ENERGY MANAGEMENT SYSTEM (EMS) AS A TOOL IN LIMITING THE COAL TRACE IN INDUSTRY

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Abstract

Increasing energy efficiency will be crucial to achieving the climate goals laid out in European Union directives. This is particularly true for industries whose share of heat and energy consumption, with Poland as an example, is about one-third of the total. This challenge entails implications both for the reduction of greenhouse gas emissions, especially CO_2, and for maintaining the competitiveness of EU industry on the global market. This article presents the basic principles and application of an Energy Management System – EMS – in industrial processes, together with the monitoring of Key Energy Performance Indicators – KPIs – as a tool for making informed investment decisions to improve the energy efficiency of companies and industrial processes. An attempt is made to present the situation in Poland in terms of the energy situation, with a focus on the automotive industry as an example.

Keywords: electricity, system heat, energy management, key parameters of energy efficiency, industry, production

Energy efficiency in industry

The development of energy management systems to support production processes has its origins in the spread of digital technology and the subsequent episodes of fuel crises that shook the global economy. These two factors occurred independently in the 1970s. The oil crisis, caused by the shock of the surprise attack on Israel by Egypt and Syria on Yom Kippur in 1973, meant that the naive belief that energy could remain available and cheap, combined with the unbridled consumption of oil from the Persian Gulf, had to be drastically reduced to adapt to the consequences (Statement WEC, 2023).

DOI: 10.5604/01.3001.0054.5176
Received: 25.03.2024 Revised: 24.04.2024 Accepted: 03.06.2024
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In the economic context, industrial production was put under severe pressure by the need of reducing costs and optimizing the efficiency of production processes. It was the financial aspect that was the main driver of industrial interest in the early development stages of the Energy Management System (EMS). In the new situation of rising fuel prices, the industry began to look for an answer to the question of how to produce cheaper fuel, which in turn led to optimization, also as regards energy.

Emerging technical solutions that improve the efficiency of the manufacturing process have naturally become the basis for applications, standards and technologies in other areas. This has led to a shift in focus from the manufacturing sector alone, and then to the development of solutions that over time have become independent sub-categories. The prevailing view is that the EMS is a component of the Building Management System (BMS), thus conceding the superiority of the BMS as a whole, linking the facility and the processes that take place within it. In other studies (Dechnik and Moskwa, 2017), the EMS appears as an independent member of the BMS. Additionally, since the beginning of the twenty-first century, various systems have gained popularity, the acronyms of which are derived from the narrowed scope of application. Thus, Industrial Energy Management Systems (IEMS) focus on energy efficiency in industrial processes, Building Energy Management Systems (BEMS) focus on buildings, e.g. commercial buildings, and Home Energy Management Systems (HEMS) are becoming increasingly popular for individual users and small residential buildings.

The EU's energy targets

The main factor that drives the development of industrial EMS systems, in addition to increasing the competitiveness of the company in the name of the expected financial benefits, consists of targets set for the industry, mainly by regulators, such as national or European Union administrations. The overall goal of this policy is to achieve climate neutrality as early as 2050 (International Energy Agency, 2022), and one of the ways to achieve this is to improve energy efficiency, e.g. production combined with a switch to the consumption of energy from renewable sources (European Commission, 2021). The ambitious CO_2 emission reduction targets adopted by the European Commission are translated into specific requirements that the EC presents in its directives (Bukowski and Śniegocki, 2014; Statement WEC, 2023), and the member states, e.g. Poland, include in their national programmes (International Energy Agency, 2022). The adopted and revised targets, adopted and amended, assume that by the end of the decade, i.e. by 2030, member states will achieve a minimum share of 42.5% of energy from renewable sources in the overall "energy mix". At the heart of this ambitious plan is the fact that energy efficiency is one of the key elements in achieving the goal of climate neutrality by 2050 (Chevuturi et al., 2022). Previous targets were to achieve a 20% share of energy from renewable sources by 2020, which was achieved with a 2% surplus according to Eurostat (Bukowski et al., 2014; European Energy Agency, 2023; May et al., 2015) – Figure 1.

