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ENERGY PERFORMANCE INDICATORS IN A LARGE ELECTRICAL COMPANY

Summary

The paper presents the results of the measurement and analysis of energy performance indicators in a large electrical company, which deals with the processes of tailings excavation, coal production, thermal energy production, water steam production, and energy equipment production. The energy performance that is the focus of this paper refers to energy efficiency. In the initial phase, seven energy performance indicators were defined for the measurement and analysis of energy efficiency, two of which are discussed in this paper, bearing in mind that the electricity is dominantly consumed in the company, and that the primary business activity is coal production. The analysis of monthly changes in the energy performance indicators in the three-year period showed that there is a certain interdependence between those indicators This paper proposes an introduction of specific energy consumption as an additional energy performance indicator that will more adequately represent energy efficiency.

Key words: *energy efficiency; energy performance; energy performance indicators; energy baseline*

1. Introduction

Enterprise performance indicators are defined as Key Performance Indicators (KPIs) and they represent measures that reflect a company's performance based on quantified objectives. KPIs are used to assess the real situation in a company and determine the basic directions of management in the future [1].

The essential application of KPIs is reflected in the establishment of criteria for monitoring a company's performance. However, in certain fields and activities, there is no systematic approach to establishing generally applicable benchmarking indicators.

The January 2004 edition of Industry Week [2, 3] has two articles on manufacturing that include the term "key performance indicators". Both articles, for the first time, deal with the measurement and the ranking of measures in manufacturing industrial areas based on predefined standardized measures.

Measuring business process performance has nowadays become a routine practice in companies that have adopted a quality management system (ISO 9001, 2015) [4], since it is one of the key requirements of the respective standard. On the other hand, in recent scientific literature, the term KPI is introduced primarily as a tool for the analysis of the company process performance.

The conceptual framework of the energy management system requires a comprehensive approach so as to effectively use the existing potential of energy efficiency. However, the review of the mentioned literature and our insights into practical representation of the energy management in companies have shown that measuring and analysing company performance is not done by using a systematic approach, and that there is a large number of different models in use. If companies with an adopted quality management system are excluded, one can rarely find a business field where the KPI model is brought to the level of standardisation.

The energy management system based on ISO 50001:2018 [5] is one of the management subsystems that can be applied and integrated with other management systems, enabling organisations to expand their responsibility related to energy saving and energy efficiency increase.

The ISO 50001:2018 standard, in addition to other requirements related to the obligations of organisations in the establishment and implementation of energy management systems (EnMS), especially emphasises:

- the need to measure and analyse energy performance indicators,
- the need to establish the energy baseline and
- the obligation of periodic energy reviews.

In the next chapter, literature sources are presented, primarily papers that attempt to measure energy performance with appropriate energy performance indicators.

2. A brief literature review

Energy consumption is a key aspect that characterises a company's operations. Schulze et al. point out that the great potential of energy efficiency in industry remains underutilised and that a promising means of reducing energy consumption and related energy costs is the introduction of an energy management system [6]. The basic elements of energy management have been identified in the literature as strategy, planning, implementation, control, organisation and culture.

According to Capehart et al., energy management refers to the effective use of energy in order to increase profits, reduce costs, and ensure the competitive position of an organisation [7].

According to Doty and Turner, energy management implies the application of new energy-efficient technologies, new materials, and new production processes in industrial systems, which helps organisations to improve productivity, product or service quality [8]. They emphasise that energy management directly affects the improvement of the quality of the environment with the introduction of energy-efficient processes. Introna et al. also state that energy consumption has a significant impact on the environment as it is directly related to costs, productivity, and therefore possible savings [9].

Petrecca states that energy management refers to ensuring the conditions for internal users to get the required amount of energy of the required quality, when and where they need it, at the lowest cost, while respecting work safety and environmental protection [10]. To cope with increasing energy costs, organisations use different approaches to optimising and reducing energy consumption.

The optimisation of energy flows within the organisation, energy consumption and proper energy management define the energy profile of the organisation [11]. Improved energy performance (energy profile) of an organisation provides direct benefits to the organisation, maximising the diversity of energy sources while reducing energy costs and energy consumption [12, 13, 14, 15].

May et al. provided a 7-step method to develop production-tailored and energy-related KPIs as current industrial approaches lack the means and appropriate performance indicators to compare energy use and efficiency performance [16].

Bruni et al. developed a statistical method and used it on the Italian mandatory energy audits database to create sectoral reference energy performance indicators enabling sectoral benchmarking for companies and monitoring the impact of energy policies [17].

