Electricity production from CMM; a case study of JSW

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Agenda

1. Introduction
2. Methane emission in Poland
3. Case of study
4. Methods
5. Results
6. Summary

Introduction

- The energy sector is considered the second-largest source of methane emissions.
- Mining activity has a large share in this sector. Globally, it is responsible even for 8% of methane emissions.
- The increase between 2005 and 2030 may be as high as 50% (Figure 1)

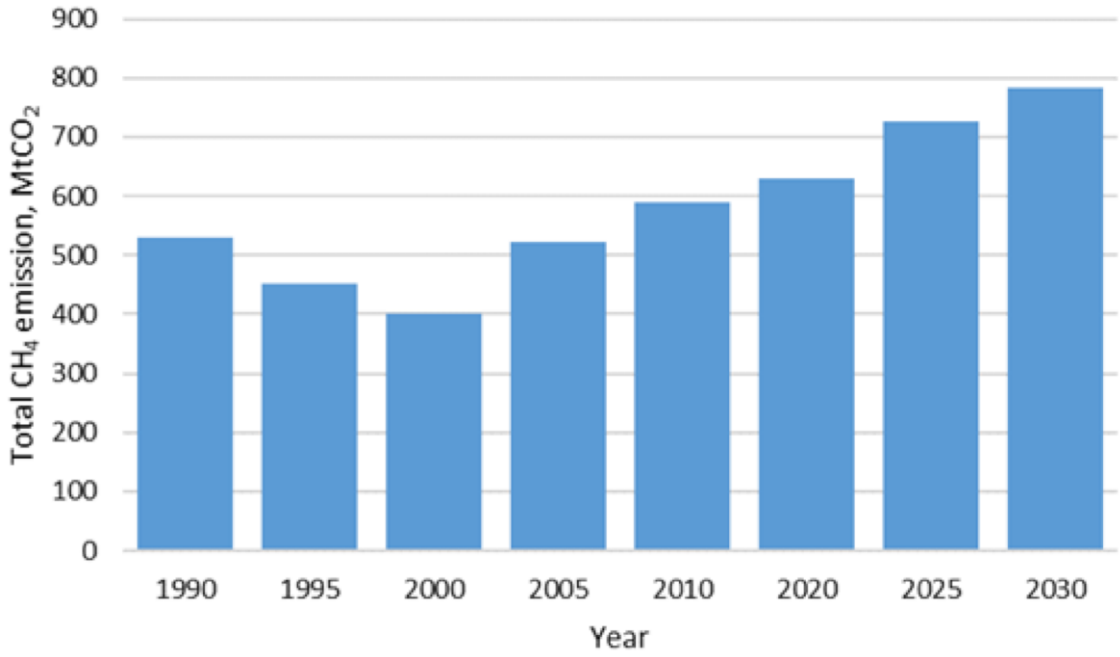


Figure 1. Total CH_4 Emissions from Coal Mining (EPA, 2012)

Methane emission in Poland

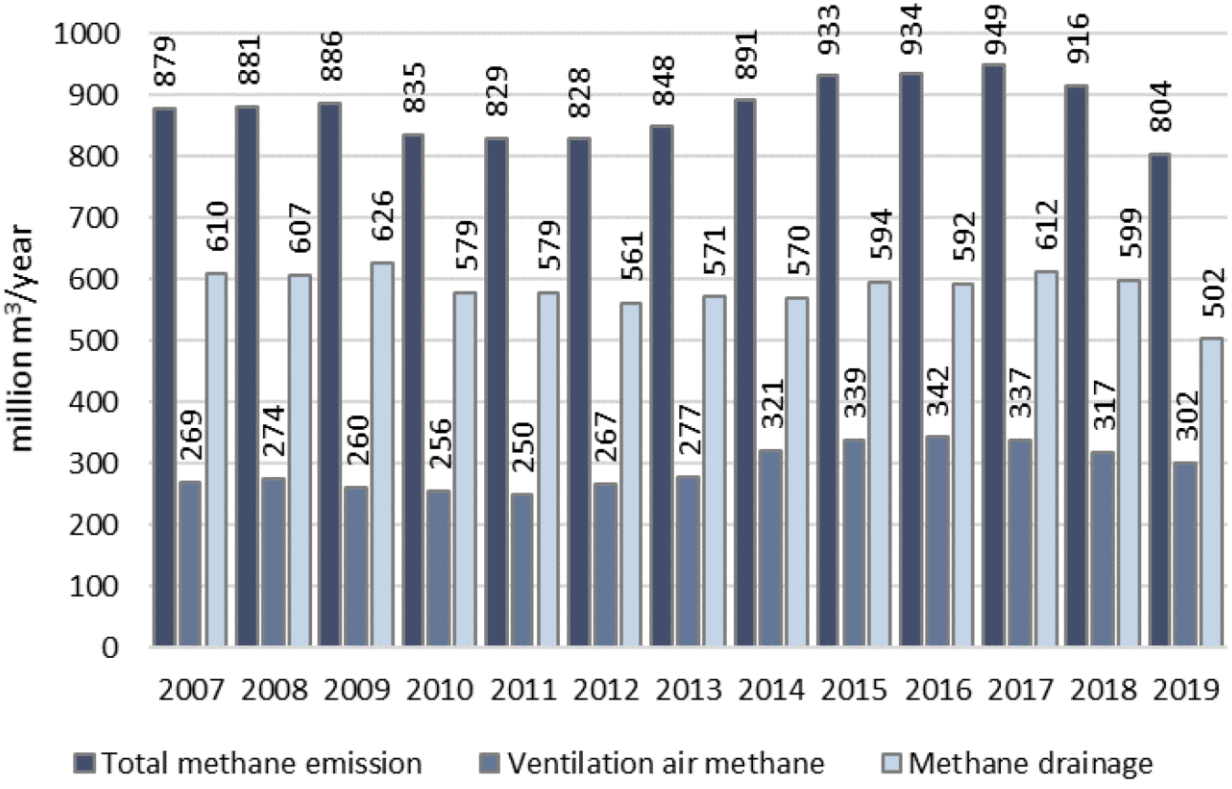


Figure 2. Methane emissions into the atmosphere—total, with ventilation air and captured by methane drainage—in Polish hard coal mining in the years 2007–2019 (WUG, 2020)

- The annual coal extraction from hard coal seams was 61.6 million Mg (Poland, 2019).
- Approximately 80% of production coming from seams containing methane (WUG, 2020).
- The captured methane from drainage systems accounts for the majority of emissions.
- The concentrations of drainage methane mostly exceed 40% - so it can be used as a low-methane fuel.

