Abstract. The paper discusses the possibility of using the coal mines infrastructure for hosting the data processing centers (DPCs). Modern technologies allow to consider the power supply system of a coal mine being sufficient to fulfill the high requirements of power supply reliability for DPCs. For this aim, the authors proposed the "coal – energy resources – information" concept with respective structure of energy supply. As a means of increasing energy efficiency, it is proposed to use cogeneration and trigeneration on coal mine methane which allows to provide power supply to power consumers, heat supply to a coal mine and cold supply to a data center. The technical risks associated with the use of DPCs and trigeneration in coal mines were identified, providing basis for future research. In the conclusion, it was noted that the development of DPCs integrally with coal mines can increase economic efficiency, as well as create new workplaces and become a driver for the development of the IT industry in mining towns.

1. Introduction
The dynamics of steam coal prices for the period from 2015 to the present have been ambiguous (Fig. 1). The maximum cost of coal over the past 5 years was observed in November 2018 which can be explained by favorable market conditions and high level of coal production in China. In early 2020, due to the global COVID-19 pandemic and, as a result, a decrease in demand for electrical energy, there was a decrease in coal prices, reaching a 5-year low of $ 34.05 per ton.

It should be noted that over the past ten years, there has been a general trend towards a decrease in coal consumption: coal consumption in the European Union has decreased by 15%, and in the USA – by 17%. The reason was the refusal of energy companies from coal-fired thermal power plants and the reliance on renewable energy sources due to constantly tightening environmental standards in developed countries.

Despite the global trend towards the abandonment of hydrocarbon fuels in favor of cleaner fuel and energy resources, the demand for coal and the development of the coal industry is likely to persist in the coming decades. Thus, in the forecast of coal demand in 2019 [2], under a...
favorable scenario of the development of events by 2040, an increase in demand is predicted by 17% (compared to the level of 2018). The program for the development of the Russian coal industry for the period up to 2035 \[3\] assumes a change in demand for coal by 2035 from −1.16% (conservative scenario) to +13.95% (optimistic scenario).

The ambiguous dynamics of coal prices has a negative impact on the economic stability of coal mining enterprises. In this regard, there is a problem of finding alternative ways to ensure economic sustainability with usage of existing infrastructure of coal mining enterprises.

The most obvious way is implementation of deep coal processing technologies by using production facilities and the territory of coal mining enterprises whenever possible. However, this option requires significant capital investments while markets for such products are not always clear.

Another promising option is the implementation of various technologies included in the “Coal — Gas — Electricity” concept \[4\], with the production of electrical energy at the output. The noted option certainly has great prospects for practical implementation, but according to the authors of this paper, it can be supplemented and expanded, namely by the creation of technologies within the framework of the ”Coal – Energy – Information” concept. In practice, this implies the use of infrastructure and production facilities of coal mining enterprises for the construction and provision of the engineering infrastructure of data processing centers (DPCs) with the necessary energy resources.

Currently, there is a constant growth in the information sector, the volume of processed data is increasing, and, consequently, the volume of electricity consumption \[5\]. The growing demand for DPCs leads to an increase in prices for their construction.

An example of the usage of mining infrastructure for DPC is Norway’s Lefdal mine \[6\] which is located in a mine where olivine, a mineral used to make heat-resistant glass, was previously mined. Norway’s Lefdal mine data center uses only clean ”green” energy, while ensuring high immunity from electromagnetic interference, as well as high physical protection of servers. In this case, the lower temperature in the shaft provides the most economical cooling.

It seems promising to use the Norwegian experience on the territory of the largest coal-mining region of Russia – Kuzbass. In Kuzbass, there are a large number of unexploited underground mine workings that can be used as premises for IT-equipment, while the existing power supply systems of mining enterprises in terms of reliability, as a rule, meet the requirements of DPCs
power supply reliability.

