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ISO 50001 ENERGY MANAGEMENT SYSTEM EFFECTIVENESS INDICATORS IN A CHEMICAL SECTOR ENTERPRISE

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Purpose: The article presents a set of indicators for assessing the effectiveness of an energy management system (EnMS) based on the authors' own research findings.
Design/methodology/approach: The work uses qualitative methods such as systematic review of literature, analysis of the content of existing documentation, participatory observation and self-observation.
Findings: The literature on the subject features few publications dedicated specifically to energy management systems. Moreover, no practical solutions with a set of practical metrics to be applied in the regular process of realising energy programs and goals exist. Hence, the authors propose a model of assessment.
Practical implications: The set of indicators presented in the article offers good practical value and high application and adaptation potential. The model may be applied in individual businesses in the chemical sector or as a benchmarking tool in capital groups or a group of entities demonstrating functional connections. Consisting of the universal part (indicators for goals and processes) and the sector-relevant indicators, the model may be adapted for use in other sectors through appropriate corrections for the sector-relevant criteria.
Originality/value: The assessment model presented in the article fills a publication void and represents an innovation. It is intended for use in managing and supervising energy-related activities in various organisations. It shall prove of assistance to system users and auditors alike.

Keywords: effectiveness, effectiveness indicators, energy management, systems.

Category of the paper: Research paper.

1. Introduction

The available scientific databases feature only individual publications relating to the effectiveness of energy management systems for compliance with ISO 50001 (Włas, 2017; Dzik, Dzik, 2017; Hajduk-Stelmachowicz, 2018; Olkiewicz, Bober, 2017; Marimon, Casadesus, 2017; Jovanović, Filipović, 2016; Gopalakrishnan, Ramamoorthy, Crowe, Chaudhari, Latif, 2014; Kanneganti et al., 2017). Arguably, this is due to the fact that the systems are a relatively recent development thus:

- firstly, as the standard for energy management systems is a relatively ‘young’ document compared to other normalized systems, there are still few organisations that use energy management systems for compliance with ISO 50001,
- secondly, realizing their energy efficiency programs, some businesses employ – predominantly for continual improvement – environmental systems or the quality base standard.

Effectiveness is a praxeological category, an attribute of efficient operation, where – together with efficiency – it constitutes one of the most important pillars of such activity (Pszczołowski, 1978; Kieżun, 1997; Kotarbiński, 2019; Zieleniewski, 1969). Such understanding of effectiveness was embodied in the terminology standard (PN-EN ISO 9000:2015) where “effectiveness” is defined as the ‘extent to which planned activities are realized and planned results are achieved’. Therefore, effectiveness may refer to the degree of realisation of a goal expressed either in a binary format: the goal was either achieved fully or not, or as a percent of its realisation. In praxeological terms, individual actions may be effective, ineffective or counterproductive. The last term describes actions that set one further from achieving the desired goal.

As the standard implies that efforts ought to be focusing exclusively on those activities that are efficient, the authors of this paper attempted to study how an energy management system may provide practical support for such activities. Are the tools mentioned in the standard sufficient, or is there a need to enhance the process of assessing effectiveness with a suitable set of indicators comprising parameters to facilitate it? According to the standard, decisions ought to be made based on analysing and assessing data, preferably from multiple sources to counter the inherently high degree of uncertainty. The measurement model proposed by the authors shall be a step towards such triangulation.

The process of developing a set of metrics to assess the effectiveness of an energy management system (as of any other) ought to consider its specific nature where the main reference criteria in the system are energy efficiency and continual improvement - programs and activities aimed at reducing energy consumption. Therefore, putting process efficiency aside, the authors focused on such categories as: energy use, energy consumption, energy performance, significant energy use, energy efficiency indicator or energy baseline (EN ISO 50001:2018).

The goal of the article is to develop, based on own research, a set of metrics to measure the effectiveness of an energy management system.

2. Methodology

Due to the use of qualitative methods in the study, no hypothesis was formulated (Kostera, 2003).

In order to realize the goal stated above, it is necessary to define and then resolve the following research problems:

P1. Are any analytical tools used by the organisation subject to the study in order to assess the effectiveness of processes and the energy management system?

