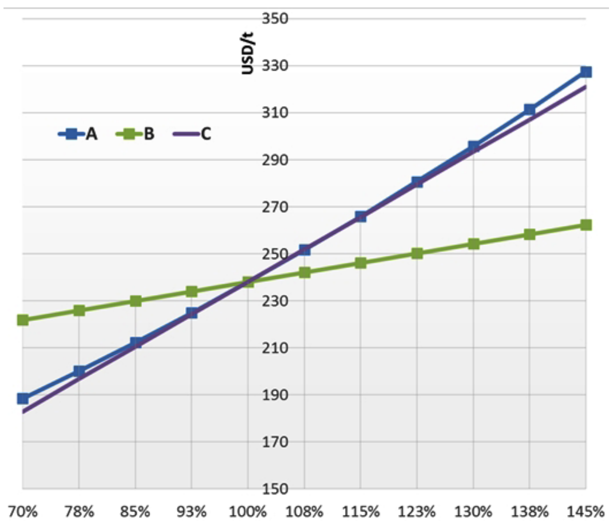

Fig. 4. A graph of FMAC stress analysis to produce ammonia on the basis of Novo-Dmytrivka surface mine:

A is a change in interest rate; B is a change in production operational cost; C is a change in the amount to be invested

The project for mining operations concerning the development of Novo-Dmytrivka deposit demonstrates that rock mass extraction in the amount of up to 6 million t/year will start only after four years of its opening. In this context, it is recommended to apply cyclic equipment within the experimental site which will make it possible to start the mineral mining after two years from the moment of beginning construction activities. Simultaneously, an experimental-industrial enterprise is installed to gasify and synthesize ammonia and, supposedly, another product.

During the following stages when rotary-conveyor systems have been manufactured and mounted, and the mineral has started to be mined, the capacities of the processing enterprise expand.

The studies have shown that the total capacity of the surface mine and processing enterprise when they achieve their full production may be up to 20 million tons in terms of the mineral (rock mass) with the production of up to 3.8 million tons of ammonia per year.

To obtain more accurate data concerning the determination of production capacities and the construction stages as well as technical-and-economic indices, it is recommended to carry out feasibility studies as for Novo-Dmytrivka deposit development and the mineral processing.

It is expedient to analyze the formation of fuel and chemical complexes with different output capacities in the context of other Ukrainian lignite deposits including the possibilities for underground gasification of off-grade coal seams [22, 23] and synthetic gas generations for the needs of chemical industry [24, 25].

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Обґрунтування шляхів використання бурого вугілля при комплексному освоєнні буровугільних родовищ України

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Мета. Обґрунтування шляхів комплексного використання бурого вугілля, а також застосування продуктів його переробки в енергетичній, металургійній, хімічній і будівельній галузях промисловості України для підтримки конкурентоспроможності ринку країни.

Методика. Для досягнення поставлених задач використані наступні методи дослідження: математичного моделювання – для визначення обсягів видобутку бурого вугілля, а також встановлення інтенсивності водопритоків у виробки розкриття при формуванні робочої зони кар’єру; графо-аналітичного й гірничо-геометричного аналізу – для оптимізації параметрів відкритих гірничих робіт у процесі їх поглиблення; техніко-економічного аналізу варіантів – для вибору ефективних технологічних схем відпрацювання продуктивних буровугільних горизонтів у складних гідрогеологічних умовах; економічного моделювання – для виявлення інвестиційної привабливості продуктів переробки бурого вугілля.

Результати. Проаналізовано сучасний стан роботи гірничих підприємств з видобутку бурого вугілля з метою встановлення економічно ефективних технологій його переробки. Виконана оцінка інвестиційної привабливості виробництва аміаку із застосуванням методики фінансово-математичних витрат. Наведені рекомендації для подальших досліджень з видобутку й переробки бурого вугілля для будівництва єдиного переробного підприємства.

Наукова новизна. Виконана техніко-економічна оцінка привабливості й рентабельності виробництва аміаку на основі методики фінансово-математичних витрат як найбільш ефективного продукту переробки бурого вугілля. Дослідження показали, що реальна процентна ставка інвестиційного капіталу (IRR) отримання аміаку з бурого вугілля становить більше 10 %. Оцінка техніко-економічних параметрів виробництва аміаку, як основної продукції, дозволяє рекомендувати буре вугілля й попутні запаси вуглистих глин як сировини для отримання синтез-газу замість природного газу, що використовується на підприємствах хімічної промисловості України. Розрахунки за прийнятою системою розробки родовища показали, що можливо отримати вуглеводневу сировину за найнижчою вартістю в еквіваленті до 1-ої тонни умовного палива на ринку енергоресурсів України. Отримані значення вартості однієї тонни умовного палива, у порівнянні з природним газом, більш ніж у 5 разів менше.