Kanchiralla et al. argues that energy efficiency potential largely remains untapped due to the lack of information regarding potential energy efficiency measures, knowledge regarding energy use and inconsistencies in the evaluation of energy use. Kanchiralla et al. presented a novel taxonomy with hierarchical levels for energy end-use in manufacturing operations for the engineering industry as well as potential new energy performance indicators that are suitable for the engineering industry [18].

Hasan et al. investigated the impact of energy efficiency measures on the operational performance of production recourses and the contribution of specific Industry 4.0 technologies to boost the performance of industrial energy efficiency measures [19].

Gopalakrishnan et al. analyses the application of standards in the manufacturing industry sector. A structural model was developed as a basis for a software solution that enables organisations to establish an energy management system [20].

The Law on efficient use of energy of the Republic of Serbia [21] defines the conditions and methods of efficient use of energy and energy sources in the sector of energy production, transmission, distribution, and consumption, as well as the obligations related to efficient use of energy. The energy development strategy of the Republic of Serbia for the period from 2025 to 2030 [22] promotes an energy policy that, along with an adequate economic, social, and environmental protection policy, leads to a sustainable energy system.

3. Methodology for energy performance improvement

Standard ISO 50001:2018 introduced the requirement that when an organisation has data indicating:

- that the set target sizes of energy baseline EnB are reached or exceeded, new, “stricter” energy management goals should be set, or
- that the set target sizes of energy baseline EnB are not reached, corrective measures should be applied for the purpose of bringing the energy performance within target limits.

Essentially, this is the basis of an organisation’s energy performance continuing improvement mechanism, based on the approach known as the PDCA cycle (P - plan, D - do, C - check, A - act) promoted by Deming [23]. To such end, the energy performance improvement process is constant in time and the energy management system operates as shown in Fig. 1.

4. Analysis of energy performance in a large electrical company

This case study was carried out in the public enterprise Electric Power Industry of Serbia, Branch RB Kolubara, Lazarevac, which is involved in coal production, thermal energy production, water steam production, and energy equipment production. A comparative analysis of electricity consumption and coal production was performed for the four-year period from 2016 to 2019.

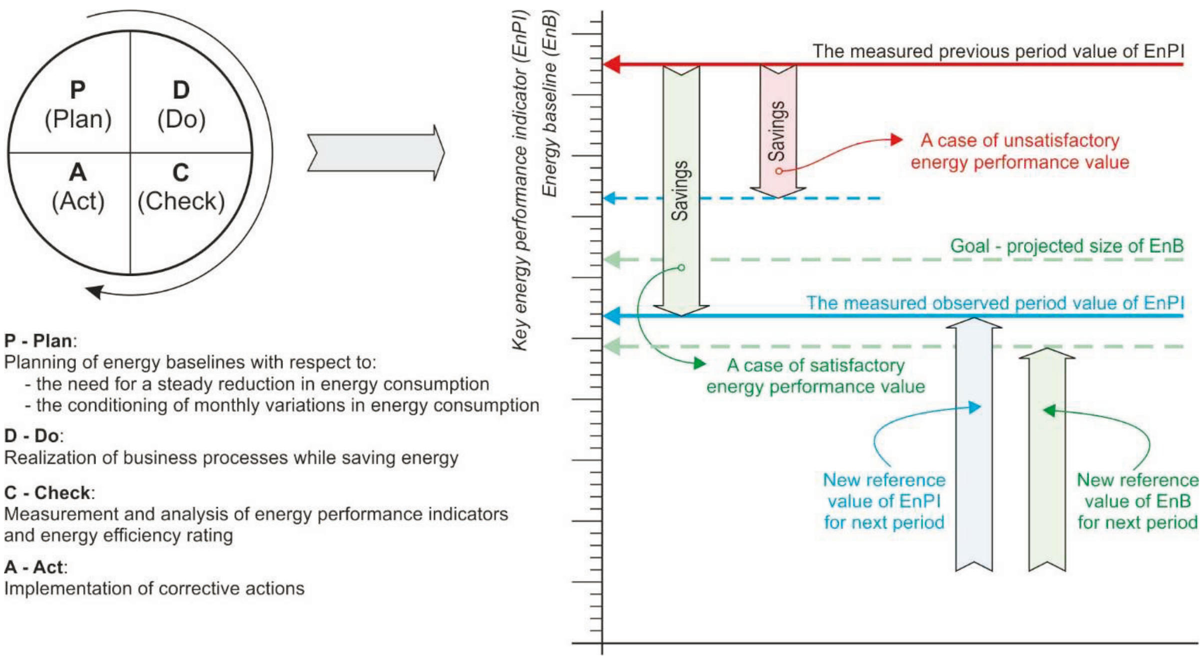

Fig. 1 A mechanism for improving energy performance

4.1 Energy performance, energy performance indicators and energy baseline

The company's energy management system contains a mechanism for constant measurement, monitoring and analysis of energy efficiency as the basic energy performance (EnE). This basic energy performance can be expressed through relationships between EnPI, i.e. the energy performance indicator and EnB, i.e. the appropriate energy comparative value (energy baseline):