P.2. What are the current, or feasible, effectiveness metrics for an ISO 50001 energy management system?

The following research methods were applied in the study:

1. Systematic review of the literature (Czakon, 2013). The search for relevant records took into account key phrases, such as 'effectiveness of energy management systems', 'effectiveness of processes', 'energy review' ('management review' in the nomenclature of the quality standard), 'effectiveness of audits of energy management systems', or 'effectiveness as a praxeological category'. Then, a query of selected scientific databases such as Google Scholar, EBSCO, Business Source Ultimate, etc. was performed. Once records were identified suggesting convergence with the purpose of the study, a preliminary selection process was carried out on the basis of the content contained in the abstracts. The main focus was put on papers concerning: energy management systems for compliance with ISO 50001 (articles on other standardized systems were rejected); classics of praxeology in terms of effectiveness as an attribute of efficient operation; as the content and purpose hereof fall within the discipline of management and quality sciences, purely technical works relating to energy audits were rejected. The content of the selected articles and studies was then studied. Due to their limited number, mapping was abandoned in favour of a thorough review of all the available publications.
2. The internal documentation specified in the research part was reviewed using the method of content analysis. Next, the literature and documented information were organized (Łuczewski, Bednarz-Łuczewska, 2012; Kostera, 2003).
3. The research also employed the participatory observation method (e.g. during the management review and during an audit performed by a certified unit, as well as self-observation of methods and tools used by unit auditors) (Ciesielska, Wolanik Boström, Öhlander, 2012).

The selection of research methods described above is consistent with methodological guidelines used in the disciplines of management and quality (Creswell, 2013; Easterby-Smith, Thorne, Jackson, 2015).

The research problems specified in this study are practical in nature. This, together with the applicability of the indicators put forward herein, places them within the functional-systemic paradigm (Lisiński, Szarucki, 2020).

The research was carried out in a fertilizer and chemical production company in September 2022 as part of a wider study covering also the categories of efficiency of energy management systems.

3. Research results

The studied organisation maintains an energy management system for compliance with ISO 50001 which, together with the ISO 31000 risk management system, is not included in the company's integrated quality, environment, health and safety system, although shared areas exist. They are mainly procedures and instructions relating to the past improvement and supervision procedures, which used to be referred to as 'mandatory components'. The following internal documents were reviewed in the course of the research:

1. Integrated system ledger.
2. Procedures and instructions concerning the operation of the integrated system and the energy management system, including: internal audits, corrective actions, energy review, control of energy consumption and energy use, risk management, control of manufacturing processes, supervision of compliance with legal and other requirements, corporate directive on agreeing future demand for energy utilities.
3. Reports from: energy review; unit consumption of energy utilities; the rules for providing technical security services; annual energy consumption and production balance.
4. Internal and third-party reports from audits conducted as part of activities aimed at energy management system improvement.
5. Results of a study conducted to assess the feasibility of integrating the energy and the environment management systems were included in the research (Kądzielawski, Goranczewski, 2022).
6. Results of a study on the evaluation of praxeological aspects of energy management systems we included in the research (Goranczewski, Kądzielawski, 2022). The results indicate that the system used in the studied organisation supports the realisation of energy-related objectives, especially that the recent implementation of the system enables a comparative analysis of pre- and post-implementation documentation. Energy-related aspects whose supervision is currently not required under the standard but which are supervised on the operational level of the environmental management system.

7. The guidelines of the benchmarking model for assessing the effectiveness and efficiency of management systems in a collective heating company were included in the research. The model had been validated and applied in the group of collective heating companies by the ISO in Collective Heating Consultation Team operating within the Chamber of Commerce Polish District Heating (*pol. Izba Gospodarcza Polskie Ciepłownictwo*) and subsequently used within one of capital groups of the collective heating sector.

As a result of applying the research methods (literature review, content analysis of existing documentation, participatory observation, self-observation) and analysing the above specification of internal documentation, the authors propose a proprietary set of indicators aimed to support both the users and the auditors of energy management systems in assessing the effectiveness of the system and its components.

