Ecologically and Economically Effective Methods of Coal Bed Methane Using

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Abstrakt

CBM are ecological fuel obtained by two ways: during coal mining or by specially made holes from surface to the virgin seam or abandoned coal mines. Increased demand for electricity and implementation of CO_2 emissions get more profitable investing in modern technologies, especially local power plants fueled by CBM. Article presents possible main technologies for the use of CBM.CMM on the background of forecasting an increase in electricity prices and the cost of purchasing CO_2 emission allowances.

Keywords: methane, gas drainage, carbon footprint, environmental protection, mining

1. Introduction

Coal accounts for nearly a quarter of the total electricity production in the EU. It is also a significant economic driver, providing jobs to around 240,000 people in mines and power plants across 41 regions and 12 EU countries.

While coal remains a central fuel in the European energy mix, the transition to cleaner forms of energy and innovative technologies such as carbon capture and storage is imperative to meet the EU's commitment to reduce CO_2 emissions by at least 40% by 2030.

CO_2 is the largest contributor to anthropogenic greenhouse gas (GHG) emissions, followed by CH_4. About 60% of total methane emissions are estimated to be from anthropogenic sources.

CH_4 is a more potent GHG than CO_2, but it has a shorter atmospheric lifespan, on average 8–12 years compared to CO2 that persists in the atmosphere for centuries. Consequently, methane emissions have a much stronger climate impact in the short-term, than they do over the long term.

When combusted, natural gas – which comprises mostly methane – generates about half as much CO_2 as from coal for the same quantity of energy generated. It is the most heat intensive and highly efficient fuel, particularly when used directly.

Methane emissions from gas operations represented 6% of the total EU methane emissions, equivalent to 0.6% of the total EU GHG emissions in 2016. In the same period, gas consumption augmented by 25% (from 360 to 449 bcm) as well as the length of the gas network having been increased.

The EU emissions trading system (EU ETS) is a cornerstone of the EU's policy to combat climate change and its key tool for reducing greenhouse gas emissions cost-effectively. It is the world's first major carbon market and remains the biggest one. The EU ETS works on the 'cap and trade' principle. A cap is set on the total amount of certain greenhouse gases that can be emitted by installations covered by the system. The cap is reduced over time so that total emissions fall. Within the cap, companies receive or buy emission allowances which they can trade with one another as needed. They can also buy limited amounts of international credits from emission-saving projects around the world. The limit on the total number of allowances available ensures that they have a value. After each year a company must surrender enough allowances to cover all its emissions, otherwise heavy fines are imposed. If a company reduces its emissions, it can keep the spare allowances to cover its future needs or else sell them to another company that is short of allowances. Trading brings flexibility that ensures emissions are cut where it costs least to do so. A robust carbon price also promotes investment in clean, low-carbon technologies.

According to Szuflicki et all. 2019, coal bed methane (CBM) is natural gas trapped in coal and occurring in the form of gas particles adsorbed at coal grains. A drop in bed pressure along with mining activities is followed by an increase in the coal bed methane desorption and its release from coal and surrounding rocks to work areas of a coal mine. The release of methane is a serious safety concern as it can create an explosive hazard. Therefore, much attention is paid to the draining methane from coal beds before and in the course of coal mining. This is achieved by a methane capture on advance of longwall coalfaces by boreholes drilled in front of the face and a reduction of concentration of methane to the acceptable level by the ventilation of work areas.

The last decades witnessed a development of a technology of a draining methane from coal beds by multiple boreholes drilled from the surface. The technology of drainage involves the hydrofracturing of coal beds and surrounding rocks and filling up fissures with a permeable medium (usually sand) to facilitate migration of CBM released by desorption. The next step is a removal of water from coal beds to achieve a drop in a bed pressure in the area of a given borehole, necessary for the start of processes of desorption, emission and migration of CBM. Draining of CBM by production wells is treated as the natural gas production from unconventional source.