$$EnE = \frac{EnPI}{EnB} \; [\text{-}] \tag{1}$$

For the stated needs, the following energy performance indicators and corresponding energy baselines have been established in the company under study:

1. Total electricity consumption ($EnPI^E$) with energy baseline
   EnB^E - average three-year electricity consumption,
2. Total coal production ($EnPI^C$) with energy baseline
   EnB^C - average three-year coal production,
3. Total fuel consumption ($EnPI^F$) with energy baseline
   EnB^F - average three-year fuel consumption,
4. Water steam production ($EnPI^{WS}$) with energy baseline
   EnB^{WS} - average three-year water steam production,
5. Heat energy production ($EnPI^{HE}$) with energy baseline
   EnB^{HE} - average three-year heat energy production,
6. EnB^{CC} - average three-year coal consumption with energy baseline
   EnB^{CC} - average three-year coal consumption,
7. Total fuel oil consumption ($EnPI^{FO}$) with energy baseline
   EnB^{FO} - average three-year fuel oil consumption.

It is necessary to bear in mind that the company is a major electricity consumer and that the business result is expressed by the achieved coal production. This paper presents an analysis of energy efficiency for the four-year period from 2016 to 2019, which is based on the first two energy performance indicators.

4.2 Analysis of electricity consumption

Relevant data on electricity consumption ($EnPI^E$) for the period from 2016 to 2020 and the average consumption values (EnB^E) are presented in Table 1. All data were taken from the measuring points of the company and are given for each month and in total for the corresponding years.

As relevant data, the average consumption of electricity in the period from 2016 to 2019 is taken as a comparative value (energy baseline) and it amounts to $EnB^E_{2016\text{-}2019}$ = 406,883 GWh. Table 1 also shows the ratios of electricity consumption for the four-year period (2016-2019) and the three-year period (2016-2018) with a corresponding increase (+) or decrease (-) in that ratio, as well as the relationship between the electricity consumption in 2020 and the comparative values for the four-year period (2016-2019).

Table 1 Data on electricity consumption

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
$EnPI^E_{2016}$ (GWh)	37.7	34.3	36.4	34.2	31.5	29.7	29.4	31.8	28.6	35.1	33.2	36.6	398.6
$EnPI^E_{2017}$ (GWh)	35.9	34.6	30.7	32.8	31.7	30.3	32.6	29.5	33.5	35.2	35.2	41.9	403.9
$EnPI^E_{2018}$ (GWh)	41.4	36.3	38.5	34.5	29.2	30.0	31.4	32.7	32.1	33.3	35.7	39.2	414.3
$EnPI^E_{2019}$ (GWh)	38.1	34.1	36.4	34.5	32.6	30.2	32.3	31.8	31.2	32.9	35.5	40.8	410.4
$EnPI^E_{2020}$ (GWh)	40.9	36.2	36.7	35.1	32.1	30.5	31.2	31.4	30.8	33.7	35.9	40.2	414.7
$EnB^E_{2016\text{-}2018}$ (GWh)	38.4	35.2	35.0	33.8	30.8	30.1	31.2	31.3	31.4	34.4	34.7	39.3	405.6
$EnB^E_{2016\text{-}2019}$ (GWh)	38.3	34.9	35.5	34.1	31.2	30.1	31.3	31.5	31.3	34.1	34.9	39.6	406.8
$\frac{EnB^E_{2016-2019}}{EnB^E_{2016-2018}}$ (%)	-0.2	-0.8	1.0	0.6	1.5	0.2	0.9	0.4	-0.3	-1.1	0.6	1.0	0.3
$\frac{EnPI^E_{2020}}{EnB^E_{2016-2019}}$ (%)	6.85	3.64	3.44	3.08	2.44	1.68	-0.80	-0.12	-1.65	-1.02	2.94	1.31	1.92

A histogram of electricity consumption by month for the period 2016-2020 is shown in Figure 2.