Case study - The Pniówek mine

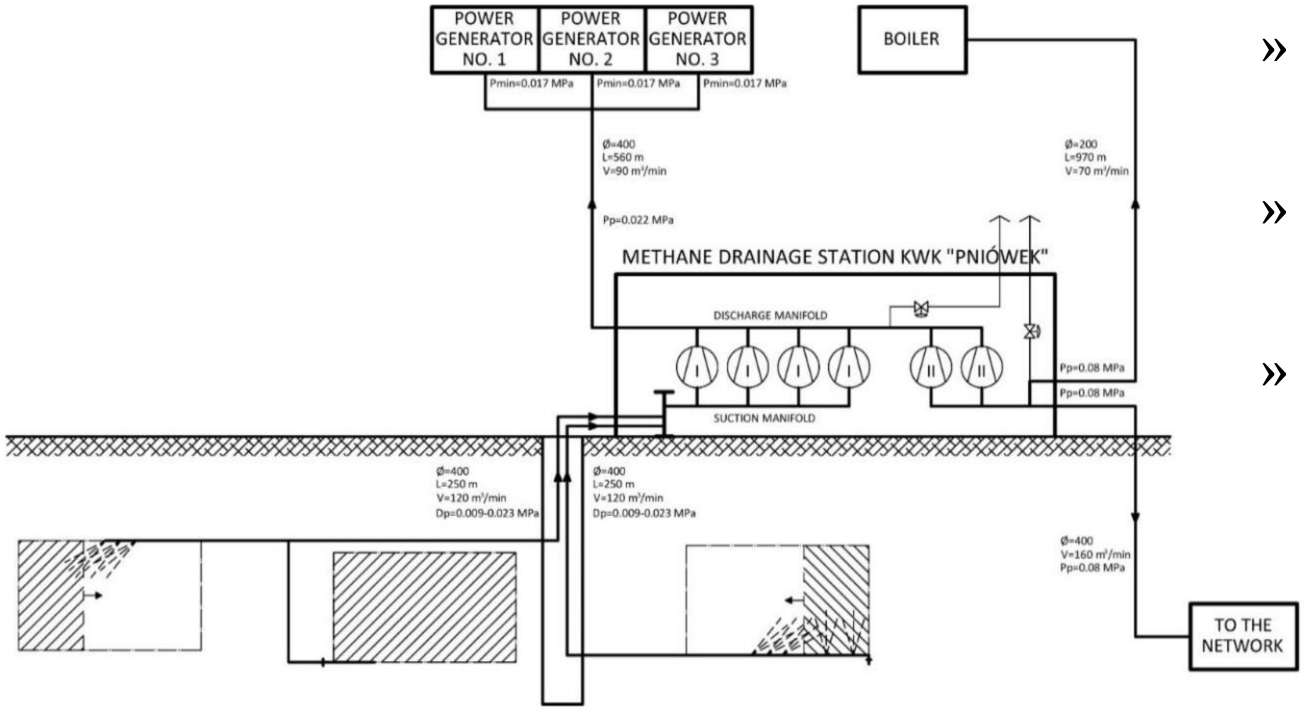


Figure 3. Methane drainage system installation located in the Pniówek coal mine.

- » two Deutz TBG 632 V16 gas engines;
- » two absorption refrigerators with a cooling capacity of 4700 kW;
- » two compression refrigerators with a cooling capacity of 3200 kW;

Case study - The Pniówek mine

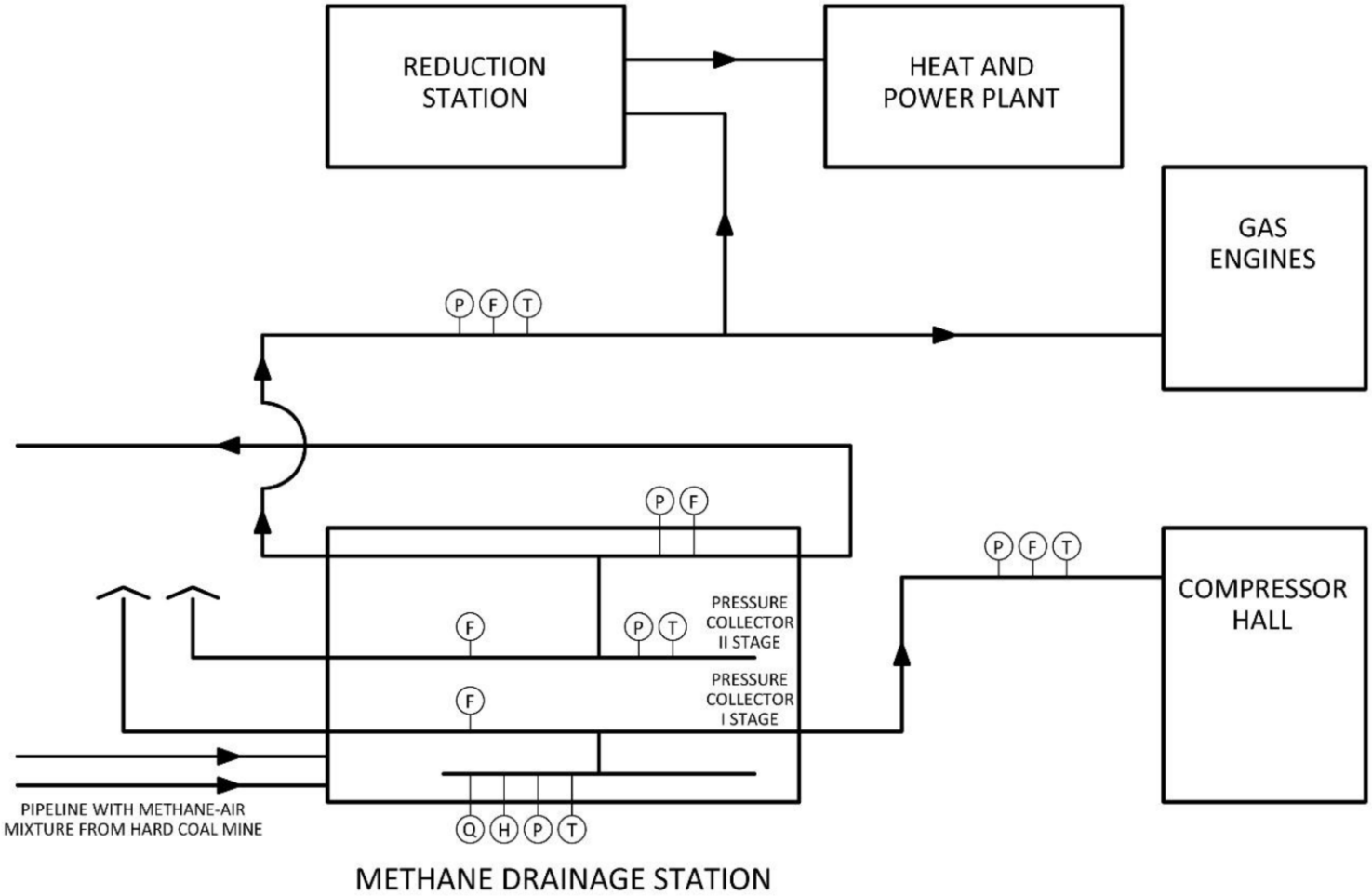


Figure 4. The Pniówek coal mine methane utilization measuring system:
T - gas temperature measurement;
H - gas humidity measurement;
P - gas pressure measurement;
F - gas flowrate measurement;
Q - gas quality measurement

