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Features of determining the cost of production of coal methane as an independent mineral

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Abstract

Relevance. The sustainable development of the industry for the development of coal methane resources largely depends on a reasonable assessment of the economic effects and costs of gas production and processing. Therefore, determining the cost of coal methane production is an urgent economic task.

The purpose of the research is to identify the features of determining the cost of production of coal methane as an independent mineral.

Results. All projects for the extraction of methane from coal beds can be divided into two types: projects for the degassing of coal mines and projects for the extraction of coal-bed methane as an independent mineral. An important difference is that degassing projects are characterized by obtaining economic benefits not only from the sale of methane and its products, but also economic benefits in the coal industry. On the other hand, in industrial production projects, there is no need to link the location of gas wells to the scheme of development of coal beds, and therefore, the article highlights four areas of cost savings.

Conclusion. Determination of costs in projects for the extraction of coal-bed methane as an independent mineral is similar to the calculation of costs for the degassing of coal mines by wells from the surface. At the same time, due to the most rational placement of wells and other facilities for industrial gas production, it is possible to reduce both capital and operating costs. On the other hand, there are no economic effects in the coal industry in industrial mining projects. Comparing the cost savings in industrial mining with the economic effects in the coal industry, one can make an informed decision on the choice of one of the options for the development of gas-bearing coal beds.

***Keywords*:** unconventional gas sources, degassing, commercial production of methane, economic effect, cost reduction, field development scheme.

Introduction

The needs of the Russian economy in natural gas and products of its processing require the involvement in the development of unconventional gas sources, which include gas-bearing coal beds. According to the International Energy Agency, the predicted gas resources from unconventional sources in the world amount to 921 trillion m^3, which is more than 2.2 times higher than gas resources in traditional fields (405 trillion m^3) [1]. At the same time, it should be noted that in Russia today the resources of coal-bed methane exceed the resources of shale gas and tight sand gas combined. This determines the special role of coal methane in the development of domestic gas production [2, 3].

The sustainable development of the industry for the development of coal methane resources largely depends on a reasonable assessment of the economic effects and costs of gas production and processing. Therefore, the determination and analysis of the cost of coal methane production is an urgent economic task.

The most important problem of projects for the extraction of methane from coal beds is their low economic efficiency. Methane in coal beds is in a bound sorbed state. Associated with this is the need for additional costs aimed at breaking the coal-methane bond and intensifying gas production. In addition, it must be taken into account that the flow rates of gas wells drilled in coal beds are usually lower than those of traditional gas wells. As a result, coal bed methane projects are characterized by higher costs and lower revenue compared to conventional gas projects. At the same time, it should be noted that the extraction of methane from coal beds solves a number of problems in coal regions that are not typical for traditional gas production. The solution of these problems leads to the emergence of additional economic effects, considering which it is possible to significantly improve the efficiency of projects for the extraction of methane from coal beds [4–6].

Theoretical foundations of the research

In general, all projects for the extraction of methane from coal beds can be divided into two types:

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Table 1. Direct economic effects in coal-bed methane extraction projects
Таблица 1. Прямые экономические эффекты в проектах по добыче угольного метана

Economic effects	Projects for the extraction of coal-bed methane as an independent mineral	Coal mine degassing projects
Economic effect from the use of extracted methane	+	+
Economic effect of reducing methane emissions into the atmosphere	–	+
The economic effect of improving the use of the front of mining operations in coal mines, associated with a decrease in the influence of the gas factor	–	+
Economic effect of reducing the accident rate associated with methane explosions	–	+
The economic effect of reducing the cost of previously conducted degassing	–	+
Economic effect from full or partial replacement of natural gas supplied to the coal region by coal-bed methane	–	+
Economic effect from the release of natural gas at conventional fields due to its replacement with coal methane	–	+
Economic effect from changes in the utilization of gas transmission capacities	–	+

1) coal mine degassing projects;

2) projects for the extraction of coal-bed methane as an independent mineral (industrial production).