The comparison of monthly electricity consumption in 2020 with the energy baseline shown in Fig. 3 shows an increase in the consumption from January to June, a decrease in the consumption from July to September, and a new increase in the consumption from October to December (seasonal nature of consumption in winter and summer).

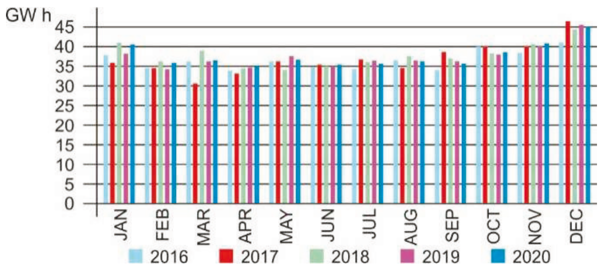

Fig. 2 Histogram of electricity consumption for 2016-2020 period

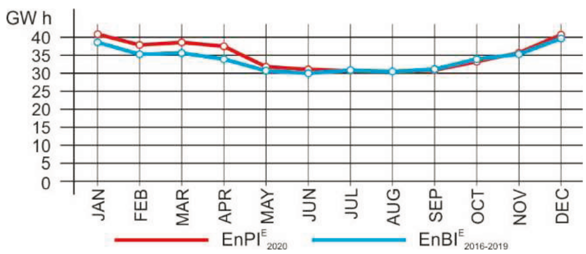

Fig. 3 Comparison of monthly electricity consumption with energy baseline in 2020

The comparison of electricity consumption for the period from 2016 to 2020 with the energy baseline shown in Fig. 4 shows significant variations in the deviation of the electricity consumption from the energy baseline, where they were minimal in 2016 and maximal in 2020.

The deviation of monthly electricity consumption in 2020 from the energy baseline shown in Fig. 5 shows that the largest deviation (increase in consumption) was in January (6.58%) and the smallest (decrease in consumption) was in September (-1.65%).

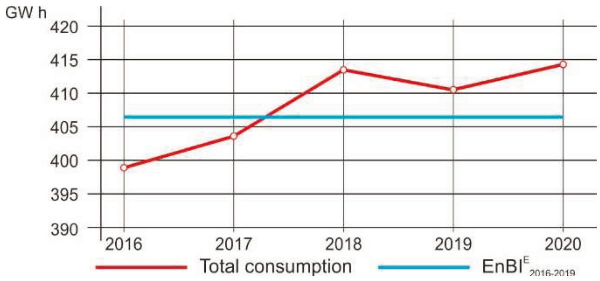

Fig. 4 Comparison of electricity consumption with energy baseline (period 2016-2020)

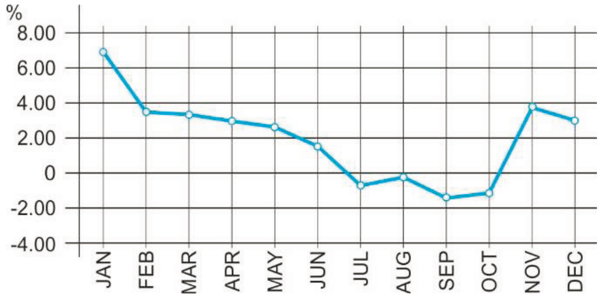

Fig. 5 Deviation of monthly electricity consumption from energy baseline in 2020

4.3 Analysis of coal production

Relevant data on the actual coal production ($EnPI^C$) for the period from 2016 to 2020 and the average consumption values (EnB^C) are presented in Table 2. All data was taken from the company's reports, and the data is displayed for each month and in total for the corresponding year.

The average production of coal in the period from 2016 to 2019 ($EnB^C_{2016\text{-}2019}$) is taken as a comparative value (energy baseline) and amounts to $EnB^C_{2016\text{-}2019}$ = 29.001(106 kg).

Table 2 shows the ratios of the comparative values of coal production for the four-year period (2016-2019) and the three-year period (2016-2018) with a corresponding increase (+) or decrease (-) in that ratio. The relationship between the coal production in 2020 and the comparative values for the four-year period (2016-2019) is also shown.