Table 1.
Set of indicators for assessing the effectiveness of energy management systems and processes

Pos.	Indicator name	Symbol	Formula	Interpretation
1	Indicator of effectiveness (dynamics) of processes related to energy management	SP	$\frac{S_{n+1}}{S_n}$ x 100% where: S_n is the number of corrective actions in a given process in the preceding year	**Desired trend: falling.** The number of corrective actions within a given process should be falling, which means goals are realized effectively. Otherwise, it may imply misidentification of the cause of nonconformity, insufficient level of awareness among the system users, inadequate implementation of corrective actions, etc.
2	Indicator of the structure of corrective actions	**SDK**	$\frac{S_n}{S_o}$ x 100% where: S_n is the number of corrective actions in a given process in relation to the total number of corrective actions (S_o) implemented in a given year under the energy management system	**Desired trend: falling.** A decreasing number of corrective actions means higher process realisation effectiveness, assuming reliable performance of process documentation and auditing activities.
3	Indicator of the average number of corrective actions in relation to process 1, 2, .., n under the energy management system	LDK	$\frac{\sum_{i=1}^{n}}{n}$ where: *n* is the total no. of entities	**Desired trend: falling.** The indicator may be applied in the analysis of: − number of actions in relation to a given process in the period of several years, − benchmarking comparisons, provided comparison-relevant documentation is available from the compared entities. The indicator may be applied for internal and external benchmarking.

Cont. table 1.

Energy management system effectiveness indicators				
4	Indicator of the degree of implementation of the energy management system	SW	$\frac{\text{no. of audits without nonconformities}}{\text{total no. of audits}}$ x 100%	**Desired trend: rising.** Caution is advised in applying and interpreting this indicator. Audits which yield no nonconformities may not be the final confirmation of achieving a given level energy management system implementation or excellence. Highly competent auditors and audit reliability and accuracy is required, which are not always the case. It ought to be noted that audits are based on a random sample.
5	Indicator of white certificate dynamics	**DBC**	$\frac{B_{n+1}}{B_n}$x 100% where: B $_n$ number of certificates obtained in the previous year	**Desired trend: rising.** Values expressed in [toe]. May be presented quantitatively or in terms of value, in which case the indicator measures system effectiveness.
6	Energy efficiency indicator	**WWE**	$\frac{\sum EF}{\sum P}$ where: $\sum \boldsymbol{EF}$ is final energy consumption needed to manufacture a given product, e.g. in a quarter, $\sum \boldsymbol{P}$ total output of a given product, e.g. in a quarter	**Desired value: [*comment*]** The share of energy expressed in GJ needed to produce a unit of product should be falling
7	Indicator of energy consumption against energy baseline	**ZLB**	$\frac{current\ energy\ consumption}{EnB}$ where: **EnB** average energy converted to GJ consumed for manufacturing the product in the selected reference period (minimum 1 year)	**Desired value: [*comment*]** The participation of energy for manufacturing a given product expressed in GJ should be falling
8	Indicator of the degree of realisation of energy management system goals and targets	**SOC/S**	$\frac{\text{no. of realised goals and targets}}{\text{no. of goals to be realised in a given year}}$ x 100%	**Desired value = 100%** Applicability of the indicator is conditional upon the methodical setting of objectives, cascading them, linking to the strategy, etc., or using the Management By Objectives (MBO) method or the SMART tool
9	Indicator of effectiveness (dynamics) of EnMS goal and target realisation	SCO/S	$\frac{C_{n+1}}{C_n} x\ 100\%$ where: C_n is the value of the indicator in the base year	**Desired value: 100%**. Failure to reach 100% of the goal completion may result from: Processes being realised inconsistent with requirements, Overambitious goals, e.g. based on wrong data.

Source: Own research: indicators: 1-4, 8, 9 based on: B. Goranczewski, *Effectiveness and efficiency of energy management systems in collective heating companies in Poland*, a doctoral thesis, University of Opole, 2006 (unpublished material); indicators 6 and 7 – documentation of the energy management system in the enterprise where the study was conducted.

Indications included in comments referring to the desired trend may be inconclusive due to numerous situational factors.