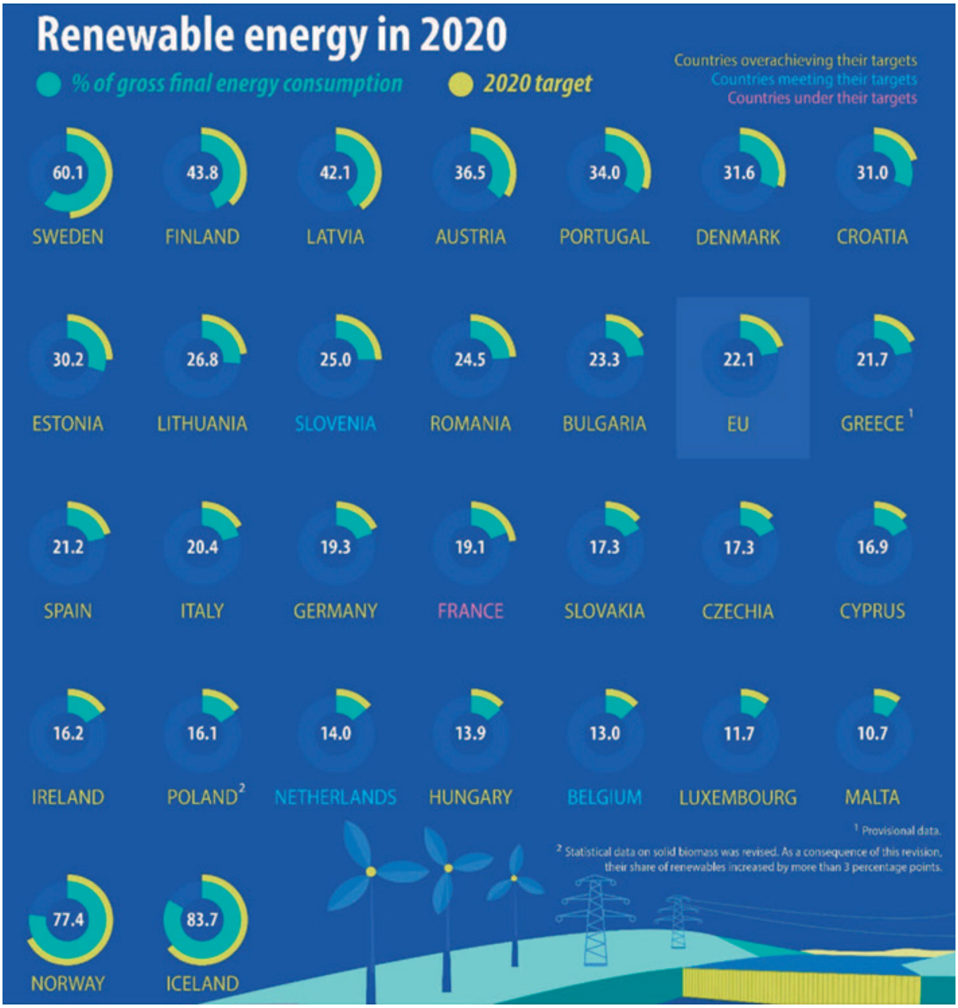

Figure 1. Share of energy from renewable sources, in the European Union and member countries 2020 target (Eurostat, 2022)

According to European Environment Agency (EEA), 22.5% of energy consumed in the EU in 2022 was generated from renewable sources). This slight increase compared to 2021, was largely driven by strong growth in solar power – Figure 2. The highest penetration of renewables in 2022 occurred in the power sector, with a representation of 40.7% of all electricity generated in the EU. It was followed by the heating and cooling sector with a renewable energy sources (RES) share of 23.2%.