Table 2 Data on coal production

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
$EnPI^C_{2016}$ (10^6 kg)	2742	2677	2626	2174	1648	1816	2418	2443	2409	2443	2424	2722	28542
$EnPI^C_{2017}$ (10^6 kg)	2455	2605	1794	1995	2186	2160	2489	2594	2764	2845	2656	2846	29389
$EnPI^C_{2018}$ (10^6 kg)	2659	2258	2524	2236	1473	1962	2361	2494	2559	2673	2586	2588	28373
$EnPI^C_{2019}$ (10^6 kg)	2474	2441	2863	2536	1606	2062	2466	2655	2478	2742	2657	2721	29701
$EnPI^C_{2020}$ (10^6 kg)	2756	2634	2728	2659	1817	2215	2201	2503	2544	2474	2688	2804	30023
$EnB^C_{2016\text{-}2018}$ (10^6 kg)	2618	2515	2316	2137	1769	1979	2426	2502	2579	2655	2554	2718	28768
$EnB^C_{2016\text{-}2019}$ (GWh)	2584	2497	2453	2235	1728	2002	2435	2546	2552	2675	2582	2712	29001
$\frac{EnB^C_{2016-2019}}{EnB^C_{2016-2018}}$ (%)	-1.37	-0.72	5.91	4.69	-2.31	1.03	0.46	1.46	-0.97	0.84	1.00	-0.24	0,81
$\frac{EnPI^C_{2020}}{EnB^C_{2016-2019}}$ (%)	6.69	5.55	11.25	18.97	5.12	10.78	-9.57	-1.71	-0.34	-7.52	4.18	3.41	3,52

A histogram of the actual coal production for the period 2016-2020 is shown in Fig. 6 and a comparison of the monthly coal production in 2020 with the energy baseline is shown in Fig. 7.

A comparison of the monthly coal production in 2020 with the energy baseline shows a drop in production in the summer period, in accordance with the seasonal nature of the demand for this energy source.

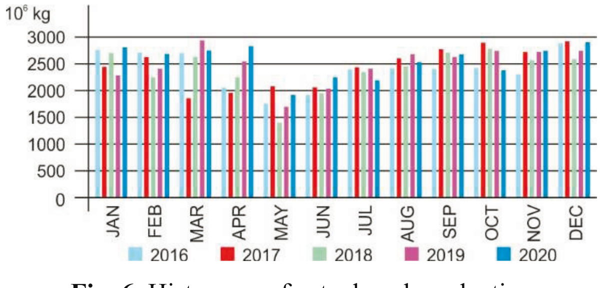

Fig. 6 Histogram of actual coal production by month for 2016-2020 period

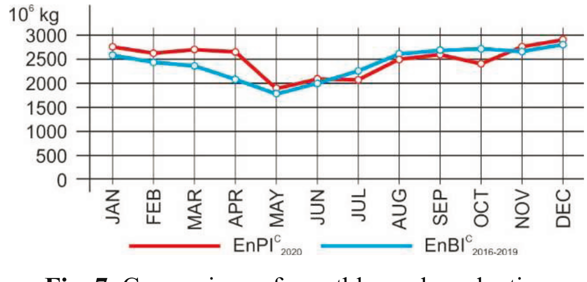

Fig. 7 Comparison of monthly coal production with energy baseline in 2020

A comparison of the actual coal production for the period from 2016 to 2020 with the energy baseline shown in Fig. 8 shows significant variations in the deviation of the coal production from the energy baseline, where they were minimal in 2018 and maximal in 2020.

The deviation of the monthly coal production in 2020 from the energy baseline shown in Fig. 9 shows large and unregulated deviations of the monthly coal production from the energy baseline in the observed year .

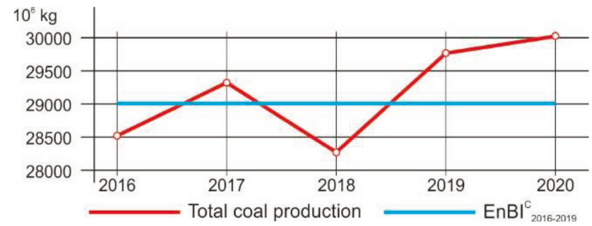

Fig. 8 Comparison of actual coal production with energy baseline (period 2016-2020)

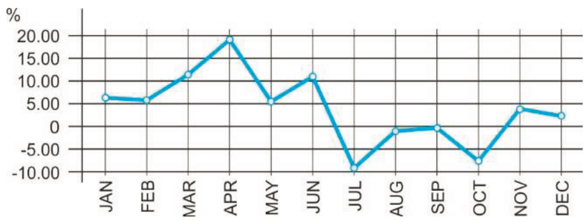

Fig. 9 Deviation of monthly coal production from energy baseline in 2020

4.4 Specific electricity consumption

The presented analysis of changes in the indicators defined as total electricity consumption ($EnPI^E$) and total coal production ($EnPI^C$) in the five-year period showed that:

- there are significant variations of the mentioned indicators at the monthly and annual level, which are expected and primarily caused by the seasonal nature of the demand in coal production and
- a certain interdependence of these two indicators can be observed, but the character of this interdependence is not clearly expressed when these indicators are observed separately.