CBM has been documented only in coal deposits of the Upper Silesian Coal Basin. CBM concentrations in coal de-

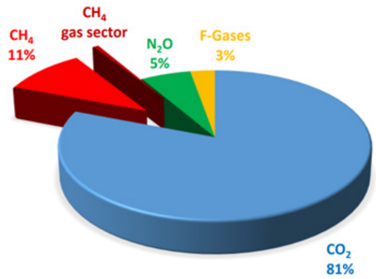

Fig. 1. GHG emissions in 2016 for EU-28 and Iceland
Rys. 1. Emisja gazów cieplarnianych w 2016 r. dla Unii Europejskiej oraz Islandii

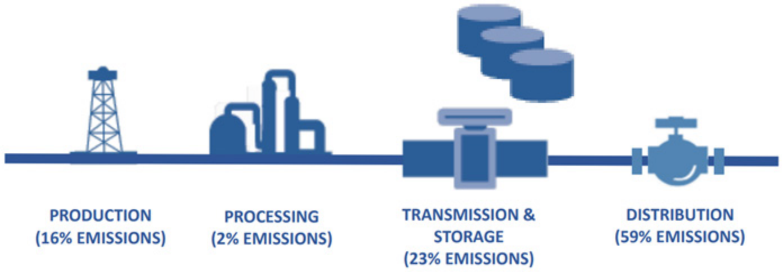

Fig. 2. CH^4 emissions from natural gas operations across the EU gas chain in 2016
Rys. 2. Emisja CH_4 pochodząca z transportu gazu ziemnego w ramach Unii Europejskiej w 2016 r.

posits of the Lower Silesian Coal Basin and the Lublin Coal Basin appear to be much smaller than in the Upper Silesian Basin. Their economic importance is still to be established.

The CBM usage is determined on one hand by the safety issues and on the other hand is treated as collecting the gas from the unconventional sources – due to its form of occurring which demands the application of the special recovery desorptive technology.

The prospecting made it possible to evaluate CBM resources and show the presence of important CBM resources in 65 hard coal deposits in the area of the Upper Silesian Coal Basin. These anticipated economic resources amounted in 2018 to 102,021.34 million m³ and increased by 5,073.67 million m³ in comparison with 2017.

The majority of anticipated economic resources constitute the resources documented in the C category (92,764.34 million m3 – 90.93%). Resources documented in A and B categories amount only to 9,257.00 million m³ and account for only 9.07% of domestic anticipated economic resources. Anticipated sub-economic resources have been documented within 8 deposits and are equal 11,410.12 million m³, from which 11,315.02 million m³ are resources in C category (99.17% of the total anticipated sub-economic resources) and only 95.10 million m³ are resources in A and B categories (0.83%).

CBM output amounted in 2018 to 320.94 million m³. This figure covers the amount of CBM which is picked up by every hard coal mine in Poland and the amount of methane which is being exploited independently – as a self-outflow from the boreholes reaching the cavings of abandoned coal mines. In the case of several deposits (due to the technical capabilities) the output covers also the amount coming from the low-methane area – it is the part of coal deposit where the methane presence was proved but due to the low content the resources have not been documented.

Economic resources of CBM, established for 27 coal deposits, are equal 6,439.73 million m³ and increased by 748.41 million m³ in comparison with the previous year. In 2018 there were new mine management plans with recalculated resources prepared for: Budryk (+960.09 million m³), Staszic (-5.86 million m³) and Zofiówka (+6.62 million m³) deposits.

The USCB is characterized by the highest potential of CBM deposits concentrations. Prognostic and perspective resources of coal bed methane in USCB amounted to 107 billion m³ as of 31.12.2009. Perspective resources in LCB and LSCB are much lower and amounted to about 15 billion m³ and 1.75 billion m³ respectively.

It is very important to use CBM local for energy purposes instead of transporting gas from distant places.

2. Methods

Scientific research and practical experience, especially in recent years, have enabled the development of many devices and technologies enabling economic use of CBM in heating and energy installations.

Technologies for CBM using (energy or chemical) depend mainly on methane concentration in fuel.

2.1 Injecting CBM into natural gas networks

The method is characterized by the fact that CBM (over 50% CH_4 concentration) from the mine's methane drainage station is injected into the natural gas pipeline by compressor in controlled and regulated way, that the quality parameters of natural gas do not change within the scope of separately regulations.