The main method of producing coal methane in Russia is the degassing of coal mines. In this case, joint mining of coal and gas is carried out. At the same time, gas production (degassing) is an auxiliary process aimed primarily at ensuring the safety of coal mining. It should be noted that, unlike projects for the extraction of coal-bed methane as an independent mineral, degassing is characterized by obtaining economic benefits not only from the sale of methane and its products, but also economic benefits in the coal industry. The main ones are: the economic effect of improving the use of the mining front in coal mines; the economic effect of reducing methane emissions into the atmosphere; the economic effect of reducing the accident rate associated with methane explosions; the economic effect of reducing the cost of previously conducted degassing [7–9]. Also, if a gas producing enterprise is engaged in degassing and it is it that receives the economic benefit from the use of the produced coal methane, direct economic effects in the gas industry can be calculated (table 1).

Projects for the extraction of coal-bed methane as an independent mineral, unlike projects for degassing mines, are aimed exclusively at the production and use of coal gas. The implementation of such projects does not provide for the possibility of obtaining economic effects in the coal industry. Thus, the effect of using the extracted gas should pay off all the costs of production and processing [10, 11].

Given the low flow rates and high costs of methane inflow stimulation, the implementation of such projects faces serious economic problems. Therefore, when planning and implementing such projects, special attention should be paid to reducing the cost and increasing the flow rates of production wells [12–14].

The extraction of coal-bed methane as an independent mineral, which is also called industrial production, is carried out by vertical and directional wells from the earth's surface using modern methods of production rates stimulation [15, 16]. Therefore, the costing of such projects is similar to the costing of degassing coal mines from the surface, although, as shown above, there are no effects in the coal industry.

The main costs for degassing by wells from the surface are formed around the following processes:

– construction and operation of degassing wells;

– well piping construction;

– acquisition and operation of gas production stimulation equipment;

– construction and operation of infield pipelines;

– construction and operation of a gas collection point (or vacuum pumping stations (BHC)).

Capital expenditures are determined in the following areas:

– construction of degassing wells;

– well piping construction;

– acquisition of gas production stimulation equipment;

– construction of infield pipelines;

– construction of a gas collection point (or BHC).

The costs for each area are determined by calculating the estimated cost of facilities, as well as the cost of purchasing certain types of equipment. At the design stage, capital costs are determined as follows.

Costs for the construction of degassing wells $K_{скв}$ are calculated by the formula:

$$K_{скв} = HC_{1м}, \quad (1)$$

where H – total footage for all wells, m; $C_{1м}$ – cost of 1 m of footage, rub./m.

Well piping costs $K_{обв}$ are calculated by the formula:

$$K_{обв} = N_{дег} C_{обв}, \quad (2)$$

where $N_{дег}$ – number of degassing wells, well; $C_{обв}$ – cost of piping one well, rub./well.

The costs for the purchase, delivery and installation of equipment for the stimulation of gas production are calculated by the formula:

$$K_{инт} = \frac{N_{дег}}{Y_у} C_у, \quad (3)$$

where $Y_у$ – number of wells per gas production stimulation unit, well; $C_у$ – cost of one installation for stimulation, rub.

Costs for the construction of infield pipelines $K_{п.т}$ are calculated by the formula:

$$K_{п.т} = N_{дег} L_{п.т} C_{п.т}, \quad (4)$$

where $L_{п.т}$ – length of pipelines per well, km/well; $C_{п.т}$ – cost of 1 kilometer of pipelines, rub./km.

Costs for the construction of degassing wells, costs for the construction of well piping, the costs for the purchase of equipment for the stimulation of gas production and costs for the construction of infield pipelines are calculated by formulas (1)–(4), respectively.

The costs for the construction of a gas collection point or BHC are calculated by formulas 2.5 and 2.7.

BHC construction costs $K_{ВНС}$ are calculated by the formula:

$$K_{ВНС} = N_н C_н + З_{об}, \quad (5)$$

where $N_н$ – number of pumps, pcs.; $C_н$ – cost of one pump, rub./piece; $З_{об}$ – BHC construction costs, rub.