For these reasons, it is proposed to establish a special indicator - specific electricity consumption ($EnPI^{speE}$) - which will be calculated as:

$$EnPI^{speE} = \frac{EnPI^E}{EnPI^C} \text{ (kWh/kg)} \tag{2}$$

At the same time, the following corresponding energy comparative value is proposed: $EnBs^{peE}$, i.e. the average value of $EnPI^{speE}$ for the previous period. An analysis of the energy consumption for the period from 2016 to 2020 is presented below, with the help of the proposed specific electricity consumption indicator. Relevant data on the indicator of the specific electricity consumption (EnPIspeE) for the period from 2016 to 2020 and the corresponding mean values ($EnBI^{speE}$) resulting from Tables 1 and 2 are presented in Table 3. All the data are given for each month and in total for the corresponding year.

As relevant data, the average specific electricity consumption from 2016 to 2019 is taken as an energy baseline and amounts to $EnB^{speE}{}_{2016\text{-}2019}$ =14.03 kWh/106 kg.

A comparison of the monthly specific electricity consumption for the period from 2016 to 2020 shown in Fig. 10 reveals relatively uniform changes in the monthly specific electricity consumption in the period from 2016 to 2020. However, it is observed that these changes are not aligned with the seasonal nature of the required quantities of coal as the basic product of the company.

The relationship between the specific electricity consumption in 2020 and the specific energy consumption in 2019 shown in Fig. 11 reveals large deviations of the specific electricity consumption in two consecutive years. This is in contrast to the comparison of the monthly and total energy consumption in those years (data presented in Table 1).

This observation additionally points to the conclusion that the scope for reducing energy consumption and increasing energy efficiency should be primarily sought in the processes that do not involve coal production.

Table 3 Data on specific electricity consumption

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
$EnPI^{speE}{}_{2016}$ (kWh/10^6 kg)	13.7	12.9	13.8	15.7	19.2	16.4	12.2	13.0	11.9	14.4	13.7	13.5	13.9
$EnPI^{speE}{}_{2017}$ (kWh/10^6 kg)	14.7	13.3	17.1	16.5	14.5	14.0	13.1	11.4	12.2	12.3	13.2	14.7	13.8
$EnPI^{speE}{}_{2018}$ (kWh/10^6 kg)	15.6	16.1	15.2	15.4	19.8	15.3	13.3	13.2	12.6	12.5	13.8	15.2	14.6
$EnPI^{speE}{}_{2019}$ (kWh/10^6 kg)	15.4	13.9	12.7	13.6	20.3	14.7	13.1	11.9	12.6	12.0	13.4	15.0	13.8
$EnPI^{speE}{}_{2020}$ (kWh/10^6 kg)	14.9	13.7	13.4	13.2	17.6	13.8	14.2	12.6	12.1	13.6	13.4	14.3	13.8
$EnB^{speE}{}_{2016\text{-}2019}$ (kWh/10^6 kg)	14.8	14.1	14.7	15.3	18.4	15.1	12.9	12.4	12.3	12.8	13.5	14.6	14.0
$\frac{EnB^{speE}{}_{2020}}{EnB^{speE}{}_{2019}}$ (%)	-3.6	-1.6	5.5	-3.3	-13.2	-5.9	8.3	4.8	-3.3	13.6	0.1	-4.7	-0.1
$\frac{EnB^{speE}{}_{2020}}{EnB^{speE}{}_{2016-2019}}$ (%)	0.1	-2.3	-8.6	-13.9	-4.42	-8.58	9.71	1.48	-1.28	6.68	-1.22	-1.81	-1.6

Deviation of the annual specific electricity consumption for the period from 2016 to 2020 from the energy baseline shown in Fig. 12 reveals variations in the deviation of the specific electricity consumption from the energy baseline.

