Assessment and data analysis of beneficial implementation of
cogeneration modules at mining enterprises to minimize
negative influence on the environment

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Abstract. This article analyses the negative influence on the environment exerted during coal
mining and draining-out gases from coal deposits. A large quantity of side gases can be recycled
into useful energy or warmth. Co-generation stations seem to be a perspective solution for
recycling these wastes with minimal environmental casualties. This research describes and
assesses an operation result based on the example of one co-generation station. The data for the
analysis have been collected during two years. The data analysis reveals that during a two-year
period of co-generation station maintenance, a mining enterprise has obtained benefits from CH₄
utilization. The enterprise was able to cover its own peak power consumption (10 MW average)
and even earn money delivering generated energy into the city network due to correct planning
and efficient gas burning. Moreover, data analysis proves that integration of such cogeneration
modules allows making networks with distributed generation (DG) sources more efficient and
eco-friendlier because of utilization of side-gases from different technological processes even in
small amounts

1. Introduction
One of the main problems that world’s society faces is appearance of th global energy crisis. Many
attempts were made to prevent it, humanity deals with associated problems, which worsen and destroy
our environment and ecology. In addition, energy production increases accumulation of wastes that
pollute our planet and slowly lead to the greenhouse effect. Mining industry is not an exception and it
has a huge number of ecological problems that should be solved. However, being one of the main power
consumers in the world (and fuel generator, at the same time), it requires implementation of the latest
techniques and inventions, but also search for new methods of zero waste production [1-3].

Nowadays efficiency increase of technological processes together with automation is the most
perspective and beneficial method in reduction of waste production. Certanly, this is an input intensive
technology that repays itself not momently. However, the future benefits are always positive not only
for the enterprise income, but also for surrounding environment. Fossil fuels production and mining are
not exceptions, and improvements in technological cycles and raw materials processing always help to
increase product outcome [4].

At the present time, oil, coal and gas are primary energy carriers in developing countries. Renewables
and their technologies are being integrated efficiently, but still they are too expensive and cannot cover
all power demands. That is why fossil fuels occupy main part in the world’s energy system. Figure 1
shows prognosis of their balance for the next twenty years. It is obvious that the oil component will
come down and percentage of gas and coal will increase. This happens because of fast-growing economics in such countries like China and India [5, 6], where technological developments require a bigger amount of electricity and coal as the cheapest fossil fuel fits best these demands.

However, we should not forget about a devastating ecological impact on the surrounding environment in an attempt to satisfy fast-growing demands of electricity. Figure 2 demonstrates hazardous influence of inefficient mining and coal combustion on our lives.

Different modern technologies are being implemented widely all over the world in order to increase efficiency of power and heat generation, decrease the amount of pollution and generation of greenhouse gases. Fossil fuels are being slowly pushed out of the energy market. Nowadays they are being replaced with different alternative sources of renewable energy. In addition, many different technologies try to change traditional design concept of power networks: they are modernized from centralized to decentralized. However, due to many descriptions of distributed generation benefits only a small amount of research is devoted to the data analysis of power stations and networks maintenance.

The purpose of this article is to analyze a positive effect on the environment of the co-generation power station that was built close to the mine and utilized associated methane-gas. The main aim was to collect, accumulate and assume data about co-generation station operation, to show the real efficiency and the benefits that company received after two years of maintenance.

2. Structure of co-generation plant at Zasyadko Mine
Nowadays coal and oil are two primary energy carriers. Their leading position changes from time to time. However, their common share in total energy production stays approximately equal [5, 3]. Recently China and India have started quick development of their own coal deposits in order to fill power deficiency at the local markets. It is expected that the oil and coal share in the worlds energy
generation will be approximately equal (near 30% for each fuel) up to 2030. Other 40% will be divided between nuclear, hydro, thermal energy and renewables. All these facts testify that the rational usage of coal and oil is still an important task [6, 7].

Some useful products are obtained together with coal extraction. These are different types of associated gases. The most common is methane (CH$_4$). In Donbass region, where coal is mixed with shale rocks, contamination of methane reaches huge values. Earlier this gas was emitted in the atmosphere or burned without any processing. This inefficient utilization generated CO$_2$, CO and other hazardous greenhouse gases in big amounts. However, it can be effectively utilized in co-generation modules for energy and heat production. In addition, this utilization lowers the price for extracted coal and produced electricity [8, 9].

One of the first enterprises in Donbass region was the coal mine “Zasyadko” that has installed a big co-generation plant on its territory in order to utilize associated methane gas. Its total maximal power production capability can reach 36 MW electric energy and 33.6 MW warm energy.

The co-generation plant consists of twelve modules. Their design is shown in Figure 3. An Austrian company Jenbacher that is currently a subdivision of GE Company is their manufacturer. 20-cylinders gas reciprocating engines are directly connected with synchronous generators. Maximal generation power of each module consists of 3 MW electric power and 2.8 MW heat power [8, 9].