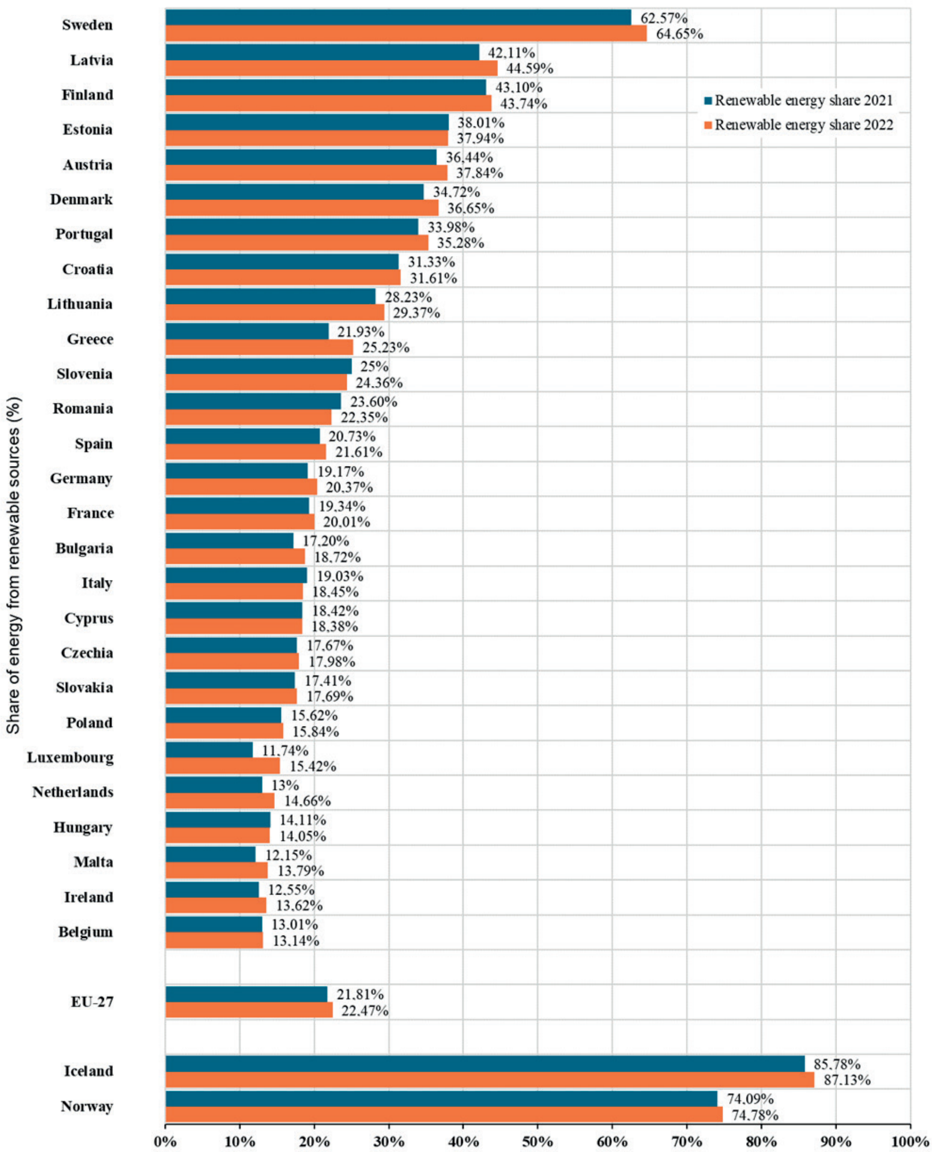

Figure 2. Change in share of energy from renewable sources, in the European Union and member countries between 2021 and 2022 (European Energy Agency, 2023)

An equally important area of action, according to the European Commission, is to reduce Europe's energy consumption. This task is and will remain a real challenge if the old continent wants to stay and count in the race for technological leadership. As Ray Dalio points out (Dalio, 2021), the position of a united Europe as a global player has been weakened in recent decades and Europe has slipped into the second world league. The reasons for this is an economy that is too weak, high and growing debt, political conflicts between countries, insufficient innovation, military weakness and high income inequality leading to the rise of populism, which ultimately led to the separation of the United Kingdom from the rest of the European Union. In addition, the European Union presents further reductions in the amount of primary and final energy consumed, which, for example, in relation to electricity, was 6% lower in the second quarter of 2023 compared to the same period in 2022 (European Commission, 2023) – Figure 3.