Case study - The Budryk mine

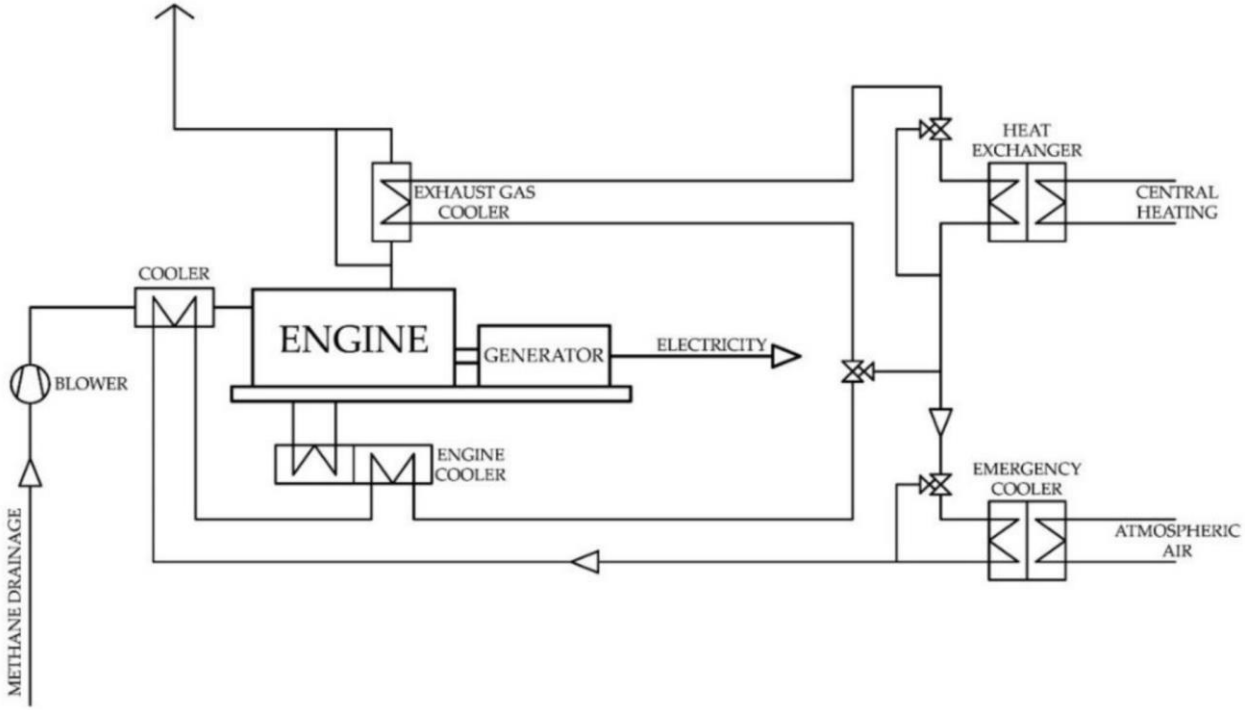


Figure 5. Combined heat and power generation system at the Budryk mine

- A methane utilization system based on TBG 620 V 20 K gas engines
- In the year 2020, 33,009,267.2 m^3 of the methane–air mixture was captured at the Budryk mine with the simultaneous capture of pure methane amounting to 18,019,344.4 m^3.

Methods

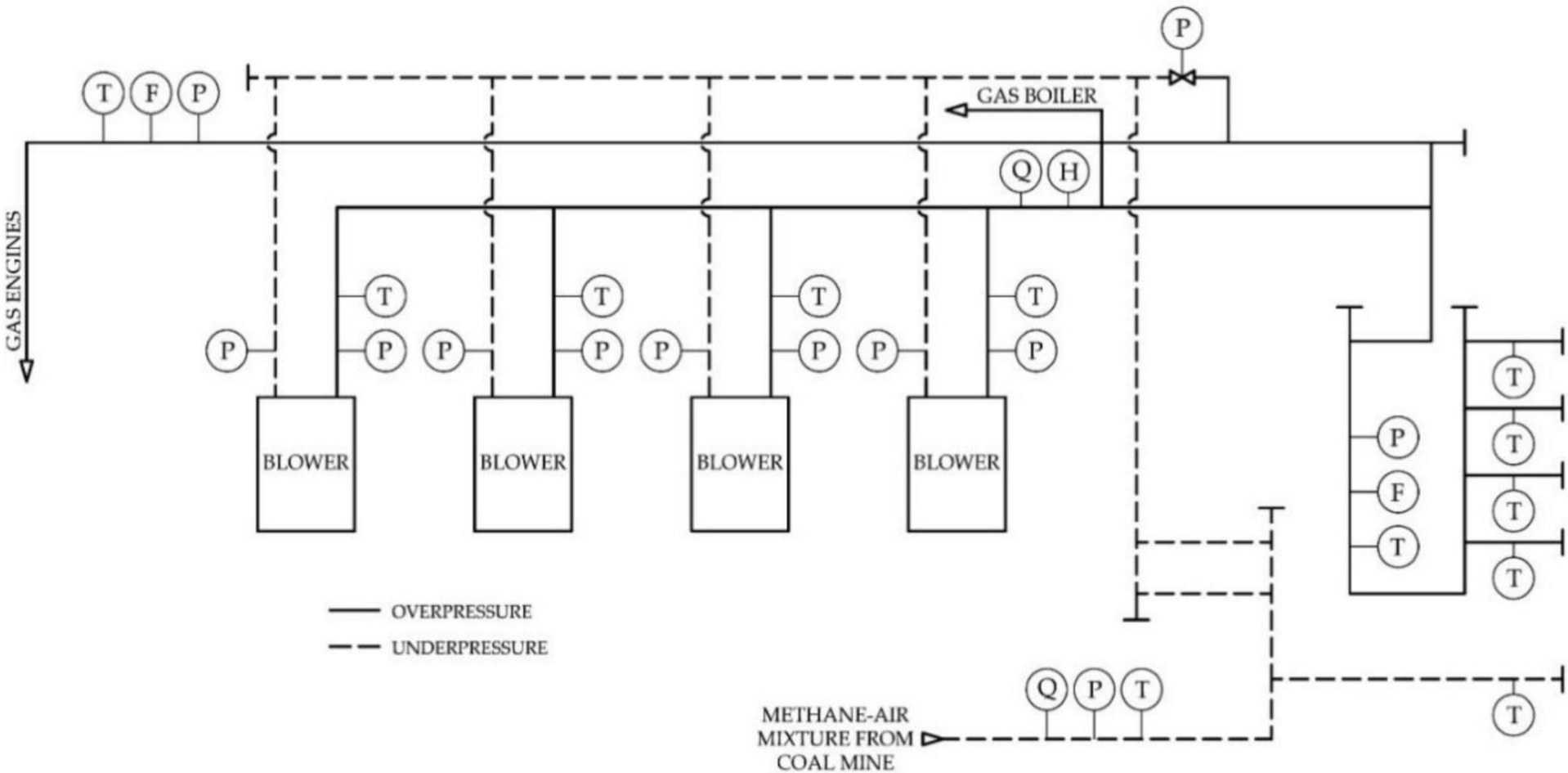


Figure 6. Measurement system for methane utilisation in the Budryk mine with measurement points of gas parameters: P—Pressure; T—Temperature measurement; H—Humidity; Q—Quality; F—Flowrate.