The work [7] notes the need to use renewable energy sources to create green data centers. However, the use of "traditional" renewable energy sources in Kuzbass is far from always cost-effective. The use of another unconventional energy resource for electricity generation – coal mine methane (CMM) – is of growing interest. According to [8], the cost of CMM generation is 30-50% lower than the cost of wind power plants. At the same time, the investment to eliminate one ton of equivalent annual carbon dioxide emissions when using CMM is US$34 which is 4 times lower than the capital cost for the construction of wind farms ($100-142). A properly designed and managed CMM scheme can provide a reliable source of energy to an established consumer, the mine itself, whereas the wind power schemes are often remote and invariably diurnally and seasonally intermittent in their operation. Flaring at US$6.5 per ton CO₂ equivalent annual destruction capacity provides the lowest cost mitigation option and should be introduced where CMM utilization is not feasible or pending design and construction of a suitable CMM scheme.

When a power plant operates on CMM, heat energy will also be generated which can be used for various industrial and domestic purposes, as well as, using trigeneration technology, to provide cooling of server rooms. Thus, the overall efficiency of the power plant can reach values above 90%.

This article is structured as follows. The second section discusses the requirements for the reliability of power supply to coal mining enterprises and DPCs, as well as a structural diagram of the power supply of a coal mine with a DPC and possible ways to increase the KPI of organization “coal mine – DPC”. The third section provides a preliminary assessment of the risks associated with the placement of DPCs and trigeneration in coal mines. Finally, the fourth section contains the conclusion of the article.

2. Energy supply structure of the "coal mine - DPC" system

The structure of coal mines energy supply in terms of the requirements for the reliability of power supply largely equal to DPCs. In DPCs, as well as in coal mines, there are electrical receivers of a special group, the energy consumption constraint of which can lead to economic, environmental, and social consequences.

According to the requirements for the design of coal mines, their power supply must be carried out from at least two circuits of power transmission lines. In case of failure of one of them, the lines remaining in operation must ensure the normal operation of all power consumers of the enterprise. In order to provide power to power consumers of a special group, autonomous power supplies with automatic start should be provided in mines.

It should be noted that the DPC also contains power consumers of a special group which are necessary to maintain the functioning of climatic, energy, information and other engineering systems that ensure the normal functioning of IT equipment.

For DPCs, there is a clear fault tolerance classification in accordance with the TIA-942 standard [9] which, unlike, the consumer classification adopted in the Russian Federation, has clear numerical characteristics (annual downtime, infrastructure reliability, probability of shutdown, etc.). According to the TIA-942 standard, data centers are divided into 4 levels: level 1 (N); level 2 (N + 1), level 3 (2N); level 4 (2 (N + 1)).

Considering that most coal mines receive power supply in the first category for power supply reliability (2N), their power supply scheme satisfies level 3 (Tier3). Some mines, with sufficient capacity of autonomous power sources, according to the authors, can be equated to level 4 (Tier4).

To improve the reliability of DPC and coal mine energy supply, coal mine methane generation can be used; in this case, the structure of the coal mine’s energy supply is as shown in Fig. 2.
2.1. Electric load of "coal mine - DPC" system
The load of the "coal mine - DPC" system includes the following components: coal mine equipment load, IT equipment load, cooling system load, and other electrical receivers.

2.1.1. Coal mine equipment
The coal mine load is represented by technological equipment located in the underground and above-ground parts of the coal mine. The aboveground part of the power supply system feed the ventilation equipment, cage hoist, and equipment for the administrative buildings. Underground electric receivers of coal mines are represented by the equipment of the coal mine extraction area (shearers, conveyors, belt elevator, etc.).

2.1.2. Information technology equipment
The data processed by DPC determines its power consumption. However, this relationship is not linear and is determined by the efficiency of heat removal from the DPC. It is assumed that the DPC equipment should be located on the surface, however, it is possible to place the IT equipment in the underground part of the coal mine using the special equipment.

The IT equipment includes a server farm which consumes half of all energy, and uninterruptible power supplies (UPS).

It should be noted that DPCs equipment can be used to build applied control systems for technological systems of a coal mine. In this case, it is recommended to use the platform approach which can be realized on the basis of the data center tools for creating applied control systems for various purposes [10].

In China, the concept of manless coal mines is gradually being implemented using cloud technologies, the Internet of Things and Big Data [10]. Implementation of such a concept requires the DPC implementation on the territory of a coal mine. In addition, DPCs can be used in the implementation of the Smart City concept within the framework of mining towns.