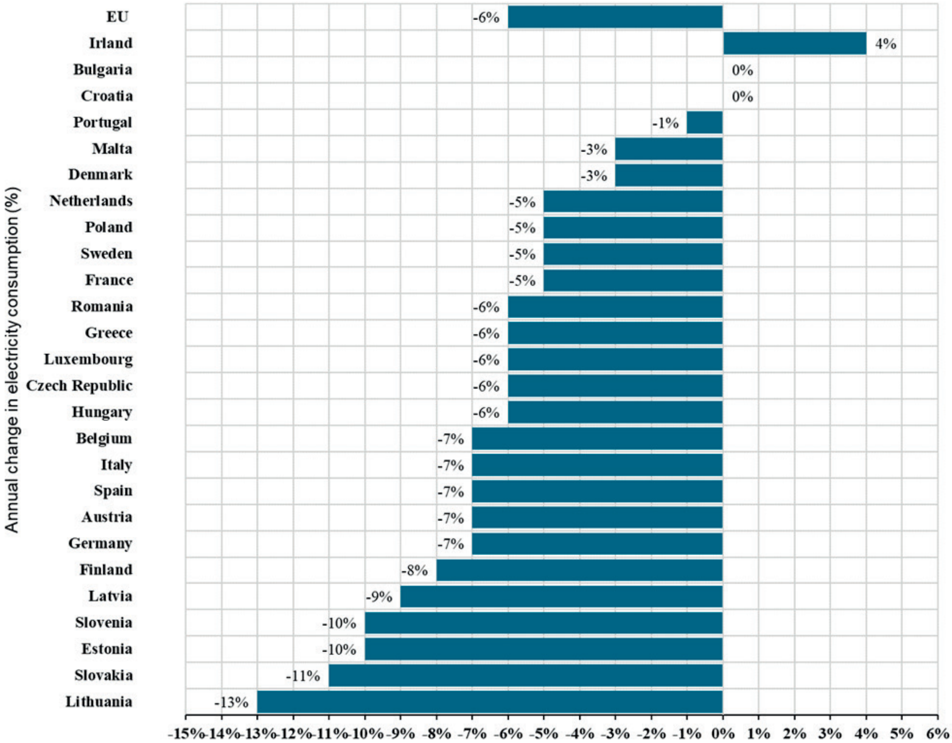

Figure 3. Annual change in electricity consumption in the European Union and member countries. Own study, based on data from DG Energy of the European Commission (European Commission, 2023)

In recent decades, energy consumption peaked around 2005 and has gradually decreased since then (Eurostat, 2021). In 2022, primary energy consumption across the Union was 4% below the 2020 target and 26% above the 2030 projection. Similarly, final energy consumption was about 2% below the 2020 target and 23% above the 2030 target (Eurostat, 2021).

Energy intensity of industrial production in Poland

Industrial production in Poland accounts for about 33% of heat and energy consumption (Dusiło et al., 2023; GUS, 2022). According to the Polish Central Statistical Office (GUS), the industrial sector's share of total energy consumption has fluctuated slightly in recent years.

Electricity is the basic energy medium for industry, and perhaps the most important one, as it cannot be omitted in any modern production. Direct consumption by industry (all sectors) in 2022 will account for 51% of total domestic consumption, with the share of companies in the "manufacturing" group at the level of 33.5% (Eurostat, 2021).