Methods - ANNs

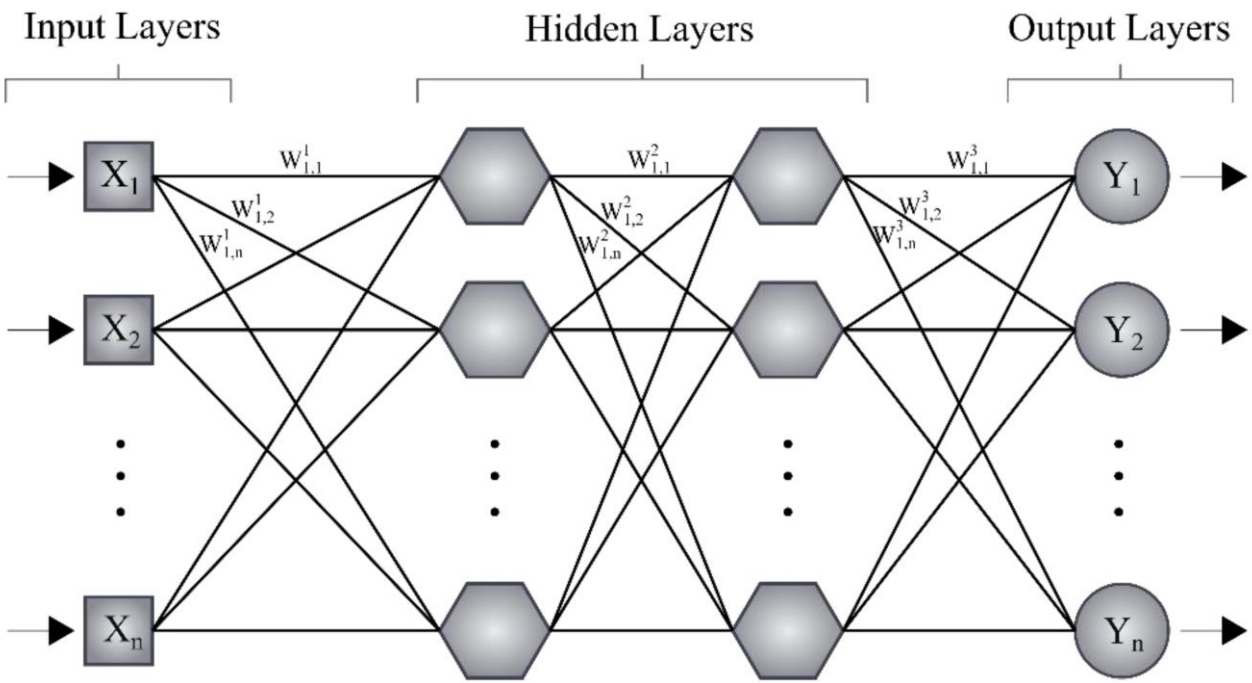


Figure 7. Example of a multilayer perceptron (MLP) neural network structure

Data Collection → Artificial Neural Networks → Evaluation of the Models

Methods – data and models

» Five models to predict the electricity production;

» Selection based on the accuracy indicators.

The Pniówek Mine

» Data from 1 January to 31 March 2017.

» Five variables: day of the week, hour, pressure, methane capture, and methane concentration.

The Budryk Mine

» Data from 1 January to 31 December 2020.

» Six variables: month, day of the week, hour, methane capture, methane concentration, methane-air mixture capture.

Methods - evaluation

The accuracy of the given models was tested using five fit indices:

» the correlation coefficients (r),

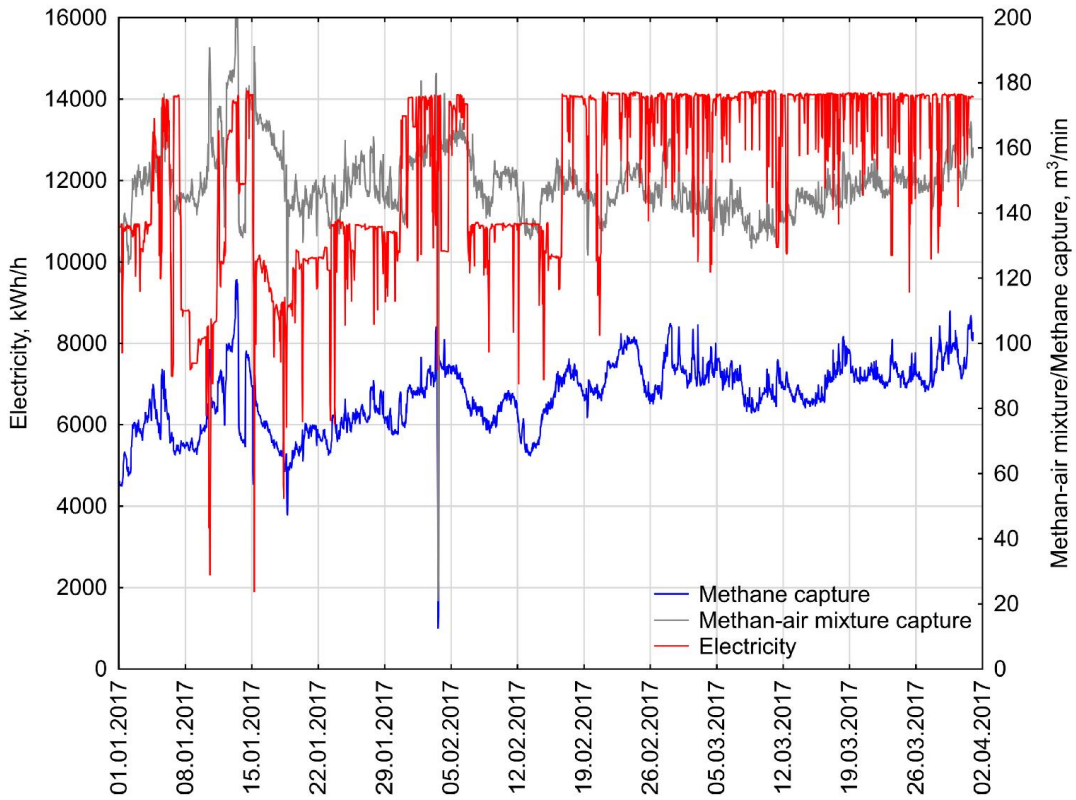
» the mean absolute error (MAE),

» root mean squared error (RMSE),

» mean absolute percentage error (MAPE)

» weighted absolute percentage error (WAPE).