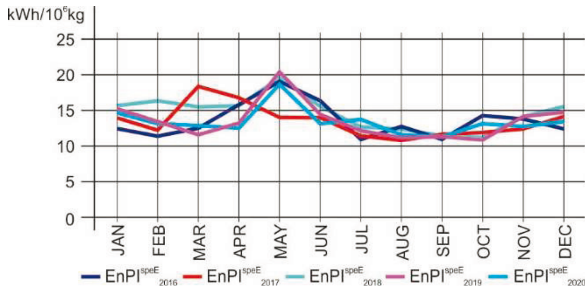

Fig. 10 Comparison of monthly specific electricity consumption (period 2016-2020)

Fig. 11 Relationship between specific electricity consumption in 2020 and 2019

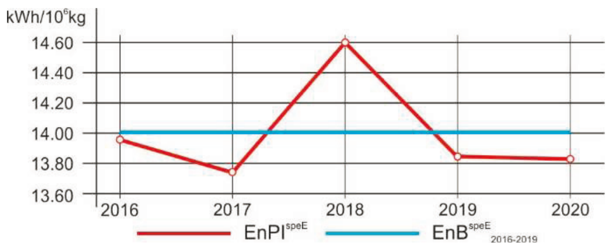

Fig. 12 Deviation of annual specific electricity consumption from energy baseline (period 2016-2020)

Since electricity is not the only energy source used in the company under study, as it also uses the energy obtained by burning coal and liquid fuels, for the purpose of measuring the energy efficiency, corresponding energy performance indicators have been established in the form of the total consumption of these additional energy sources used for various needs.

That is why it is necessary, in the manner proposed for the consumption of electricity, to introduce new additional indicators of energy performance that also refer to the specific consumption of these additional energy sources. Examples of these indicators are given below.

4.4.1 Specific fuel consumption ($EnPI^{speF}$)

Energy performance indicator, i.e. the total fuel consumption ($EnPI^{F}$) refers to the auxiliary machinery part of the company, and the introduction of a new relative energy performance indicator, i.e. the specific fuel consumption ($EnPI^{speF}$) and the corresponding comparative value (EnB^{speF}) is justified, by putting this absolute consumption in relation to the total income (TI_{AM}) of the mentioned part of the company or the observed period as follows:

$$EnPI^{speF} = \frac{EnPI^{F}}{TI_{AM}} \text{ (l fuel/RSD)} \tag{3}$$

$$EnB^{speF} = \frac{EnB^{F}}{TI_{AM}} \text{ (l fuel/RSD)} \tag{4}$$

4.4.2 Specific coal consumption ($EnPI^{speCC}$) and specific fuel oil consumption ($EnPI^{speFO}$)

Energy performance indicators, i.e. the total coal consumption ($EnPI^{CC}$) and the total fuel oil consumption ($EnPI^{FO}$) refer to the use of these energy sources in the production of water steam and the production of thermal energy. That is why the introduction of new relative energy performance indicators, i.e. the specific coal consumption ($EnPI^{speCC}$) and the specific fuel oil consumption ($EnPI^{speFO}$), as well as corresponding comparative values (EnB^{speCC} and EnB^{speFO}) is justified, by putting their absolute consumption (separated for water steam production and heat energy production) in relation to the corresponding actual production for the observed period as follows:

$$EnPI^{speCCWS} = \frac{EnPI^{CCWS}}{EnPI^{WS}} \text{ (kg coal/kg water steam)} \tag{5}$$

$$EnPI^{speCCHE} = \frac{EnPI^{F}CCHE}{EnPI^{HE}} \text{ (kg coal/kWh)} \tag{6}$$

$$EnPI^{speFOWS} = \frac{EnPI^{FOWS}}{EnPI^{WS}} \text{ (l fuel oil/kg water steam)} \tag{7}$$

$$EnPI^{speFOHE} = \frac{EnPI^{FOHE}}{EnPI^{HE}} \text{ (l fuel oil/kWh)} \tag{8}$$

In this case, the following energy baselines are used to calculate the energy performance, i.e. the energy efficiency:

$$EnB^{speCCWS} = \frac{EnB^{CCWS}}{EnB^{WS}} \text{ (kg coal/kg water steam)} \tag{9}$$

$$EnB^{speCCHE} = \frac{EnB^{F}CCHE}{EnB^{HE}} \text{ (kg coal/kWh)} \tag{10}$$

$$EnB^{speFOWS} = \frac{EnB^{FOWS}}{EnB^{WS}} \text{ (l fuel oil/kg water steam)} \tag{11}$$

$$EnB^{speFOHE} = \frac{EnB^{FOHE}}{EnB^{HE}} \text{ (l fuel oil/kWh)} \tag{12}$$

5. About the possibility of assessing total energy efficiency

The analysis of the company success in terms of reaching its energy goals and possibilities of energy performance improvement is based on the information on the total energy efficiency for a particular period, because a high number of the energy performance indicators, if taken individually, do not provide a quick insight and clear picture of the situation in terms of the achieved energy efficiency.