Electricity prices for industrial production in 2022 were for the first time higher than for individual consumers. On the other hand, in the second quarter of 2023, industry in Poland paid wholesale electricity prices that were among the highest ones in Europe (European Commission, 2023), and their dynamic growth compared to the previous year amounted to as much as 44% (Dusiło et al., 2023). In the following months, the trend was broken and prices on the Polish Power Exchange began to fall, which was associated with a decrease in the prices of basic energy resources (coal, gas, biomass), lower activity of energy-intensive industry and lower prices in CO_2 emission allowance trading (Derski, 2024). Industry as a group is by no means homogeneous, as it is a diverse mix of industries operating under very different economic, energy and technical conditions of production processes. Some of the companies have recently been able to develop their own strategy to reduce energy consumption (Backlund et al., 2012). An interesting example of this can be found in the solutions for the sustainable use and management of energy that operate within the water and wastewater management companies (Drewnowski et al., 2019; Masłoń et al., 2024).

It should be noted that electricity is by no means the only energy source used in industry. On a large scale, combustible gases, such as natural gas or LPG, are also used as fuel to be converted into heat needed to heat production halls or to convert water into steam. As far as natural gas is concerned, the industrial sector is estimated to be responsible for significant consumption of this raw material. For example, in 2021, consumption in this sector will account for 41% (Dusiło et al., 2023) of domestic consumption of this raw material. At the same time, due to very high prices, it has fallen significantly, by as much as 17% compared to the previous year. It should be noted, however, that despite the recent record decline, overall gas consumption in Poland has increased by around 10% over the last decade and by almost 27% since joining the European Union in 2004 (Dusiło et al., 2023) – Figure 4.

