Chapter 8
Analysis of the Efficiency of Energy Management at the Metallurgical Enterprise

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Keywords Efficiency · Ecosystem · Economic growth · Energy technologies · Clean energy

8.1 Introduction

The classification of energy intensity by the object being characterized is also important. So, for example, the object of determining energy intensity at a metallurgical enterprise can be a technological process, a production operation and cycle, as well as finished products. Therefore, based on this classification, a division is proposed for the energy intensity of the technological process, production operation, cycle or finished product (Kafka et al., 2022; Martínez et al., 2022; Sun et al., 2022). This classification allows you to identify the most energy-intensive objects and develop energy-saving measures for specific objects.

Also, the enterprises set standard consumption values: for products considering the specifics of their manufacture (seamless or welded pipes), for operations performed (steel smelting) and work (for generating steam boiler heat). For these cases, it is advisable to distinguish such a classification feature as "attitude to the standard", according to which the energy intensity can be within the standard and above the norm (Dinçer, Aksoy, et al., 2022; Dinçer, Yüksel, & Martínez, 2022; Dinçer, Yüksel, Mikhaylov, & Barykin, et al., 2022; Dinçer, Yüksel, Mikhaylov, & Pinter, et al., 2022; Dong et al., 2022; Mukhtarov et al., 2022).

Modern metallurgical enterprises produce a fairly large range of finished products, and each of them can significantly differ in the energy intensity of

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manufacturing. That is why, in order to identify the least energy-intensive types of products and increase the efficiency of use at enterprises, the energy intensity of various types of products is calculated (Carayannis et al., 2022; Yüksel & Dinçer, 2022; Zhang et al., 2022). Accordingly, according to the product range, the energy intensity of the i-th type of product is distinguished.

It should be noted that during the production of products, they are consumed, which in turn relate to the cost items for technological, shop, repair and general factory needs. Fuel and energy costs attributed directly to the cost of manufacturing a particular product are the costs of fuel and energy for technological needs, on the basis of which the technological energy intensity is calculated (Li, Yüksel, & Dinçer, 2022; Mikhaylov, Bhatti, et al., 2022; Yüksel et al., 2022). General shop expenses include expenses incurred by a certain structural division in the production of finished products for the maintenance of fixed assets, repair, maintenance and production management. The aggregate of fuel and energy costs used in performing capital and other repairs can be attributed to the item of the repair fund and in order to determine the energy efficiency of this process, the energy intensity of repair work is calculated (Eti et al., 2023; Haiyun et al., 2021; Li, Yüksel, Dınçer, Mikhaylov, & Barykin, 2022). Factory-wide expenses are fuel and energy costs that do not relate to a specific division or product, but occurred during the maintenance of the enterprise, for example, the cost of maintaining the factory territory in proper condition, watering lawn grass and trees (factory-wide energy intensity) (Ermiş & Güven, 2022).

The following type of classification, by time period, allows you to calculate the energy intensity of a unit of production for any time period: month, quarter, half-year, year. Detailed information by time period allows you to analyze the dynamics of energy intensity in comparison with previous periods and make timely management decisions aimed at optimizing this indicator.

For the purposes of planning and analyzing energy intensity in a given time interval, the concepts of planned and actual energy intensity are used. Comparing these values of energy intensity helps to draw conclusions about the dynamics of the indicator, understand the reasons for possible deviations from the plan, and develop corrective measures.

8.2 Literature Review

The company's production facilities include an electric steelmaking shop, a pipe rolling shop, and a pipe welding shop. The structure of the plant's energy service includes two auxiliary workshops—power and electric, as well as the department of the chief power engineer, which provides general management of the service and performs the function of analysis, planning and monitoring of use. Professional training of technical specialists and service personnel is carried out on the site of our own training center, which has good technical equipment with various information and production support systems (Bhuiyan, Dinçer, et al., 2022; Conteh et al., 2021; Daniali et al., 2021; Denisova et al., 2019; Huang, Masrur, et al., 2021; Huang, Yona, et al., 2021; Khan et al., 2021; Liu, Kato, Mandal, Mikhaylov, Hemeida, & Senjyu, 2021; Liu, Kato, Mandal, Mikhaylov, Hemeida, Takahashi, et al., 2021; Mikhaylov, 2018, 2022; Mikhaylov et al., 2019; Moiseev et al., 2023; Nie et al. 2020; Nyangarika et al., 2019a, 2019b; Sediqi et al., 2022).