In 2014, in Europe (L. Maggioni et all 2016) there are over 360 plants for the production of biomethane, showing that the purification technology is now mature and tested and is therefore not to be considered as a limit. 83 new biogas

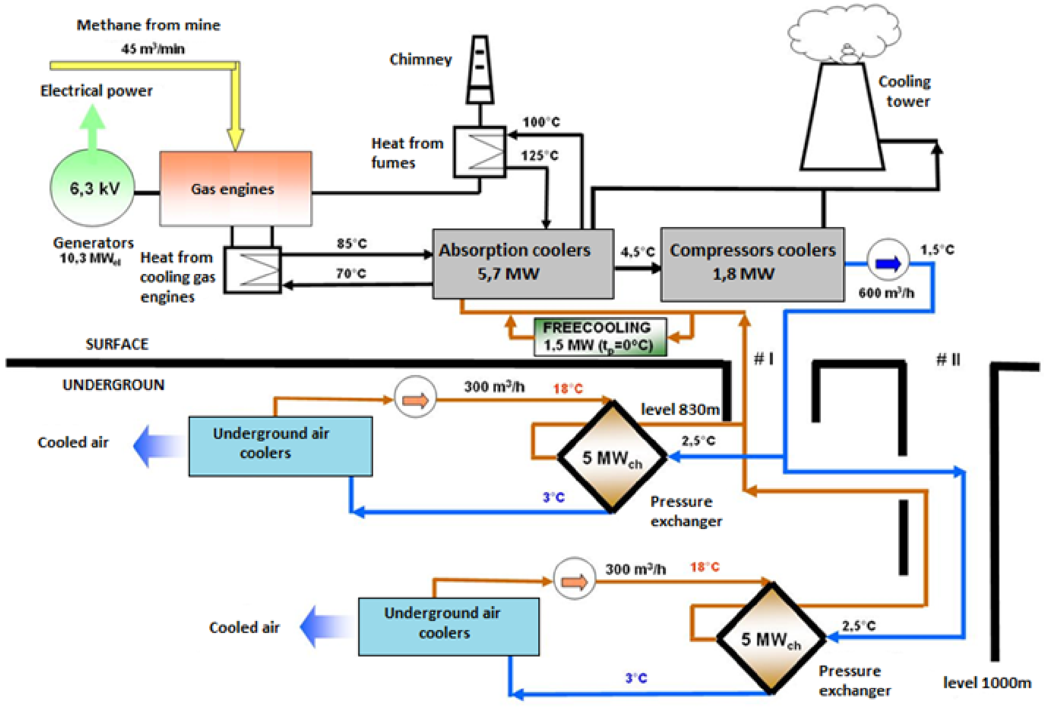

Fig. 3. Pniówek mine – scheme of CBM/CMM use
Rys. 3. KWK Pniówek – schemat klimatyzacji centralnej wykorzystującej metan z odmetanowania

upgrading units were commissioned in Europe in 2014 representing 23% INCREASE compared to 2013. Biogas is characterized by very similar properties as CBM taken from mines, hence the wide applicability of this technology. A big selling point for the biogas-biomethane supply chain (M. Abeysekera et all.) is the fact that the existing infrastructure for transport and distribution of natural gas can also be used to bring biomethane to the final consumer. Thanks to its flexibility, CBM can contribute to the reduction of greenhouse gases (GHG – GreenHouse Gases) in the production of electricity, heat production and transport.

2.2 Using CBM as a fuel for gas engines

Coal provides 25 percent of global primary energy needs and generates 40 percent of the world's electricity, according to the World Coal Institute. The anthropogenic release of methane (CH_4) into the environment is a byproduct of the coal mining process and the global warming potential of this methane continues to draw attention globally. Stakeholders responsible for coal and power production are looking for ways to safely and economically mitigate the release of coal mine greenhouse gases. Sequestering coal mine methane (CMM/CBM) as an alternative fuel for reciprocating gas engine generator sets is a mature and proven technology for greenhouse gas mitigation. Prior to commissioning CMM/CBM-fueled power systems, the methane gas composition must be evaluated. The project is then developed by utilizing an integrated systems approach. As with any type of alternative energy, the economics of electric power CMM/CBM projects play a major role in the success of the project. CBM/CMM combustion in gas engines was used for the first time in Poland at Jastrzębska Spółka Węglowa S.A. in KWK "Krupiński" in 1997 Due to the high efficiency and relatively low level of capital expenditure required, most of the associated energy and heating systems are built based on internal combustion piston engines. Although in the EU most natural gas-generated energy is produced in large scale (e.g. above 200 MW) open or combined cycle turbine power plants operated by major utilities, such facilities require large scale operational and capital expenditures as well as long planning times. As mentioned above, all known mine gas-sourced electricity in the EU is generated using small (1-8 MW electric power capacity) modular reciprocating gas engines, which can be installed quickly and on-site, and added to as needed in order to flexibly adjust operational size.