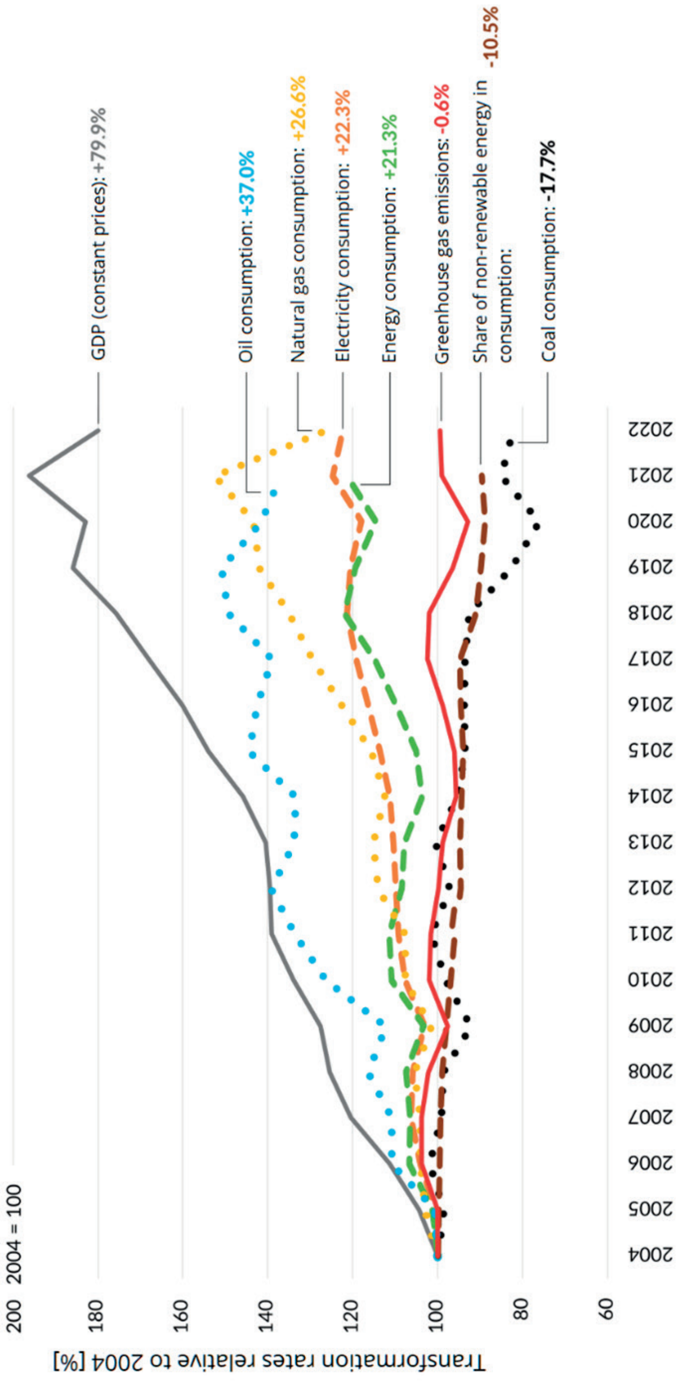

Figure 4. Indicators of the Polish energy transition, since entering the European Union, related to GDP (Dusiło et al., 2023)

Carbon footprint in industry

The concept of measuring or calculating the Product Carbon Footprint (PCF) generated in the production process is derived from the broader concept of Life Cycle Assessment (LCA) in general (Rüdele and Wolf, 2023). The PCF is expressed in Green House Gas (GHG) equivalent units, i.e. CO_2. The essence of the calculation of the PCF indicator is a multifaceted approach to the issue of GHG emission sources, from the extraction of the raw material, its processing with the use of tools and energy supplied to the process, through the supply chain and transport to the customer. Each of these stages generates a cost in the form of equivalent greenhouse gas (GHG) emissions to the natural environment, and the sum of these costs is the present carbon footprint (PCF). Typically, the largest part of a product's PCF is the extraction, transport and pre-treatment of the raw material itself (Żelazna et at al., 2018; Rüdele and Wolf, 2023).

A major advantage of using the PCF to track production is that it incorporates a cradle-to-gate perspective. This means that a raw material, e.g. imported from a country that has a high GHG content in its production, will automatically 'deposit' in the PCF of the product, making it less attractive on the market. This mechanism is intended to encourage manufacturers to use raw materials from more environmentally friendly sources.

The issue of calculating PCFs is so complex that already in 2010 the European Commission identified 62 "leading" initiatives and methodologies for calculating PCFs and at least 80 methodologies for GHG reporting, of which it recommended two (European Commission, 2021).

The problem of the Polish industrial sector in the context of the carbon footprint, which is already noticeable and will become an increasing burden in the future, is the very high CO_2 emissions of the commercial energy industry. In 2022, it will be characterized by emissions of 750 kg CO_2 per MWh, which is one of the worst values in Europe, and only the nearby and relatively small Estonia has a higher coefficient among the EU countries (Dusiło et al., 2023) – Figure 5.

The source of the problem of high Polish emissions is the fact that the commercial power industry (electricity generation) is mainly based on coal (Dusiło et al., 2023), a state of affairs that dates back to the second half of the twentieth century. This factor is likely to increase the economic pressure to improve energy efficiency in the coming years, as it will be reflected not only in the price of energy, but also in an increase in the PCF that producers are obliged to report. Already today, the production of a single exemplary element, e.g. across member (a structural part of a car), results in 169 g CO_2-eq in Austria, 256 g CO_2-eq in Germany and 591 g CO_2-eq in Poland, depending on the national "energy mix" (Rüdele and Wolf, 2023). Finally, a significant change in carbon intensity is possible through the use of renewable energy sources combined with energy storage, e.g. in the form of compressed hydrogen, but this requires substantial investment (Łukasik et al., 2023).