Results - The Pniówek mine



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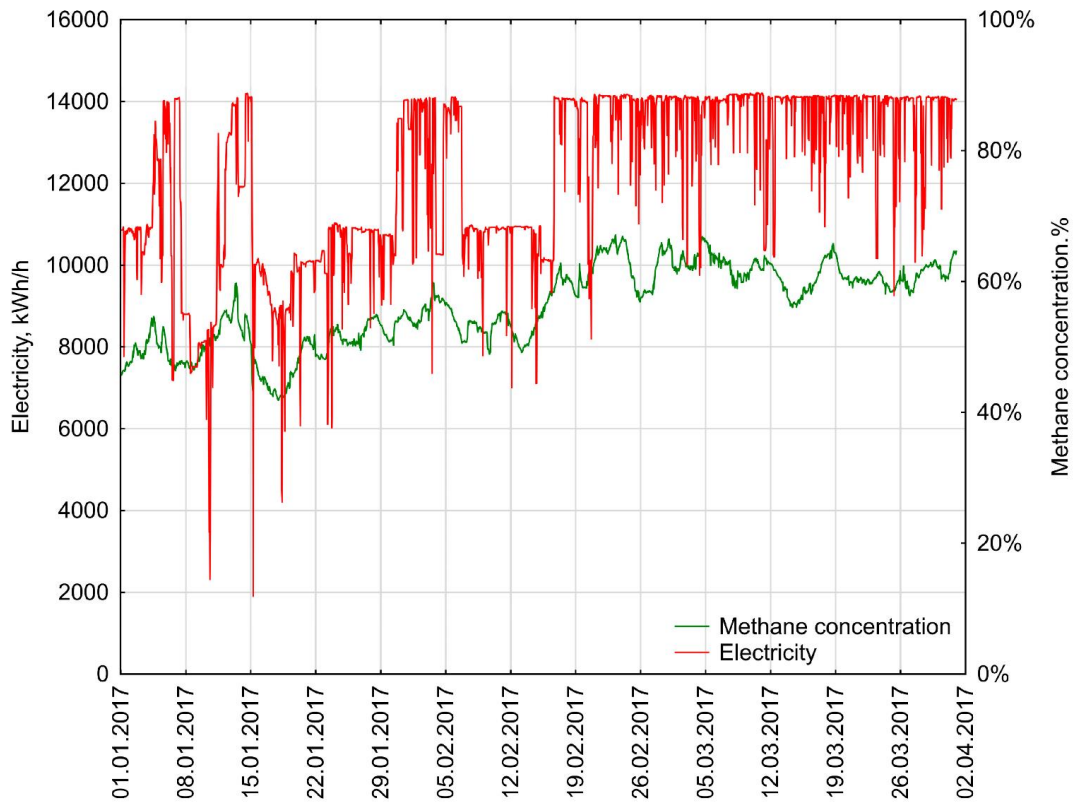
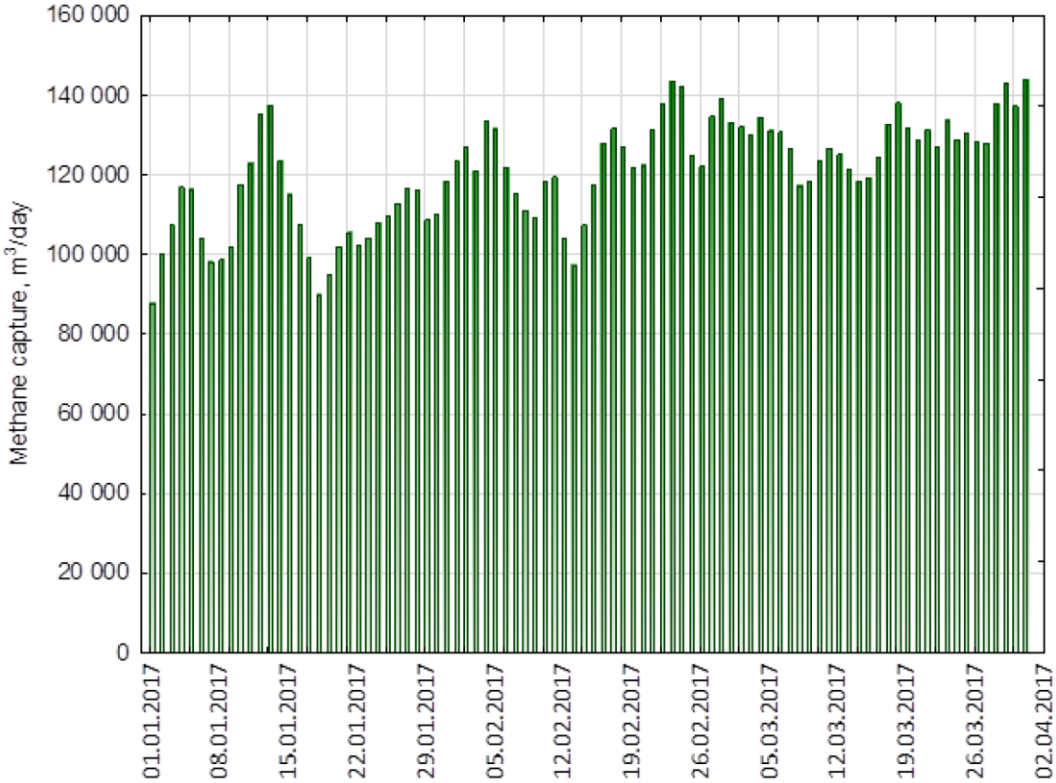


(b)

Figure 8. The course of variables in the analysed period: **(a)** Electricity production, clean methane, and methane–air mixture capture; **(b)** electricity production and methane concentration in the mixture.

Results - The Pniówek mine



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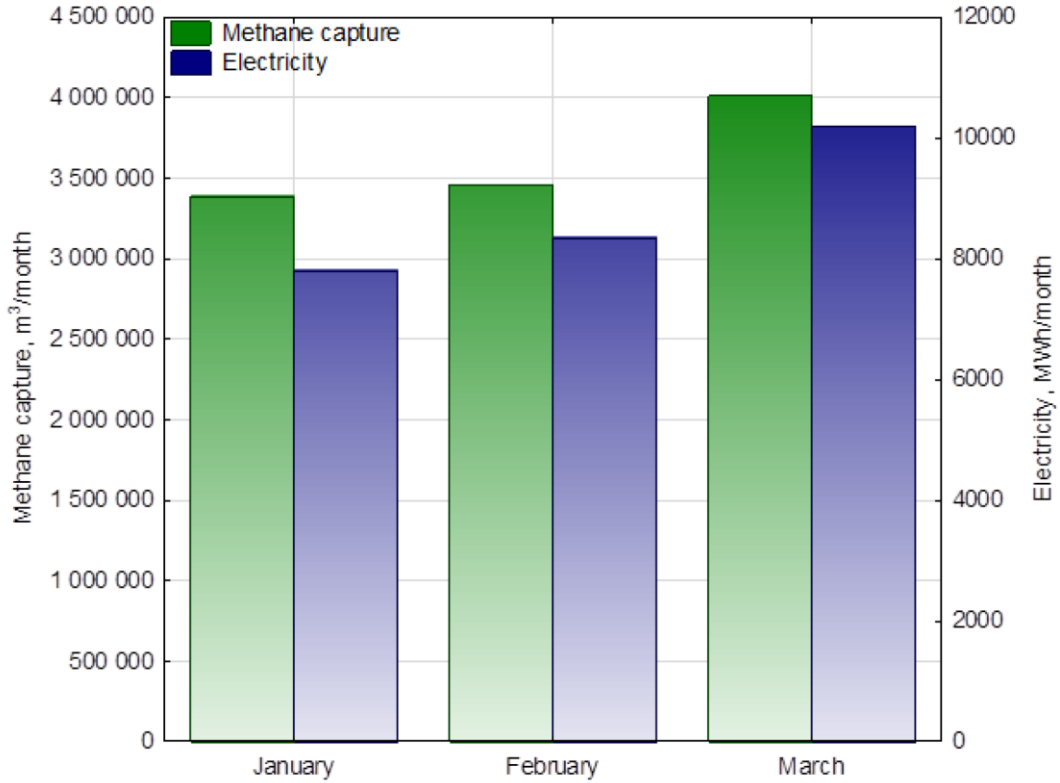


(b)

Figure 9. Variability of methane capture in the analysed period **(a)** in a daily cycle and **(b)** in a monthly cycle, taking into account electricity production.