2.3 Gas flaring

Gas flaring is the lowest-cost technically feasible approach (Karl H. Schultz 2015) to reducing coal mine methane emissions from any drained gas that does not find an economic market. Flaring is standard practice in many industries worldwide for environmental, health and safety reasons. In contrast, in the coal mining industry, methane recovered from underground mines which is not utilized is typically vented directly to the atmosphere. Coal mines primarily vent gob gas, a gas of variable methane quality and quantity that is sometimes difficult or uneconomic to utilize. However, a number of projects developed in the last decade illustrate that mine operators can safely practice controlled gob gas flaring to benefit mining and the global environment. Although it is preferable from both environmental and energy conservation perspectives to put coal mine methane to economic use, it is much better for the global environment to flare gas than to vent it to the atmosphere. As discussed above, the global warming potential of methane is approximately 34 times that of CO_2 (over a 100-year time frame), combusting methane released from mines by controlled flaring would result in emission of a significantly less harmful gas. Methane also contributes to

Fig. 4. LNG installation in Krupiński mine
Rys. 4. Instalacja w KWK „Krupiński"

tropospheric ozone problems and harms vegetation at high concentrations. Hence, flaring coal mine methane may also alleviate local air quality problems. Flaring of vented or drained mine gas is a fairly recent practice and is generally done to earn carbon credits through the destruction of high-global warming potential methane. In the UK, flares – which have since been decommissioned – were installed at several mines in the mid-2000s in order to combust excess gas produced by the drainage systems. Largely owing to the collapse of the EU Emissions Trading Scheme carbon price following the 2009 financial downturn, most CMM flaring projects in Europe are currently mothballed. In addition, several projects for earning credits through flaring in Poland were registered under the UN's Joint Implementation scheme prior to 2008. Since then, Joint Implementation's Emission Reduction Units are not awarded for CMM projects in the EU. Flaring is generally cheaper in terms of capital and operational expenditure than other CMM technologies; under the business-as-usual scenarios developed, however, the study assumes no price signal for flaring, and thus, gas engines are preferentially installed.

2.4 Using ventilation air methane

Use of catalytic and thermal flow reversal engines to utilize extremely low concentration ventilation air methane (VAM) has become possible in recent decades. However, such systems remain relatively expensive (with capital costs about fifteen times higher per cubic meter of air treated than flaring) and difficult to operate, still requiring a minimum methane concentration (i.e. around 0.2% methane in air) to maintain operations.

Currently, the following projects / activities are carried out in Poland in this area:

- Project "Underground hybrid installation of methane utilization from ventilation air and Energy processing for air conditioning" - VAMPIRE" - implemented by Centrum Transferu i Promocji Technologii sp z o.o.,
- Project "Catalytic flameless oxidation of methane from ventilation shafts of a hard coal mine, using post-process gas for the production of cold supplied to air condition,ing of underground work zones of miners" - implemented by ICON ENTECH GROUP S.A., WARSAW,
- Project prepared by Węglokoks S.A. - location of the Brzeszcze mine,
- Cooperation between JSW S.A. started and GIG in the scope of the possibility of using the device using methane from ventilation air of the mines of the Swedish company Megtec/Durr in the Budryk mine.

2.5 Gas turbines

Turbines and gas microturbines have also been increasingly used in recent years. A gas turbine is a type of internal combustion engine in which gases resulting from chemical reactions (usually combustion) affect the turbine blades, setting them in motion. Unlike internal combustion piston engines, the conversion of chemical energy into mechanical energy takes place without the use of a crank system. This gives greater efficiency, but only at very high speeds (over 30,000 rpm).

2.6 Multiple Energy production

The "Pniówek" mine exploits coal seams characterized by a very high methane hazard and high primary temperature of the rock mass 40–45°C. The need to improve working conditions underground formed the basis for the decision to build central air conditioning in KWK "Pniówek" – the first investment of this type in Poland.

The prognostic calculations of climatic conditions in the mining excavations of KWK "Pniówek" in the years 1999 to 2005 showed that it is necessary to cool the air in the mine. The capacity of the air coolers needed to be installed in the mine should be around 5 MW per level. As a result of analyzes of central air-conditioning systems, the combined energy and cooling system based on gas engines and electricity generators as well as absorption and compressor refrigerators was selected for use (see Fig. 3). Gas engines are powered by methane from methane drainage. The heat generated in this process is used for transformation in absorption refrigerators. Part of the electricity generated by the generator is used to power screw compressors. The remaining amount of electricity and heat is used for mining needs. The installation of central air conditioning in the "Pniówek" mine was launched in 2000.