The number of pumps depends on the volume of extracted methane-air mixture (MBC) and is calculated by the formula:

$$N_н = \frac{Q_{МВС}}{M_н}, \quad (6)$$

where $Q_{МВС}$ – volume of extracted methane-air mixture, m³/min; $M_н$ – power of one pump, m³/min. In this case, the calculation result in formula (6) is rounded up to a larger integer.

Gas collection point construction costs $K_{с.п}$ are calculated by the formula:

$$K_{с.п} = N_{с.п} C_{с.п}, \quad (7)$$

where $N_{с.п}$ – number of collection points for gas, pcs; $C_{с.п}$ – cost of one collection point, rub.;

$$N_{с.п} = \frac{Q_{МВС}}{M_{с.п}}, \quad (8)$$

where $M_{с.п}$ – gas collection point capacity, m³/min. In this case, the calculation result in formula (8) is rounded up to a larger integer.

BHC construction costs and gas collection point construction costs are calculated by formulas (5)–(8).

Operating costs for well completion and well production stimulation consist of:

1) heat energy costs;
2) electricity costs;
3) water supply costs;
4) personnel wages costs;
5) social contributions costs;
6) major repairs costs;
7) payment for land costs;
8) other costs;
9) environmental protection costs;
10) depreciation charges.

Heat energy costs $З_т$ are calculated by the formula:

$$З_т = Q C_т P_т, \quad (9)$$

where Q – gas production volume, thousand m³; $C_т$ – heat energy cost, rub./Gcal; $P_т$ – heat energy consumption, Gcal/thousand, m³.

Electricity costs $З_{эл}$ are calculated by the formula:

$$З_{эл} = Q C_{эл} P_{эл}, \quad (10)$$

where $C_{эл}$ – cost of electricity, rub/(kW · h); $P_{эл}$ – electricity consumption, (kW · h)/thousand m³.

Water supply costs $З_в$ are calculated by the formula:

$$З_в = Q C_в P_в, \quad (11)$$

where $C_в$ – water cost, rub/m³; $P_в$ – water consumption, m³/thousand m³.

Personnel wages costs $З_{з.п}$ are calculated by the formula:

$$З_{з.п} = N_{дег} Ч_{1скв} ЗП_{с/г}, \quad (12)$$

where $Ч_{1скв}$ – number of employees per well, person/well; $ЗП_{с/г}$ – average annual salary, rub./person.

Social contributions costs $З_{с.н}$ are calculated by the formula:

$$З_{с.н} = З_{з.п} C_{с.н}, \quad (13)$$

where $C_{с.н}$ – share of deductions for social needs, %.

Contributions for social needs include payments to the pension fund, the social insurance fund, the medical insurance fund, as well as the amount of the insurance tariff for compulsory social insurance against industrial accidents and occupational diseases.

Major repairs costs $З_{к.р}$ are calculated by the formula:

$$З_{к.р} = Y_{к.р} C_{о.ф}, \quad (14)$$

where $Y_{к.р}$ – share of major repairs costs, %.

Payment for land costs $З_{п.з}$ are calculated by the formula:

$$З_{п.з} = SC_{п.з}, \quad (15)$$

where S – land allotment area, ha; $C_{п.з}$ – payment for land, rub./ha.

Other costs $З_{пр}$ are calculated as a percentage of the sum of previous operating costs

$$З_{пр} = (З_т + З_{эл} + З_в + З_{з.п} + З_{с.н} + З_{к.р} + З_{п.з}) H_{пр}, \quad (16)$$

where $H_{пр}$ – rate of other costs, %.

Environmental protection costs $З_{о.с}$ are calculated by the formula:

$$З_{о.с} = (З_т + З_{эл} + З_в + З_{з.п} + З_{с.н} + З_{к.р} + З_{п.з} + З_{пр}) H_{о.с}, \quad (17)$$

where $H_{о.с}$ – environmental protection cost rate, %.

Operating costs for well development and well production stimulation include depreciation charges for the following types of fixed assets:

– degassing wells;
– well piping;
– gas production stimulation equipment;
– infield pipelines;
– gas collection point (or BHC).