![Figure 3. Design of co-generation module.](image)

Four tube lines from two vacuum pump stations (VPS) deliver separated methane-gas. From VPS, gas is supplied to the blending node of the co-generations station’s gas-preparation module in order to receive the homogenous gas-air mixture with the required concentration at the module’s output. The allowed water contamination is 25%-40%; nominal value is approximately 30%. Uncondensed gas is burnt in the valve vent. In order to increase the gas-air mixture concentration, a highly concentrated natural gas (93%-95%) is added [10].

After the first preparation stage, the methane-air mixture (MAM) passes through some sequential processes: cooling, cleaning and heating with drying. The cooling of MAM is made in order to prepare it for cleaning and moisture separation in separating filters. MAM heating is performed for its cleaning and moisture separation too. It is made in heating blocks heated to the level of 40°C. The obtained fuel with required parameters guarantees stable end efficient operation of co-generation modules.

A highly concentrated gas from surface draining-out cracks is delivered to the co-generation modules in order to ignite the fuel mixture in combustion engines [11]. The produced energy is delivered from 12 generators to the mine substation. From that point it is divided to the two lines: one for feeding ground equipment and the other is for feeding underground technique. Heat energy that is obtained during co-generation units operation is used for own station needs and technical mine buildings. The rest of the heat sometimes is transferred into the city heat network.

3. Assessment of Methane-gas utilization
Main data about co-generation station operation was collected in order to assess its real efficiency. All calculations and modeling were performed in Matlab Simulink software. The analysis included detailed data processing. The statistics about consumed gas and utilized methane was collected during 2 years.
At the same time equipment was monitored for uninterruptible operation. Data analysis is connected to the energy situation in the region. As a result, methane consumption diagrams, heat and electrical energy generation and the amount of CH$_4$ were obtained. Figures 4-7 demonstrate results of co-generation station productivity during past two years. Calculations were performed for the amounts of utilized CO$_2$ [12].

Figure 4 demonstrates station’s high efficiency. Its own energy consumption is less or equal to 2%. It means that almost all generated energy from methane utilization can be delivered directly to the consumer. Generated heat energy is used for water heating for mine’s own needs (see Figure 4). Creation of the co-generation station allowed to improve the ecological situation in the surrounding region in addition to money economy (Figure 5). An emission rate of greenhouse gases into the atmosphere decreased 7 times (methane is 7 times more toxic than CO$_2$ and one ton of CH$_4$ is equivalent to 23 ton of CO$_2$). In addition, the mine created a CH$_4$ fuel station for provision of the local bus park with free fuel. Moreover, gas utilization saves Kyoto Protocol shares, do not buy them and even sometimes sell mine’s share to the local metallurgical plant. Calculations reveal that for utilization of one ton of CO$_2$, the enterprise pays approximately 18 € (Figure 6). It is visible that the co-generation plant not only recompenses its own expenditures in electricity and warm energy, but also decreases utilization costs due to efficient utilization of harmful substances and this allows to decrease expenditures for ecological charges.

![Figure 4. Results of generated and transmitted energy: green area – generated energy; grey area – transmitted energy.](image-url)
Figure 5. Amount of generated heat energy.

Figure 7 demonstrates additional benefit of the cogeneration station – money economy. It was achieved not only due to utilization of heat and electricity that combustion units were producing from previously thrown methane-gas, but also due to economy in penalties imposed for pollution. As an intermediate result it can be said and summarized that gas volume being recycled depends directly from gas volume in geologic horizon and mine productivity. All Figures 4-7 reveal that the co-generation station had maximum productivity in 2007-2009 when all five long faces were in operation. In addition, l1 geologic horizon was under development. Later, due to a series of disaster l10, shell was closed and mine’s productivity was significantly decreased. This fact influenced the total productivity of the co-generation station. Station’s own consumption comprises 0.5-2% of the generated amount of electricity. This demonstrates high efficiency of used equipment.

Figure 6. CH₄ and CO₂ utilization results
4. Conclusion
Data analysis reveals that utilization of cogeneration modules (or stations) has a beneficial effect on environment due to recycling possibility. Many industrial factories, especially in mining, have a lot of secondary outputs that were until now just thrown away without any recycling. This happened due to imperfection of existing energy generating methods and low efficiency of existing technological processes. Nowadays, beneficial recycling or utilization of hazardous gases is possible with very good economical outcome.

Analysis of two years statistics reveals that correct burning of CH$_4$ (that was always burnt as side gas from draining processes) at mining enterprises can not only save money due to reduction of ecological penalties, but also generate a necessary amount of electricity to feed the whole enterprise and even inject rests to the central city network.

Positive experience of cogeneration modules utilization opens a very good opportunity for distributed generation technology. The organization process of microgrids can be done using such kind of equipment. Moreover, during cold winter seasons or in the northern regions, general efficiency factor increases because of warmth generation and utilization.

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