In reference to the first research problem [P1], having analysed the content of the available documents, as well as through self-observation and participatory observation, it was found that the studied organisation used no analytical methods to assess the system effectiveness other than the classic auditing methods performed routinely under the ISO 19011 and ISO 9004 standards, especially for monitoring trends within particular processes. However, it shall be reiterated that the system had been introduced fairy recently and viable trend assessment requires a time period of several years.

In reference to the second research problem [P.2], it was concluded that the literature on the subject offers no ready-made, adaptable models for assessing the effectiveness of energy management systems. As all systems, it is governed by the base ISO 9001 standard with a process-oriented focus. Therefore, the authors have put forward a proprietary effectiveness assessment model which had previously been applied in the collective heating sector. The model takes into account all the vital aspects of the process- and system-based approaches and may be further developed and adapted for other sectors and industries.

System effectiveness is best reflected in the dynamics and the structure of the corrective actions as shown by indicators 1 and 2. Indicator 3 may serve as a benchmarking tool, especially that the studied organisation forms parts of a large capital group. The paper features no indicators referring to the effectiveness of corrective actions as in the new edition of the ISO 50001 standard the notion was replaced with risk and opportunity assessment. Another group consists of the following energy management system indicators:

- the degree of system implementation expressed as the number of audits which detected nonconformities in relation to the total number of audits, subject to the comments featured in the table;
- the dynamics of obtaining white certificates in quantitative terms; another way of employing this indicator to measure system effectiveness could be as a cost effect (year on year) of limiting spending on CO2 emission allowances, expressed in [toe], taking into account the cost of asset modernisation, including repairs and investments;
- indicators 6 and 7 refer respectively to energy consumption per unit of product and current consumption to the average value over a given calculation period;
- the remaining two indicators refer to the effectiveness of goal attainment, both in static and dynamic dimensions.

Conclusions and summary

Rather than being a fixed specification, the set of energy management system effectiveness indicators proposed in the research part of the paper shall form a base tool to be developed depending on current needs. This may be achieved through a modification of the proposed indicators or the addition of new ones. Ultimately, appropriate measures will depend on local conditions as well as practices used, both in terms of system users and auditor competence. Undoubtedly, enhancing audit findings with effectiveness assessment parameters makes for a better-informed decision-making process based on the course of a given trend. The dynamics indicators proposed in the table serve that very purpose, while the structure indicators present a given process in the context of the entire system, adding an explanatory dimension.

The set of indicators put forth herein offers a considerable potential for development. It may be applied as a benchmarking tool for:

- internal, cross-area comparisons in a single enterprise, e.g. between business units (the studied organisation comprised fertilizer production, chemical production, and energy-generation units), between individual production plants, etc., taking into account the cost specificity, especially in terms of expenditure on energy efficiency,
- internal comparisons between a capital group subsidiaries or entities with functional connections,
- external, mesoeconomic (industry-specific), and other comparisons, e.g., in the activities of economic self-governments.

In the case of benchmarking applications, attention shall be paid to the appropriate selection of the entities for comparison or, alternatively, to the development of appropriate indicators to achieve comparability of the studied population.

The proposed set of indicators is so universal that it allows comparative analyses to be carried out both at the level of processes, products, systems, and organizational areas. Depending on the type of process, device, installation or product, e.g. back-pressure energy-generation systems, production of demineralized water, production of nitric acid, production of aldehydes, etc., the sum of all energy carriers used in the production process is converted into GJ per unit of product expressed, depending on its character, as mg, dam^3, m^3, etc. The benchmarking approach is one of the elements of the synergy effect, especially in a capital group. It also provides the basis for proper brand management through the dissemination of good practices to entities recording sub-benchmark results, provided that such a transfer is viable considering the technological or raw material conditions.

Based on the conclusions stemming from the solved research problems, the purpose of the study is deemed to have been realised, with the proposed measuring tool offering practical applications.

Further research on the topic is required to validate the proposed model, especially for its application as a benchmarking tool.

From a praxeological point of view, effectiveness is only one of the two basic attributes of efficient operation, hence future research shall also take efficiency into account.

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