The primary task of the analysis is to identify the fuel and energy resources used in the enterprise. At the surveyed enterprise, there is a significant shortage of energy metering systems, which significantly complicates control over their use and does not allow for an adequate assessment of the actual efficiency and energy intensity (Barykin, Mikheev, et al., 2022; Bhuiyan et al., 2021; Bhuiyan, Zhang, et al., 2022; Candila et al., 2021; Danish et al., 2022a, 2022b; Dong et al., 2021; Li, Yüksel, Dınçer, Mikhaylov, et al., 2022; Liu et al., 2022a, 2022b; Mikhaylov, 2021b; Mikhaylov & Grilli, 2022; Mukhametov et al., 2021; Saqib et al., 2021).

Analysis of indicators indicates the presence of the main consumer of energy resources, which is a pipe rolling shop. However, due to the specific nature of electric steel production, more than 50% of the electricity consumed is consumed by the electric steelmaking shop, making it the undisputed leader in this category. If you perform a comparative analysis of consumption relative to the previous year, you can see a decrease in most indicators, which is due to a decrease in production volumes due to the introduction of anti-covid restrictions around the world. At the same time, there is an increase in natural gas consumption in the pipe welding shop, which is explained by the stabilization of demand in the market of welded pipes and, as a result, a large load, relative to 2019, of this division (An et al., 2022; Badr et al., 2022; Barykin, Kapustina, et al., 2022; Dinçer, Aksoy, et al., 2022; Dinçer, Yüksel, & Martínez, 2022; Dinçer, Yüksel, Mikhaylov, & Barykin, et al., 2022; Dinçer, Yüksel, Mikhaylov, & Pinter, et al., 2022; Kalinina et al. 2022; Khan et al., 2022; Mehta et al., 2022; Mikhaylov, Bhatti, et al., 2022; Mikhaylov, Yumashev, et al., 2022; Nyangarika et al., 2022; Shaikh et al., 2022).

A more detailed analysis of energy consumption by main consumers indicates that the specific consumption depends on the stage of conversion. So, for example, the highest indicators are typical for the main processing areas, namely, steel smelting and hot rolled pipe billets, and a significant decrease in specific consumption at the finishing and delivery of finished products. This fact is explained by the high energy intensity of the process of primary processing of steel and its reduction as it passes through the technological chain (Alwaelya et al., 2021; An & Mikhaylov, 2020, 2021; Mikhaylov, 2021a; Mikhaylov et al., 2023; Mutalimov et al., 2021; Varyash et al., 2020; Yumashev et al., 2020; Yumashev & Mikhaylov, 2020; Zhao et al., 2021).

When analyzing the main technical measures for energy saving carried out at the enterprise from 2019 to 2020, the average annual effect of these measures is 90 million rubles. The main directions in the implementation of measures are organizational actions of personnel aimed at seasonal reduction of consumption due to decommissioning of electricity consumers, as well as replacement of electric drives with less powerful ones (An, Mikhaylov, & Jung, 2020; An, Mikhaylov, & Kim, 2020; An, Mikhaylov, & Moiseev, 2019; An, Mikhaylov, & Richter, 2020; An, Mikhaylov, & Sokolinskaya 2019; Dooyum et al., 2020; Gura et al., 2022;

Mikhaylov, 2020a, 2020b, 2020c; Mikhaylov & Tarakanov, 2020; Moiseev et al., 2020, 2021).

A comparative analysis shows a decrease in savings for all resources in 2020 and a complete lack of implementation of projects to save thermal energy. The explanation for this is the exhaustion of the potential of previously proposed organizational and technical measures and the reduction of funding for energy-saving measures in 2020 (An et al., 2021; Danish et al., 2020, 2021; Dayong et al., 2020; Nyangarika et al., 2018; Shaikh et al., 2021; Tamashiro et al., 2021, 2023; Uyeh et al., 2021).