Results - The Budryk mine

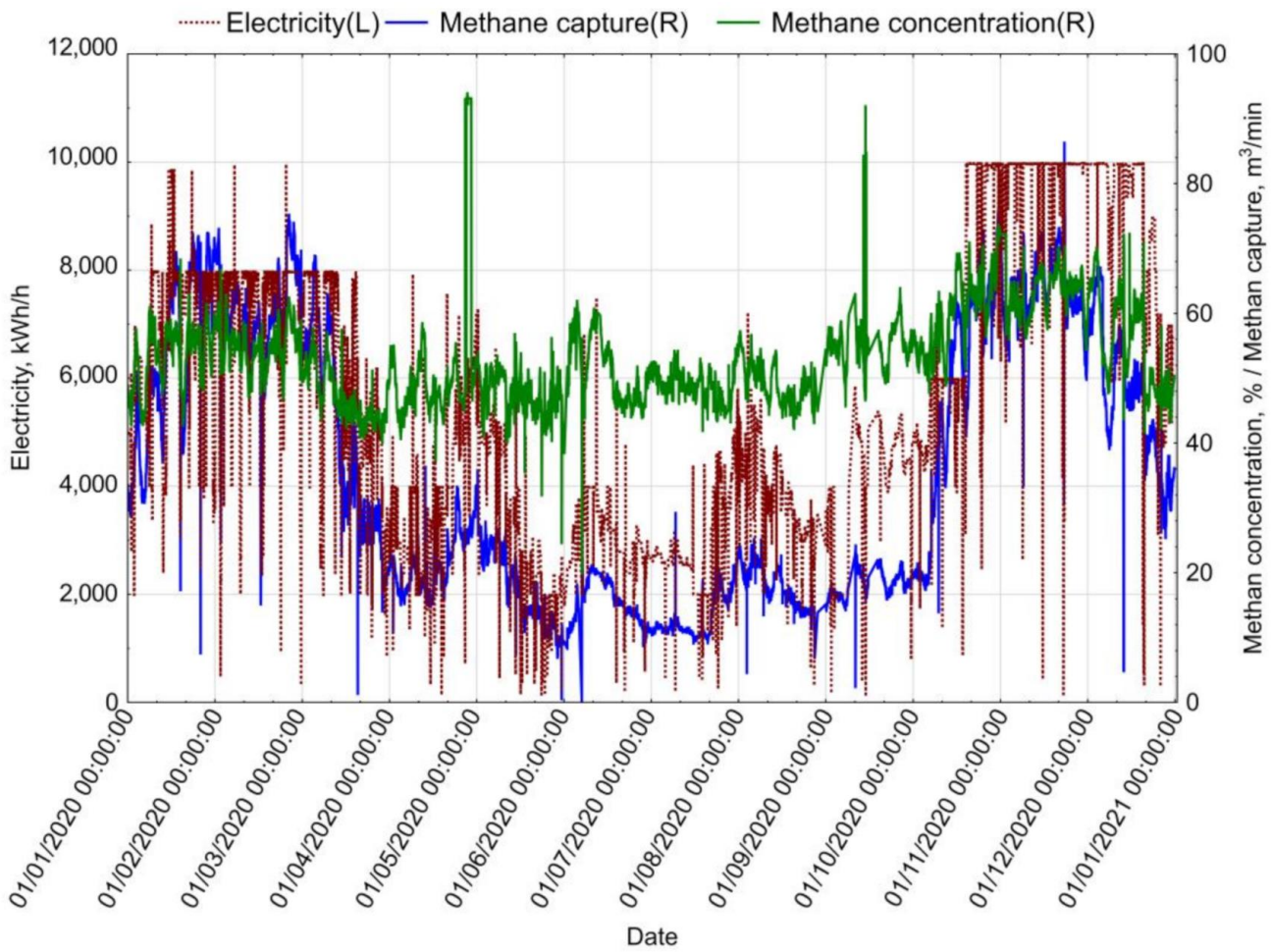
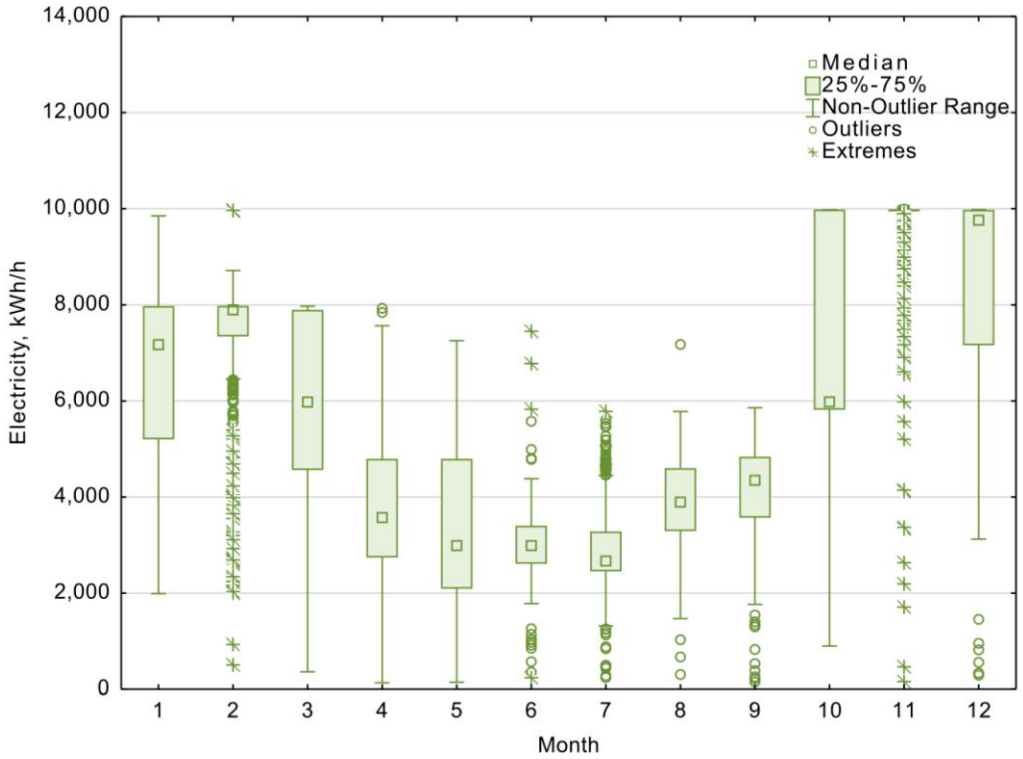
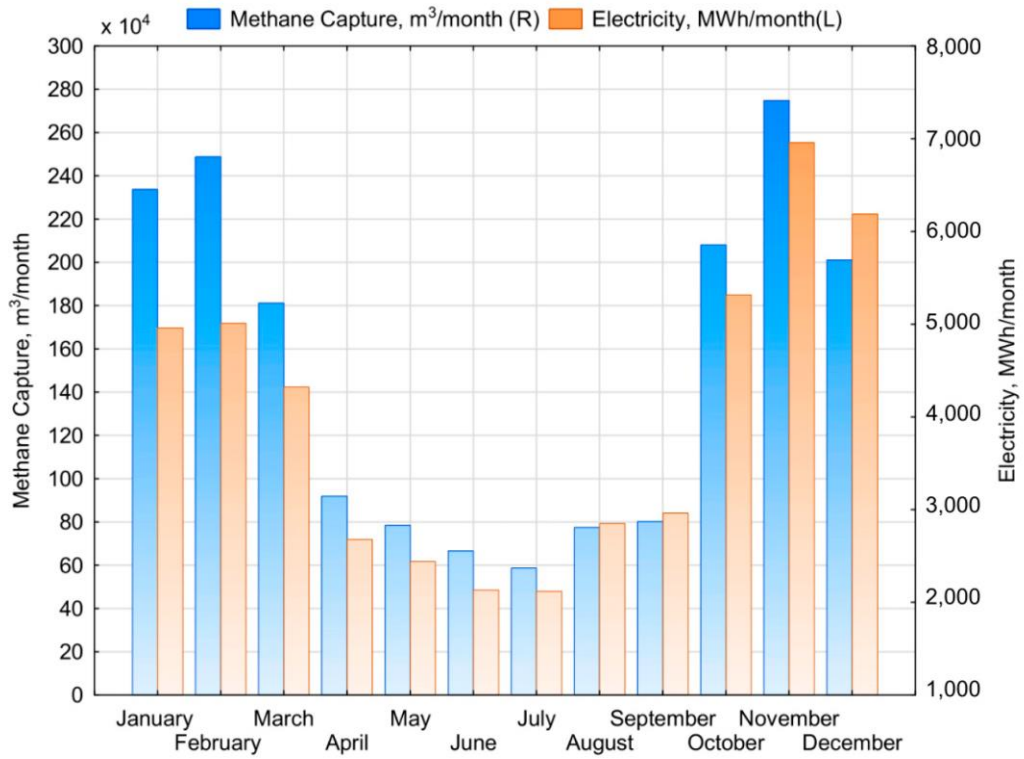