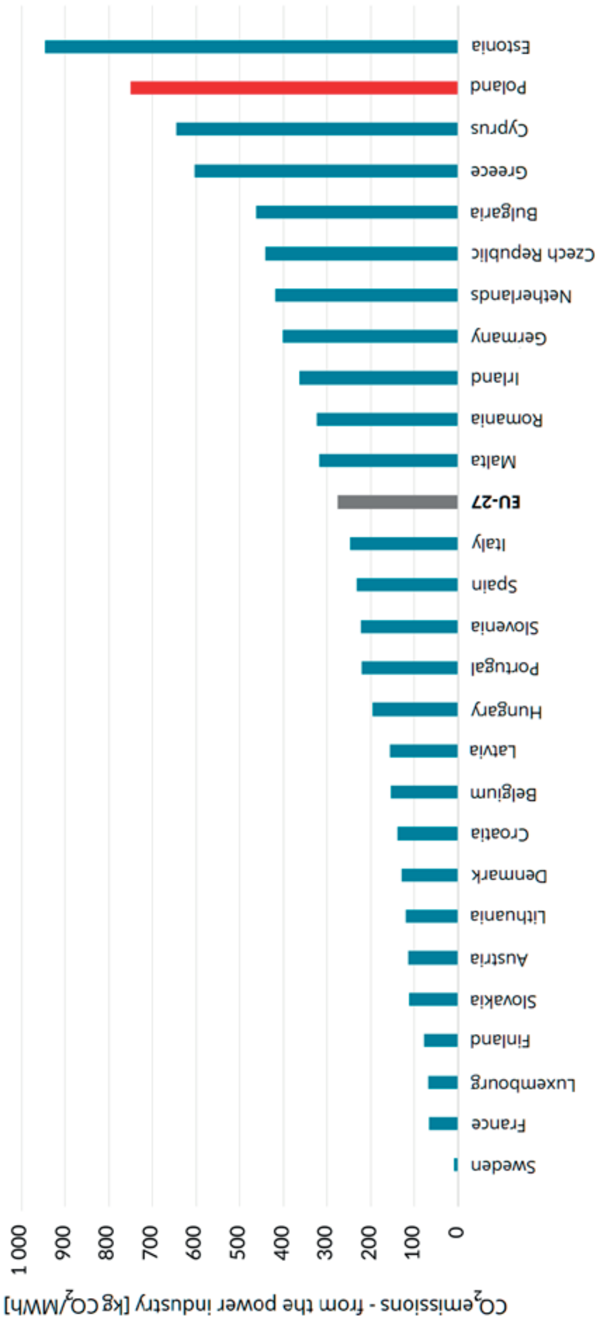

Figure 5. Emissivity of Poland's professional power industry in comparison with the European Union and member countries (Dusiło et al., 2023)

Division of production facilities by processes and construction/reconstruction period

In the last decade of the twentieth century, up to 2017, at least 325 new factories were built in Poland in the automotive industry alone (taken as an example in this study), out of a total of about 600 facilities of this type (Guzik et al., 2020). Indirect information on the time of construction, i.e. the building of new industrial plants in Poland, is also provided by data on the employment of employees in the corporate sector. Going back to the end of the last century, there is a clear change around 2005, with opposing trends. Between 1990 and 2005, employment in the sector fell from around 6 million to 4.6 million, and then rose again between 2006 and 2023, from less than 5 million to 6.5 million people (Łukasz, 2024).

At the same time, it should be noted that, according to the GUS classification, the business enterprise sector covers a wide and diverse range of activities.

A slightly less radical but similar picture emerges from data on average employment in industry, which increases from less than 2.1 million to more than 2.6 million in the private sector alone between 2005 and 2021. Importantly, the change in employment, i.e. its increase by less than 24%, correlates with an increase in production sold (from PLN 564 billion to PLN 1760 billion), i.e. by more than 310% (Kaczorowska et al., 2022).

Therefore, it can be "tentatively" assumed that during the period of industrial transformation, as predicted, the plants of the "centrally planned economy" model were closed, which led to a reduction in the number of employees and then to the creation of new ones, whose production capacity (measured in terms of sales) reached many times that of the last decade of the twentieth century, with only a slight upward change in employment.