Depreciation charges $З_а$ for each type of fixed assets are calculated by the formula:

$$З_а = C_{о.ф} H_а, \quad (18)$$

where $C_{о.ф}$ – the cost of this type of fixed assets, rub.; $H_а$ – depreciation rate for this type of fixed assets, %.

The total amount of operating costs for the development of wells and the stimulation of well flow rates З is calculated by the formula:

$$З = З_{т} + З_{эл} + З_{в} + З_{з.\,п} + З_{с.\,н} + З_{к.\,р} + З_{п.\,з} + З_{пр.} + З_{о.\,с} + З_{а}. \quad (19)$$

Operating costs for well completion and well production stimulation are calculated by formulas (9)–(19).

Results and discussion

Unlike coal mine degassing projects, there is no need for industrial production to link the location of wells to a coal bed development scheme. In this regard, there are a number of differences in the calculation of the cost of commercial production of CBM.

First, it must be taken into account that due to the most rational placement of wells for industrial gas production, it is possible to reduce the cost of their construction.

In the works of V. N. Vasyukov, I. V. Roshchina, A. N. Storonsky et al., the current and cumulative production of methane is calculated for different distances between wells at the Taldinskoye field [17].

The most interesting is the comparison of the time behavior of gas production for the options with a well spacing of 200, 400, and 600 m. In the initial period of well operation, the option with a grid of 200 200 m is characterized by a more intensive growth in cumulative gas production. Then the situation changes, so the cumulative gas production after 10 years with the grid option of 200 × 200 m is characterized by a more intensive growth in cumulative gas production. Then the situation changes, so the cumulative gas production after 10 years with the grid option of 200 × 200 m is already inferior to the option with a grid of 400 × 400 m by 28%, and the option with a grid of 600 x 600 m by 15%.

A comparison of the change in time of cumulative production shows the importance of the primary decision on the purpose of the development of this area: early degassing of bed seams before the stage of mining or industrial development of a methane-coal deposit? The answer to this question predetermines the development period and, as the comparison shows, the choice of the optimal distance between wells. If the task of early degassing of coal is set, then the placement of wells at a distance of 200 m from each other makes it possible to extract more methane and, consequently, to lower the methane content of coal more in a shorter period. In the case of considering field development, the optimal distance is 400 m. This is due to higher prospects for increasing the gas recovery factor.

Secondly, it must be taken into account that the possibility of freely choosing the direction of drilling makes it possible to achieve large volumes of production by drilling in the most productive areas with a smaller number of wells. So, for example, the use of deviated, directional, horizontal and horizontally-branched wells, which have a large length of the horizontal section in the reservoir and are aimed at crossing disjunctive break, which are natural drainage channels for gas migration from nearby gas-saturated reservoirs, has great prospects.

In the works of A. V. Keibal, V. N. Vasyukov et al., the technology of construction and operation of directional wells for the conditions of commercial production of CBM is considered [18]. The authors concluded that there are serious limitations associated with the possibility of organizing effective pumping of formation water from the wellbore and achieving maximum drawdown on the productive formation. Therefore, as early as at the stage of pre-project study, it is necessary to consider in detail various design options for directional wells and their placement schemes in accordance with the selected drilling pattern.

In the works of Tskhadai N. D., Buslaev V. F., Kane S. A. et al. a technology proposed for the use of horizontal and horizontally-branched wells with a maximum length of wells in a productive reservoir and the concentration of economic activity in limited production areas [19]. Approbation of these technologies was supposed to be carried out at the pilot site of the Vorkuta coal deposit in the Pechora coal basin. The feasibility study calculated the economic efficiency for five options that differed in production volume, number and structure of wells (vertical or horizontal). The most effective option turned out to be the one with a small number of horizontal wells aimed at crossing disjunctive break.

Thus, by optimizing the location of wells for the conditions of industrial production of CBM in comparison with the drilling grid for the purpose of degassing, it is possible to significantly reduce the cost of well construction by reducing their number.