2.1.3. Cooling System
The cooling system is the second consumer in the DPC. Within a coal mine, refrigeration can be provided by trigeneration gas piston units. This will significantly reduce the PUE (Power Usage efficiency) which is a ratio that describes how efficiently a computer data center uses energy;
specifically, how much energy is used by the computing equipment (in contrast to cooling and other overhead).

2.1.4. Miscellaneous power consumption
Lighting, alarm systems, control and monitoring systems, etc. Their share depends on the DPC size and is about 6% of the total consumption of DPC.

2.2. CMM generation
CMM is a gas released from coal seams or other seams during the process. The amount of gas emitted depends on many factors: mining and geological factors, methane content of seams, technology and intensity of coal mining. Large amounts of methane are released through ventilation along with the air.

In general, there are three main factors that determine the feasibility of methane processing: 1) ensuring safety at a coal mine; 2) improving the economic performance of the coal mine; 3) reduction of greenhouse gas emissions, one of which is methane, the global warming potential of which is 21 times greater than that of carbon dioxide.

According to [11], coal mines emit 8% of anthropogenic methane, determining 17% of the contribution to greenhouse gas emissions. At the same time, about 70% of CMM is emitted from the air in ventilation.

The general case of the concept of cogeneration and trigeneration in a coal mine is shown in Figure 3. It should be noted that there are many studies devoted to the issue of methane processing [11–13], in general, they are aimed at ensuring the maximum use of methane released from coal beds with an efficiency close to 95%. For this purpose, it is necessary to use a generating unit operating in a trigeneration cycle – to generate electrical energy to power the equipment of coal mine and data center, and also to provide the mine with heat and server installations with cold. In the future, the deep processing of methane can provide with carbon dioxide which can be used in agriculture.

Figure 3. Concept of cogeneration and trigeneration in the coal mine
2.3. Electric energy storage
Energy storage devices can be used to reduce payment for electricity by managing consumption during peak hours.

In addition, electric energy storage devices and a CMM generating unit are required to provide autonomous power supply to IT and coal mine equipment in the case of an external power outage.

3. Assessment of implementation risks
Before considering the technological features of the implementation of the proposed power supply structure, it is advisable to assess the technical risks.

(1) Problems with the CMM supply
The proposed concept is supposed to be implemented in mines with a high inflow of CMM and a modern degassing system. Therefore, it is necessary to conduct studies determining the number and location of the mines with high inflow of CMM and their applicability towards implementation of the trigeneration. In addition, the relative stability of the mine gas composition and amount over time needs to be confirmed.

(2) Malfunctions of power equipment
The introduction of CMM generation increases the complexity of energy supply structure. Therefore, the accident on generating unit can limit the energy supply of DPC. Long-term maintenance of the unit by a service company is necessary. At the same time, the mine has the main power supply which ensures sufficient reliability of the power supply.

(3) Lack of necessary electrical load
The mine and the data center consume much more electricity than the installed electrical capacity of the generators, the mine continues to increase its coal production and is a stable consumer of electricity. If the power produced by generating units is higher then power demand, the extra power can be sold to the main grid.

(4) Insufficient demand for data center services
At present, cloud IT technologies are developing at an accelerated pace, while the data center can be used for the needs of a coal mine in order to create intelligent control systems for technological processes. In addition, the implementation of the proposed concept can provide the creation of a test site for the Smart City concept with the aim of developing mining towns.

As a direction for further research, it is proposed to assess the technical and economic efficiency of the concept under consideration, for which it is necessary to simulate the power supply system of a coal mine with an assessment of the coal mine’s potential for methane release. At the same time, the development of trigeneration units applicable in coal mines becomes relevant.

4. Conclusion
Currently, there is a tendency for decarbonization, but no significant decrease in coal production is predicted in the next 20 years. In this regard, it is advisable to use technologies that make it possible to use all the resources available in a coal mine in the most efficient way. At the same time, it seems advisable to diversify the business by introducing data centers in the territory of coal mines which will not only ensure the development of a digital coal enterprise, but also provide the coal mine with an additional source of income when leasing the computing power of the data center. In conclusion, it is noted that the proposed concept is extremely expedient for the preservation of mining towns and requires modeling the energy supply system with a justification for the need to develop trigeneration units operating on coal mine methane.
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