2.7 Liquefaction of gas from methane drainage

LNG installation built in Suszec based on methane obtained from Krupiński coal mine belonging to JSW. Production capacity is 16 tons of LNG per day. The resulting fuel is distributed using specialized cryogenic tanks at minus 160

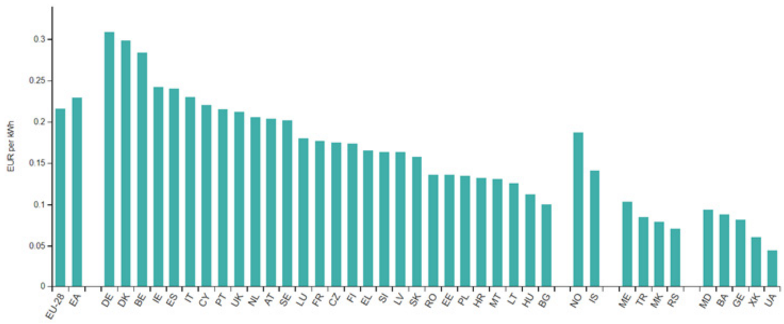

Fig. 5. Electricity price (including taxes) for household consumer in first half 2019
Rys. 5. Cena energii elektrycznej (w tym podatki) dla konsumenta domowego w pierwszej połowie 2019 r.

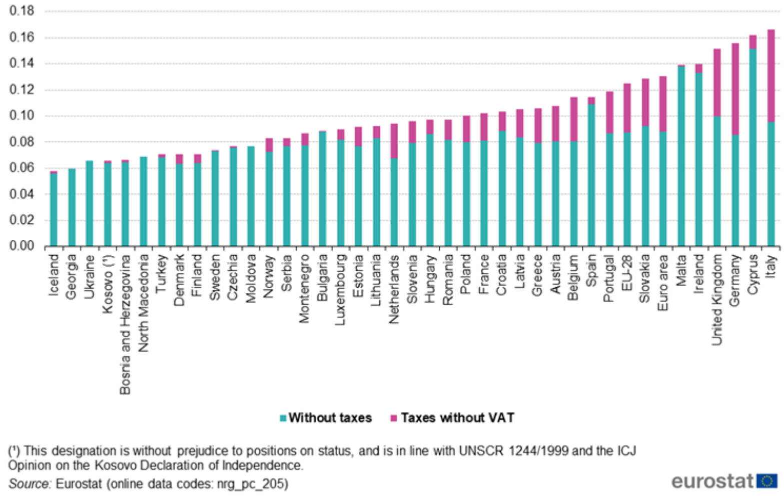

Fig. 6. Electricity price (including taxes) for non-household consumer in first half 2019
Rys. 6. Cena energii elektrycznej (w tym podatki) dla odbiorców niebędących gospodarstwami domowymi w pierwszej połowie 2019 r.

degrees Celsius. The recipients of the LNG sold by the company are enterprises from the food industry, hotels and SPA facilities. LNG is more expensive fuel than network gas however, is a competition for heating SYSTEMS using oil or LPG as a fuel. There are many industrial plants that do not have access to gas, even those located in large urban agglomerations. LNG supplies are an alternative for them.

Results

The price of energy in the EU depends on a range of different supply and demand conditions, including the geopolitical situation, the national energy mix, import diversification, network costs, environmental protection costs, severe weather conditions, or levels of excise and taxation. Note that prices presented in this article include taxes, levies and VAT for household consumers, but exclude refundable taxes and levies and VAT for non-household consumers.

Short-lived climate pollutants (SLCPs) are agents that have relatively short lifetime in the atmosphere – a few days to a few decades - and a warming influence on climate. The main short-lived climate pollutants are black carbon, methane and tropospheric ozone, which are the most important contributors to the global greenhouse effect after CO_2. They are also dangerous air pollutants, with various detrimental impacts on human health, agriculture and ecosystems. Other SLCPs include some hydrofluorocarbons (HFCs). While HFCs are currently present in small quantities in the atmosphere, their contribution to climate forcing is projected to grow to as much as 19% of global CO_2 emissions by 2050.