Formula (1) for calculating the cost of well construction $K_{скв}$ for industrial production will take the following form:

$$K_{скв} = N_{пром} H_{1скв} C_{1м} = (N_{дег} - N)\, H_{1скв}\, C_{1м}, \quad (20)$$

where $N_{пром}$ – number of wells in industrial production, well; $N_{дег}$ – number of wells during degassing, well; ΔN – the number of wells that can be reduced due to the most rational placement of wells for industrial gas production, well; $H_{1скв}$ – length of one well, m; $C_{1м}$ – cost of construction of 1 m of wells, rub./m.

Secondly, it must be taken into account that the design of wells for industrial production may be simpler than the design of degassing wells. At the same time, the reduction in well construction costs associated with the optimization of well design for industrial production of CBM can be expressed by reducing the cost of 1 m of well construction.

Formula (1) for calculating the cost of construction of wells for industrial production $K_{скв}$ will then take the following form:

$$K_{скв} = N_{пром} H_{1скв} C_{1м\,пром} = (N_{дег} - \Delta N)\, H_{1скв} (C_{1м\,дег} - \Delta C_{1м}), \quad (21)$$

where $C_{1м\,пром}$ – cost of construction of 1 m of wells for industrial production of CBM, rub./m; $C_{1м\,дег}$ – cost of construction of 1 m of degassing wells, rub./m; $\Delta C_{1м}$ – savings in the cost of construction of 1 m wells for industrial production of CBM in comparison with the cost of construction of 1 m degassing wells, rub./m.

Thirdly, if due to the most rational placement of wells for industrial gas production, it is possible to reduce their number, capital costs for gas production stimulation equipment will be reduced. In this case, formula 2.3 for determining the costs for the purchase, delivery and installation of gas production stimulation equipment will take the following form:

$$K_{инт} = \frac{N_{пром}}{Y_{у}} C_{у} = \frac{(N_{дег} - \Delta N)}{Y_{у}} C_{у}, \quad (22)$$

where $Y_{у}$ – number of wells per unit for gas production stimulation, well; $C_{у}$ – cost of one stimulation unit, rub.

Fourth, capital costs for the construction of infield pipelines can be reduced by reducing the number of wells and the length of pipelines per well. In this case, formula 2.9 for determining the costs for the construction of infield pipelines will take the following form:

$$K_{п.\,т} = N_{пром} L_{п.\,т.\,пром} C_{п.\,т} = (N_{дег} - \Delta N)\,(L_{п.\,т.\,дег} - \Delta L_{п.\,т})\,C_{п.\,т}, \quad (23)$$

where $L_{п.\,т.пром}$, $L_{п.\,т.дег}$ – length of pipelines per well, respectively, for industrial production and degassing, km/well; $\Delta L_{п.\,т}$ – reduction in the length of infield pipelines per well, km/well; $C_{п.\,т}$ – cost of one kilometer of pipelines, rub/km.

Further, it should be added that the reduction in capital costs associated with the above differences between industrial production and surface degassing leads to a reduction in some types of operating costs. Including:

– depreciation charges;
– major repairs costs;
– personnel wages costs;
– social contributions costs;
– payment for land costs.

The formula for calculating depreciation charges 2.19 will then take the form:

$$З_{а} = C_{о.\,ф.\,пром} H_{а} = (C_{о.\,ф.\,дег} - \Delta C_{о.\,ф})\,H_{а}, \quad (24)$$

where $C_{о.\,ф.\,пром}$, $C_{о.\,ф.\,дег}$ – the cost of fixed assets, respectively, for industrial production and for degassing, rub.; $\Delta C_{о.\,ф}$ – reduction in the cost of fixed assets during industrial production in comparison with the cost of fixed assets during degassing from the surface, rub; $H_{а}$ – depreciation charges rate, %.

The formula for calculating the major repairs costs 2.15 will then take the form:

$$З_{кр} = C_{о.\,ф.\,пром} Y_{к.\,р} = (C_{о.\,ф.\,дег} - \Delta C_{о.\,ф})\,Y_{к.\,р}, \quad (25)$$

where $Y_{к.\,р}$ – share of major repairs costs, %.