8.3 Assessment of the Internal and External Energy Consumption Environment

The analysis of the internal and external environment will be carried out on the basis of qualitative analysis using expert assessments. Managers and technical specialists who are more or less involved in the management development process will be involved as experts. Audit reports are considered as documentary materials confirming the compliance of the company's management system with international standards.

The assessment of the internal and external environment in this section is based on the opinions of experts participating in the study. The main task of this section of the dissertation is to determine the dependence of economic indicators obtained as a result of the introduction of energy-saving measures on the efficiency of managing the processes of planning, distribution, consumption and savings (Fang et al., 2021; Kayacık et al., 2022; Yuan et al., 2021).

The main business processes that characterize the internal environment of energy management are planning of energy resources, organization of energy supply to consumers, control of energy consumption efficiency and motivation of employees to implement the principles of energy conservation. In order to analyze the internal environment, the method of constructing organizational and managerial profiles that reflect the development of various management subsystems is widely used. The benefits of this method are the ability to generalize qualitative assessments of energy efficiency, the ability to determine the maturity of the company's energy policy, and this method allows you to see a complete picture of the level of management development (Dinçer et al., 2023; Eti et al., 2022). However, this tool has a number of drawbacks, namely, it shows only a generalized view of energy efficiency problems and relies only on the opinions of the experts involved.

In one of the studies, a fairly effective method for building a management profile is proposed. The principle of building a profile is based on filling in the fields of the energy management matrix, which reflect on the one hand—the management directions, on the other—the level of development of each of the directions on a scale from zero to four points. The main directions include energy policy, organization and motivation, development of information systems, marketing and investment activity of the company. The energy profile makes it possible to identify acute problems in the field of management and the degree of balanced development of elements of the internal environment. The study notes that achieving energy efficiency is possible only if there is a balance of all criteria and a uniform development of the energy management system.

The degree of development of the management system is ranked on a five-point scale: for example, the management system is at zero level and there is no idea about it at all. At this stage, there is also no monitoring of energy consumption and energy efficiency, there are no staff motivation programs, etc. At the next stage of development, individual specialists in the field of management appear, but due to the lack of personal responsibility, key performance indicators are not regularly recorded. All implemented measures relate to private energy facilities, do not have a strategic focus and operate in the short term.

The second level of development is characterized by senior managers' acceptance of the importance of energy efficiency management principles. At the same time, in the style of management and decision-making, a technocratic approach is mainly applied to the development and implementation of energy saving measures, which is expressed in the predominance of technical solutions over organizational ones. The basis of motivation is the enthusiasm of the team members involved in management issues.

At the third level of development, the organizational structures that are assigned for the organization and functioning of the management system become clearly distinguishable, and they provide technical and methodological support for managerial decision-making. The information system is at the initial stage of development and monitors basic energy efficiency indicators (Bhuiyan, Dinçer, et al., 2022; Kou et al., 2022; Xu et al., 2022). However, a big step towards implementing the energy saving policy at this stage is the developed and coordinated program of management activities.

At the same time, management is not yet perceived as a full-fledged direction in management, but is considered as a technical mechanism. At the fourth level of development, the procedure for delegating responsibility in the field of management at various levels of management is fully functioning. A clearly formulated energy policy appears at the enterprise, as well as the strategic direction of development of the management system is traced. When planning investment costs, all possible effects from the implementation of energy saving projects (economic, environmental) are considered. Comprehensive support for the effective integration of energy management into the company's management system is provided by the processes of personnel training, informing employees about their role in achieving the goal, as well as all possible assistance from top management. The fourth level of development is characterized by the probability of risks associated with the phenomena of formalism and bureaucracy of energy efficiency management processes. In addition, attracting long-term investments can have an impact on reducing the performance indicators of some technical projects and solutions.

Building an organizational profile, in itself, is a rather complex process that requires compliance with a certain sequence of actions. The initial profile design is based on an expert assessment conducted by a specific manager or a group of them. After that, the same procedure for developing the profile is repeated the required number of times, considering the opinions of other experts of the enterprise. After each iteration, explanatory work is required in case of discrepancies in the ratings for individual criteria, which allows you to objectively evaluate a particular direction and identify strengths and weaknesses.