In ICIS' report entitled "The European carbon market: the impact of rising carbon prices on electricity producers and industries" published on 9 May 2019, the consulting firm argues that the significant increase in EU ETS market carbon prices to levels above €20 per tonne of CO_2 in 2018 had very little influence on 2018 emission levels in the European carbon market. On the other hand, a higher carbon price, around €40 per tonne in 2023, could change future investments, leading to a substitution of coal by gas. As the EU ETS has experienced double-digit prices for the first time since 2011, this Market Insight explores whether the increasing carbon prices have been high enough to reduce emissions in 2018 compared with 2017 levels. Furthermore, starting from 2018 developments, the Insight outlines the likely developments of carbon prices in the next five years, presenting the ICIS long-term forecast for European carbon prices and the effects these developments would have on the compliance sectors. In detail, we will speak about the effect on power markets in Germany, France, the United Kingdom, Italy, Spain and Poland.

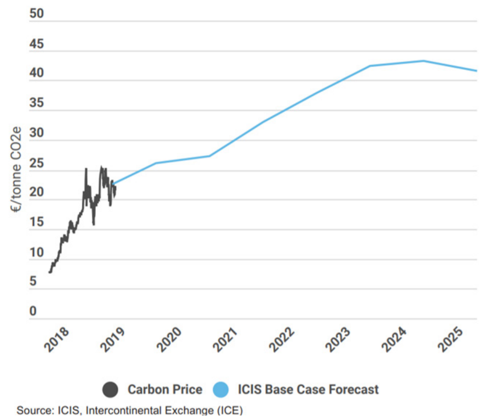

Fig. 7. EUA price forecast
Rys. 7. Prognoza cen uprawnień do emisji CO_2

In Poland higher prices increase (Ruf F. 2019) gas in generation mix With its very large coal power plant fleet, the Polish power price is very sensitive to changes in the carbon price. During 2019-2025, analysis suggests that Polish power prices would increase from slightly above €50.00/MWh to roughly €70.00/MWh. Given this carbon price development, Poland is the best example for a coal to gas fuel switch, with gas generation increasing its output by over 120% (15TWh) from 2019 to 2025 while coal reduces by 10% (6.5TWh) and lignite by 2% (1.4TWh). In the same years, renewables would increase their output by over 120% (22.6TWh).

Discussion

New reforms of the European carbon market, the increased scarcity of CO_2 allowances will make more and quicker carbon reductions necessary. This will lead, to carbon prices of above €40.00/tCO_{2e} in the next five years. Consequently, all emitting sectors covered under the EU ETS will be subject to risks, but also opportunities. Furthermore, power sector can only deliver parts of the necessary reduction with the existing and expected power generation capacity. Next to the effects on the carbon price, the utilisation of idle gas capacity and the reduction of lignite and hard coal-fired generation will have an impact on power prices in the whole of Europe. Fossil fuel-dependent countries like Poland or Germany will likely see higher power prices.

Conclusions

Investment in low carbon technologies – in the power and industrial sectors – will become more profitable. Such investments will also be inevitable in order to deliver the necessary reductions to reach the set targets. The power sector will continue to be the frontrunner in this new wave of investments. Thanks to higher carbon prices and the falling cost of technologies, renewables may reach market parity in several markets in the next five years. Additionally, flexible gas-fired generation units will regain market share, with new investments. Next to the developments in the power sector, and despite continuing to receive great parts of the allowances for free, higher prices and more stringent benchmarks will also push the industrial sectors covered under the scheme to look at long-term investments in cleaner production technologies and energy efficiency.

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Efektywne ekologicznie i ekonomicznie metody wykorzystania metanu pokładów węgla

Metan pokładów węgla jest ekologicznym paliwem pozyskiwanym dwoma drogami: podczas wydobywania węgla kamiennego lub za pomocą specjalnie wykonanych otworów z powierzchni do pokładów dziewiczych lub zlikwidowanych kopalń węgla. Zwiększone zapotrzebowanie na energię elektryczną oraz konieczność zmniejszenia emisji CO_2 do atmosfery powodują, że coraz korzystniejsze jest inwestowanie w nowoczesne technologie, szczególnie lokalne moce wytwórcze oparte o paliwo jakim jest metan pokładów węgla. Artykuł przedstawia możliwe główne technologie wykorzystania metanu pokładów węgla na tle prognozy zwiększania ceny energii elektrycznej oraz kosztów zakupu uprawnień do emisji CO_2.

Słowa kluczowe: metan, odmetanowanie, ślad węglowy, ochrona środowiska, górnictwo