The formula for calculating personnel wages costs 2.13 will then take the form:

$$З_{з.\,п} = N_{пром} Ч_{1скв} ЗП_{с/г} = (N_{дег} - \Delta N) Ч_{1скв} ЗП_{с/г}, \quad (26)$$

where $Ч_{1скв}$ – number of employees per well, person/well; $ЗП_{с/г}$ – average annual salary, rub./person.

Social contributions will decrease in proportion to the decrease in labor costs:

$$З_{с.\,н} = З_{з.\,п.\,пром} C_{с.\,н} = (З_{з.\,п.\,дег} - \Delta З_{з.\,п})\,C_{с.\,н}, \quad (27)$$

where $З_{з.\,п.пром}$, $З_{з.\,п.дег}$ – labor costs, respectively, for industrial production and degassing, rub.; $\Delta З_{з.\,п}$ – reduction in labor costs for industrial production in comparison with labor costs for degassing from the surface, rub; $C_{с.\,н}$ – share of deductions for social needs, %.

Due to a more rational placement of wells in industrial production, it is possible to reduce the area of land allotment and, accordingly, the payment for land:

$$З_{п.\,з} = S_{пром} C_{п.\,з} = (S_{дег} - \Delta S)\,C_{п.\,з}, \quad (28)$$

where $S_{пром}$,, $S_{дег}$ – area of land allotment, respectively, for industrial production and degassing, ha; ΔS – reduction of land allotment area due to more rational placement of wells for industrial production, ha; $C_{п.\,з}$ – payment for land, rub./ha.

Conclusion

Thus, it can be concluded that the assessment of costs in projects for the extraction of coal-bed methane as an independent mineral is similar to the calculation of costs for degassing coal mines from the surface by wells. At the same time, unlike projects for degassing coal mines in industrial production, there is no need to link the location of wells to the scheme for developing coal beds. Consequently, due to the most rational placement of wells and other facilities for industrial gas production, it is possible to reduce both capital and operating costs. On the other hand, there are no economic effects in the coal industry in industrial mining projects. By comparing the cost savings of industrial mining with the economic effects in the coal industry, an informed decision can be made about choosing one of the two options for developing gas-bearing coal beds.

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Особенности определения себестоимости добычи угольного метана в качестве самостоятельного полезного ископаемого

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Аннотация

Актуальность. Устойчивое развитие отрасли по освоению ресурсов угольного метана во многом зависит от обоснованной оценки экономических эффектов и затрат на добычу и переработку газа. Поэтому определение себестоимости добычи угольного метана является актуальной экономической задачей.

Цель исследования – выявление особенностей определения себестоимости добычи угольного метана в качестве самостоятельного полезного ископаемого.

Результаты. Все проекты по извлечению метана из угольных пластов можно разделить на два вида: проекты дегазации угольных шахт и проекты по добыче метана угольных пластов в качестве самостоятельного полезного ископаемого. Важное отличие заключается в том, что для проектов дегазации характерно получение экономических эффектов не только от продажи метана и продуктов его переработки, но и экономических эффектов в угольной промышленности. С другой стороны, в проектах по промышленной добыче отсутствует необходимость привязки расположения газовых скважин к схеме разработки угольных пластов, в связи с чем в статье выделено четыре направления экономии затрат.

Заключение. Определение затрат в проектах по добыче метана угольных пластов в качестве самостоятельного полезного ископаемого сходно с расчетом затрат на дегазацию угольных шахт скважинами с поверхности. При этом за счет наиболее рационального размещения скважин и других объектов для промышленной газодобычи существует возможность снизить как капитальные, так и эксплуатационные затраты. С другой стороны, в проектах по промышленной добыче отсутствуют экономические эффекты в угольной промышленности. Сравнивая экономию затрат при промышленной добыче с экономическими эффектами в угольной промышленности, можно принять обоснованное решение о выборе одного из вариантов разработки газосодержащих угольных пластов.

***Ключевые слова*:** нетрадиционные источники газа, дегазация, промышленная добыча метана, экономический эффект, снижение себестоимости, схема разработки месторождения.

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