Практична значимість. Результати дослідження з обґрунтування раціональної схеми розкриття й відпрацювання продуктивних горизонтів, а також економіко-математичного моделювання виробництва аміаку дозволяють рекомендувати буре вугілля в якості вуглеводневої сировини для хімічної промисловості, що буде сприяти відновленню буровугільної галузі України. Будівництво переробного комплексу з виробництва аміаку на базі Ново-Дмитрівського родовища з річною виробничою потужністю від 2,7 до 3,8 млн т. дозволить знизити залежність країни від імпортного природного газу, збільшити наповнення бюджетів і фондів усіх рівнів на прогнозовану суму не менше 5 млрд грн. на рік, забезпечити населення прилеглих територій новими робочими місцями, залучити близько 5–6 млрд дол. інвестицій, створити додатковий продукт у суміжних галузях промисловості.

Ключові слова: *буре вугілля, розкриття й розробка родовищ, складні гідрогеологічні умови, економі-*

ко-математичне моделювання, переробка бурого вугілля, газифікація, аміак, рентабельність виробництва

Обоснование путей использования бурого угля при комплексном освоении буроугольных месторождений Украины

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Цель. Обоснование путей комплексного использования бурого угля, а также применения продуктов его переработки в энергетической, металлургической, химической и строительной отраслях промышленности Украины для поддержания конкурентоспособности рынка страны.

Методика. Для достижения поставленных задач использованы следующие методы исследования: математического моделирования – для определения объемов добычи бурого угля, а также установления интенсивности водопритоков в выработки вскрытия при формировании рабочей зоны карьера; графо-аналитического и горно-геометрического анализа – для оптимизации параметров открытых горных работ в процессе их углубки; технико-экономического анализа вариантов – для выбора эффективных технологических схем отработки продуктивных буроугольных горизонтов в сложных гидрогеологических условиях; экономического моделирования – для выявления инвестиционной привлекательности продуктов переработки бурого угля.

Результаты. Проанализировано современное состояние работы горных предприятий по добыче бурого угля с целью установления экономически эффективных технологий его переработки. Выполнена оценка инвестиционной привлекательности производства аммиака с применением методики финансово-математических издержек. Приведены рекомендации для дальнейших исследований по добыче и переработке бурого угля для строительства единого перерабатывающего предприятия.

Научная новизна. Выполнена технико-экономическая оценка привлекательности и рентабельности производства аммиака на основе методики финансово-математических издержек как наиболее эффективного продукта переработки бурого угля. Исследования показали, что реальная процентная ставка инвестиционного капитала (IRR) получения аммиака из бурого угля составляет более 10 %. Оценка технико-экономических параметров производства аммиака, как основной продукции, позволяет рекомендовать бурый уголь и попутные запасы углистых глин в качестве сырья для получения синтез-газа взамен природного газа, используемого на предприятиях химической промышленности Украины. Расчеты по принятой системе разработки месторождения показали, что можно получить углеводородное сырье по самой низкой стоимости в эквиваленте к 1-ой тонне условного топлива на рынке энергоресурсов Украины. Полученные значения стоимости одной тонны условного топлива, в сравнении с природным газом, более чем в 5 раз меньше.

Практическая значимость. Результаты исследования по обоснованию рациональной схемы вскрытия и отработки продуктивных горизонтов, а также экономико-математическому моделированию производства аммиака позволяют рекомендовать бурый уголь в качестве углеводородного сырья для химической промышленности, что будет способствовать восстановлению буроугольной отрасли Украины. Строительство перерабатывающего комплекса по производству аммиака на базе Ново-Дмитровского месторождения с годовой производственной мощностью от 2,7 до 3,8 млн т. позволит снизить зависимость страны от импортного природного газа, увеличить наполнение бюджетов и фондов всех уровней на прогнозируемую сумму не менее 5 млрд грн. в год, обеспечить население прилегающих территорий новыми рабочими местами, привлечь порядка 5–6 млрд долл. инвестиций, создать добавочный продукт в смежных отраслях промышленности.

Ключевые слова: *бурый уголь, вскрытие и разработка месторождений, сложные гидрогеологические условия, экономико-математическое моделирование, переработка бурого угля, газификация, аммиак, рентабельность производства*

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