Although possible, attempts to set up mathematical models to present the total energy efficiency are not suitable for practical application. The reason is the difference between the nature of the energy performance indicators and relevant energy baselines in the sense of the energy type and energy products used and the units of measurement they are expressed in, and the limit of the system (location) they relate to, because this could be a whole company, but also a single part of the company.

For the aforementioned reasons, a simple, but effective method of presenting the total energy efficiency is proposed herein, based on evaluating various values of the relations EnPI/EnB and the scheme presented in Table 4.

It is necessary to emphasise that the generated averages of energy and energy product consumption, used as comparative energy benchmarks, only sustain the current energy performance levels without bringing about any improvement. Therefore, these should be replaced with the target values established by the management.

Table 4 Proposal of overall energy efficiency assessment scheme

RESULTS OF ENERGY PERFORMANCE MEASUREMENT							
Energy performance indicator						***Period of time***	
$\boldsymbol{EnPI^{speE}}$	$\boldsymbol{EnPI^{speF}}$	$\boldsymbol{EnPI^{speCCWS}}$	$\boldsymbol{EnPI^{speCCHE}}$	$\boldsymbol{EnPI^{speFOWS}}$	$\boldsymbol{EnPI^{speFOHE}}$	Year: _____ Month: _____	
Ratio ***EnPI/EnB*** *(%) - Degree of target energy efficiency achievement*							
$\frac{EnPI^{speE}}{EnB^{speE}}\times 100$	$\frac{EnPI^{speF}}{EnB^{speF}}\times 100$	$\frac{EnPI^{speCCWS}}{EnB^{speCCWS}}\times 100$	$\frac{EnPI^{speCCHE}}{EnB^{speCCHE}}\times 100$	$\frac{EnPI^{speFOWS}}{EnB^{speFOVS}}\times 100$	$\frac{EnPI^{speFOHE}}{EnB^{speFOHE}}\times 100$	***Evaluation*** *(rank determination)* ↓	
≤30	≤30	≤30	≤30	≤30	≤30	1	*Rating scale*
40	40	40	40	40	40	2	
50	50	50	50	50	50	3	
60	60	60	60	60	60	4	
70	70	70	70	70	70	5	
80	80	80	80	80	80	6	
90	90	90	90	90	90	7	
100	100	100	100	100	100	8	
110	110	110	110	110	110	9	
≥120	≥120	≥120	≥120	≥120	≥120	10	
(Enter rank)	*(Enter rank)*	*(Enter rank)*	*(Enter rank)*	*(Enter rank)*	*(Enter rank)*	← *Rank* ***R***	
3	1	0,5	0,5	0,5	0,5	← *Ponder* ***P***	
(Enter score)	*(Enter score)*	*(Enter score)*	*(Enter score)*	*(Enter score)*	*(Enter score)*	← *Score* ***R×P***	
Total score (sum of all individual scores, max 100) →						*Enter total score*	
Percentage of goal achievement →						*Enter %*	

6. Conclusion

Energy efficiency measurement carried out by using the defined energy performance indicators is one of the improvement processes built into the energy management system (EnMS) set up and applied to a large electrical company analysed in this case study. Trends in the changes in the energy performance indicators are analysed in the internal checks and review of the EnMS as well as in the course of annual energy tests. Based on such analyses, the company's management initiates the change in the respective measures for the energy efficiency increase.

The results of the initial EnMS application show that a systemically structured data source for making decisions on measures to ensure efficient energy consumption was established, and certain positive results were also observed.

Thus, for example, it can be seen in Table 3 that, by applying corrective and preventive actions as basic mechanisms for improving the energy management system shown in Figure 1, a slight decrease in the specific electricity consumption was achieved in 2020. For the above-mentioned reasons, in the future it is necessary to formally establish all the relative energy performance indicators proposed in this paper and perform their periodic analysis using the PDCA methodology (P - plan, D - do, C - check, A - act).

It is also necessary to continuously seek opportunities for improving energy performance. One such opportunity is the use of more energy-efficient equipment. Given that a significant amount of fuel is consumed in the processes of the analysed company, the use of biodiesel as fuel for vehicles in the open-pit mine instead of standard diesel fuel is a viable option, as suggested in [24].

Another possibility is the generation of solar power for internal consumption by using photovoltaic panels instead of procuring electricity generated from coal combustion, as proposed in [25] and [26]. The company under study is engaged in coal exploitation at an open-pit mine, resulting in large areas of land that are unsuitable for agriculture or other purposes. By producing solar energy on this land, a dual benefit would be achieved: an improvement in the energy performance related to electricity consumption and a partial transition to environmentally sustainable energy sources.

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