Identification of priorities and critical factors that can affect the energy efficiency of the enterprise under consideration is very important when building an organizational profile. In addition, critical points are subjected to comparative analysis, followed by decomposition and offering the most rational justification. The in-depth analysis carried out during the brainstorming discussion also involves identifying responsibility centers for each area and performance indicators that allow for subsequent monitoring of changes in this area.

Significant contradictions in the obtained estimates are noted in the areas of marketing and organization of management, in this regard, to determine the root causes of such differences, it is necessary to continue studying these areas. The high value of the assessment in the direction of energy policy indicates that there is an understanding of its importance for the development of the system, at this stage it is an element of the company's strategy. This is confirmed by the majority of managers surveyed. At the same time, it is noted that management is not sufficiently integrated into the management structure, and there is no clear delegation of responsibility in the use of energy resources. Information systems in the management structure also received a fairly high rating, which indicates the adoption of a new business model based on digital transformation and awareness of the importance of this area in strategic development. However, the most important task for the long-term development of the enterprise, along with the integration of digital transformation processes, is to create a system for continuous monitoring and analysis of energy consumption data.

Internal system marketing reflects the promotion of ideas in the field of energy saving among the company's personnel, as well as the organization of a developed benchmarking system (comparison of specific energy consumption in the production of products and services). The current state is characterized by insufficient awareness of employees on the main management tasks and methods of energy-efficient work. To improve this direction, it is necessary to organize a process for covering energy saving issues at all levels of the enterprise, including using internal information resources (mass media, information tools, social networks, etc.).

Investments in energy infrastructure received the lowest rating when building an enterprise profile. The main reason for this situation is the lack of funding for global energy sector modernization projects aimed at improving energy efficiency. Currently, the company implements activities with a relatively short payback period at the expense of the budget for current repairs and maintenance of fixed assets. Analysis of the organizational profile shows that the company is currently trying to ensure competitiveness by maximizing profits, while implementing minor energy-saving measures. However, in the long run, it seeks to make a transition to the implementation of large investment projects.

It is equally important to establish communication with the external environment for information exchange. At the enterprise under consideration, such communication is provided by the external relations department through the media, as well as through round tables, open dialogues, and participation of management representatives in regional and national conferences and exhibitions.

8.4 Conclusion

The analysis of consumption shows that there is a significant potential for savings in the pipe rolling shop for most resources, except for electricity. The leader in consumption and, as a result, the greatest potential for saving electricity has an electric steelmaking shop. The realization of potential is mainly related to the organization of production process planning and monitoring of resource consumption using digital systems.

The data obtained as a result of audits is of great importance in the analysis of energy efficiency. As a rule, the purpose of the audit is to establish the compliance of the management documentation developed at the enterprise with the requirements of the standard. If necessary, an in-depth audit can be performed with the study of energy flows and the proposal of economically justified measures, depending on the tasks of a particular enterprise. The cost of conducting an audit in different countries can reach 2% of the total energy costs of the facility, and the duration of the audit is from 20 to 50 days and depends on the volume of the management system. After implementing the recommendations received during the audit, in most cases it is possible to reduce energy costs by up to 20%. At the same time, the cost of conducting an audit is recouped in the next 2–3 years. During the audit, data from existing energy consumption devices and portable devices (if there are no standard ones) can be used. During the first stage, a flow chart is developed from raw materials to finished products with a description of the main energy consumers (boilers, furnaces, pumps, compressors, etc.). For each consumer, a flow balance is performed and the reasons for exceeding the planned indicators are analyzed.

During the audit, a number of shortcomings were identified that limit the implementation of strategic management principles. This included a low level of analysis at the enterprise, as auditors were not provided with confirmation of the achieved level of energy efficiency and an assessment of the degree of achievement of management goals. Due to the lack of the necessary principles for reporting on qualitative changes in energy efficiency, there is a possibility of incorrect interpretation of the analysis output. Energy efficiency indicators can include both production and organizational indicators, which include making managerial decisions.

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