Figure 10. Variability of generated electricity, capture, and concentration of the methane in the analyzed period.

Results - The Budryk mine



(a)



(b)

Figure 11. Variation of electricity production and methane capture by month throughout the analyzed year **(a)** box plot for electricity; **(b)** regression graph with histograms.

Results – Selected models

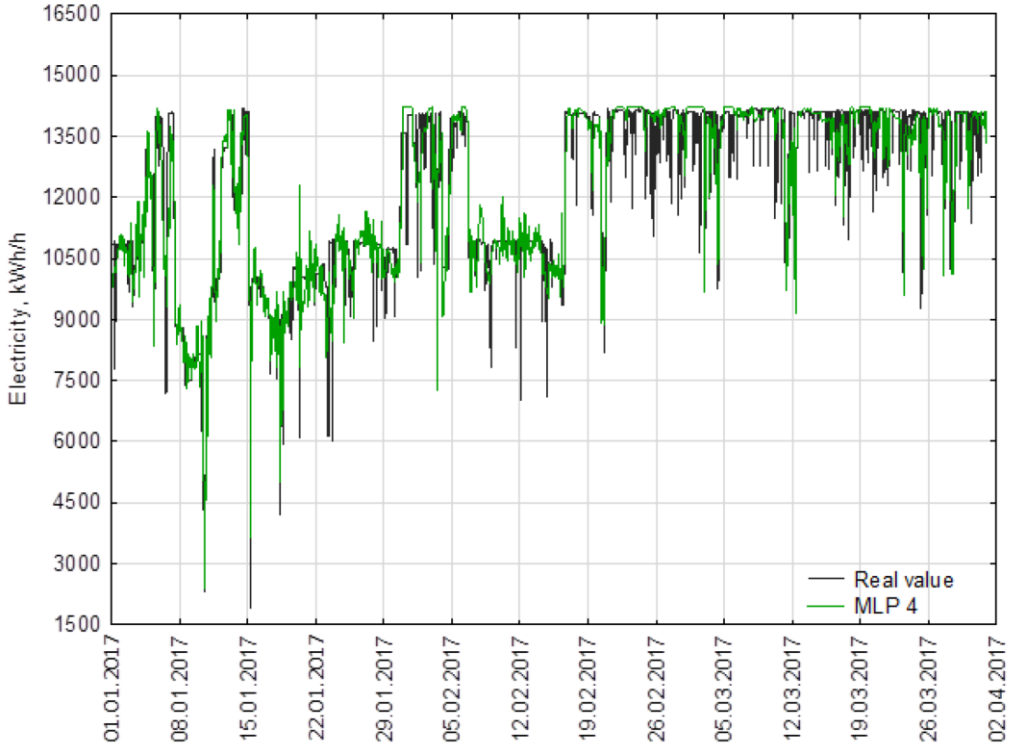
Table 1. Details of the selected MLP models for both mines.

Mine	Hidden Layer Activation-Function	Number of Hidden Units	Output Layer Activation-Function
Pniówek	Hyperbolic tangent	290	Logistic
Budryk	Logistic	293	Logistic

Table 2. Comparisons of forecasting accuracy for analyzed models. .

Mine	r	MAE	RMSE	MAPE
Pniówek	0.940	441.58	708.73	4.05%
Budryk	0.958	437.79	764.71	15.47%

Results - The Pniówek mine



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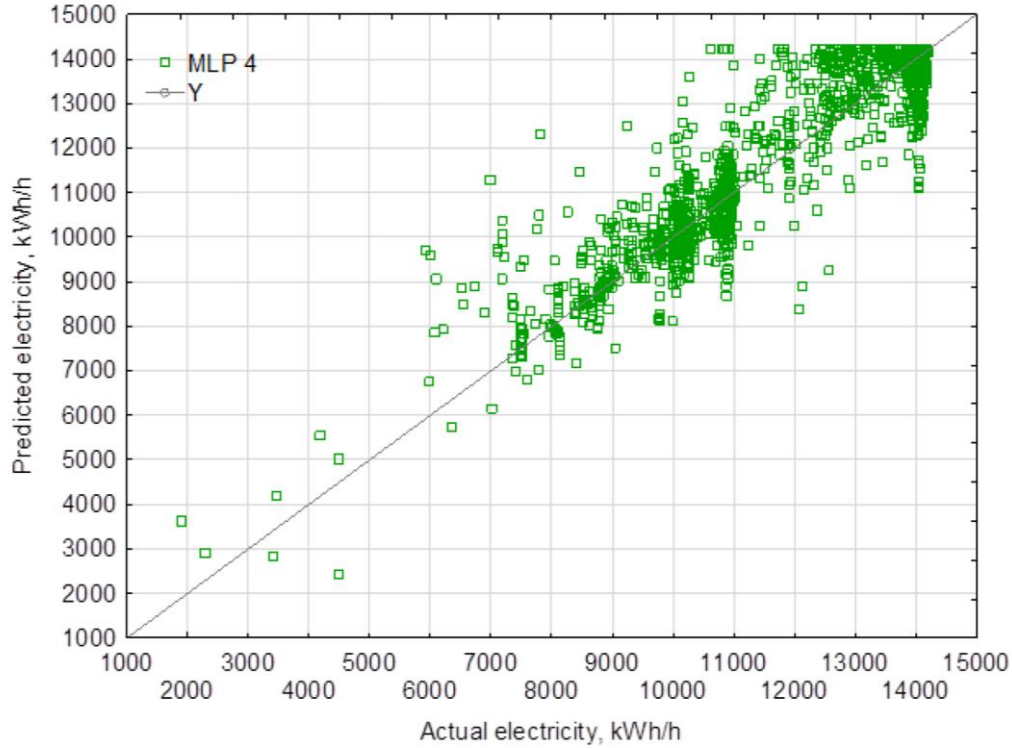
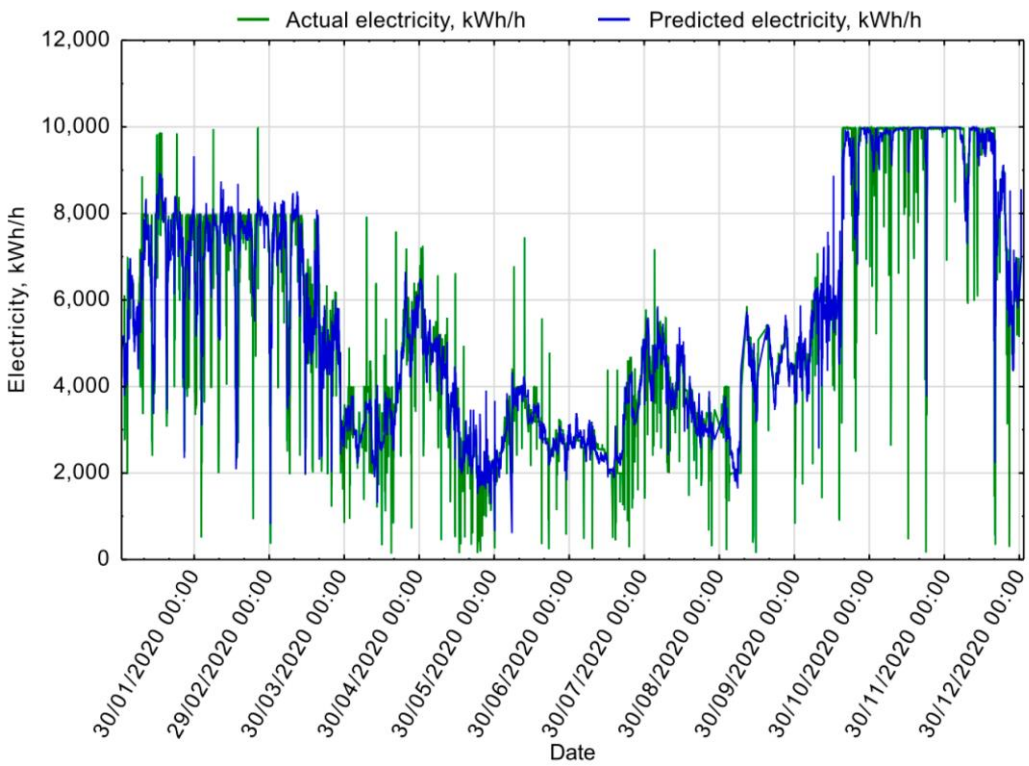


(b)

Figure 12. The prediction result of MLP 1 **(a)** Actual and predicted values for analyzed period; **(b)** Regression performance of model—predicted against the actual values.

Results - The Budryk mine



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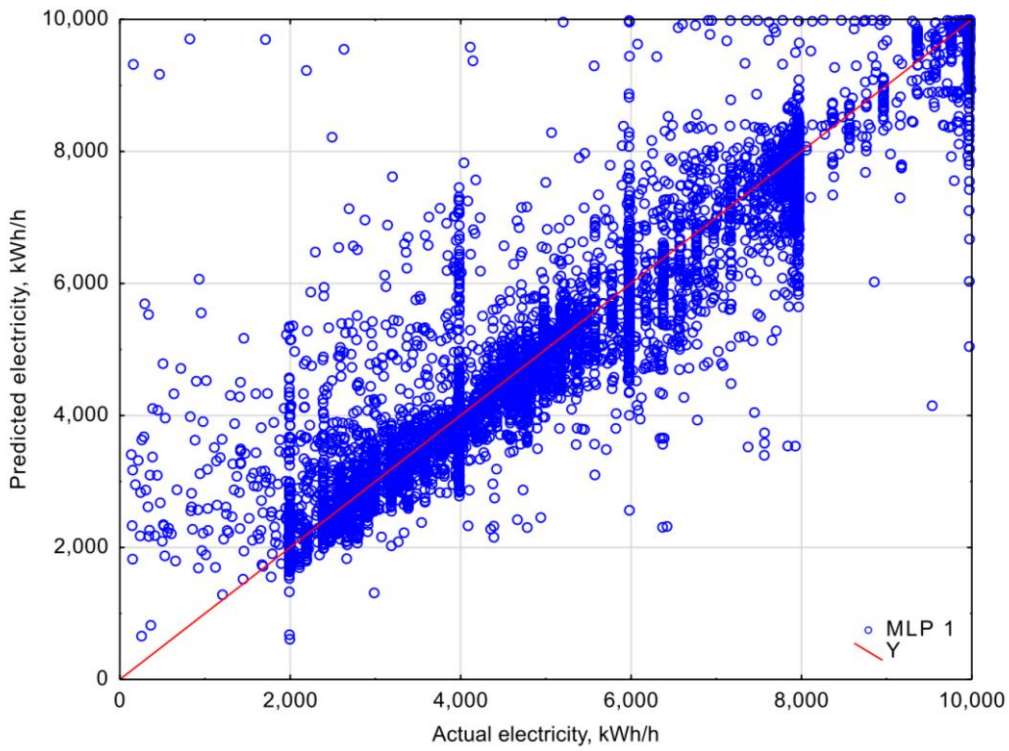

(b)

Figure 13. The prediction result of MLP 1 **(a)** Actual and predicted values for analyzed period; **(b)** Regression performance of model—predicted against the actual values.

Summary - The Pniówek mine

- Monthly methane capture ranges from 3,384,315 m^3 to 4,009,869 m^3, which corresponds to monthly electricity production from 7790 MWh to 10,190 MWh.
- Such methane emission as CO_2 equivalent amounts to approx. 66,700–79,035 tonnes of CO_2eq.

Summary - The Budryk mine

- Methane capture ranges from 587,692 m^3 to 2,749,247 m^3 per month which allowed generating from 2120 MWh to 6960 MWh of electricity, respectively.
- The annual methane capture from the analyzed mine in 2020 amounts to 18,019,344.4 m^3, which corresponds to the emission of 331,484 tonnes CO_2eq per year.

Summary

- » Predicting electricity production is vital in ensuring effective management of energy resources at mining sites.
- » Artificial neural networks make it possible to estimate the desired value with specific input parameters.
- » The proposed predictive models can estimate electricity production with satisfactory accuracy, depending on methane capture and concentration, as well as the day, month, and hour of its measurement.

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