The International Energy Agency (IEA) estimates the overall potential for energy efficiency improvements in industrial processes at 18-26% (Batorska, 2022). A survey of Swedish industry showed lower values. They estimated the combined potential of using more energy-efficient technologies and implementing good management practices in their companies at 12% (Backlund et al., 2012). The energy consumption of the industry should be assessed taking into account the scale of operations and the impact of industrial enterprises on the environment – Figure 6. A good example of the changes introduced in the field of external energy demand are the facilities shown in Figure 6 related to water supply, wastewater disposal and sludge treatment, where the technological improvements introduced were also related to the growing requirements on the amount of pollutants released into the environment (Drewnowski et al. 2019; Shourjeh et al., 2019; Masłoń et al., 2020).

A good example of changes in the approach to energy transition and energy management is the automotive industry. In the period following the political transformation, the countries of Central and Eastern Europe, including Poland, the Czech Republic and Slovakia, began to consolidate their position as the automotive base of Europe (Domański et al., 2013). The industry focused on supplying parts

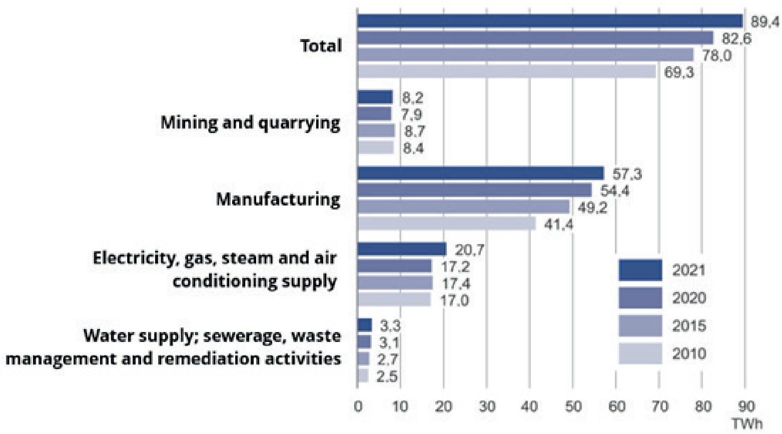

Figure 6. Industrial electricity consumption, by group (Kaczorowska et al., 2022)

and components for car production in factories that had been operating in Western European countries for many years. There was also a concentration of new companies in this industry, mainly in the south-west of Poland, in the Upper and Lower Silesia regions (Domański, 2015), from where the supply lines to the neighbouring Czech Republic and Germany were the shortest. It is not surprising, therefore, that most of the car plants in Poland and the neighbouring countries are new, built to the standards in force at the time they were designed and approved. However, when assessing their energy consumption, it should be taken into account that, depending on the intensity of production, the area indicator (e.g. kWh/m^2 per year), i.e. information on the efficiency of the use of the facility itself for the purpose of the production process, is and will remain significantly different from facilities of a different nature, i.e. non-production ones. For example, the value of the final energy demand in administrative and office buildings built in the same period will fluctuate around 100 kWh/m^2 per year, while in an industrial facility, depending on the type of production carried out in it, this value will range, for example, from 300 to 600 kWh/m^2 per year.

Key Energy Performance Indicators (KPIs)

Key Performance Indicators (KPIs) are an important part of any monitoring system. The purpose of KPIs is to support the decision-making process of those responsible for the effectiveness of, for example, the organization, on the basis of a factual cause-and-effect relationship. In other words, they communicate the most important (key) data to the right people so that they can make better-informed decisions. Therefore, KPIs are an information base, and their presentation can be, for example, as a set of indicators (dashboard), on which critical data about the execution of the process is presented. These indicators are based on measurements of the process status, which can be collected manually or come from software, e.g. the monitoring of the production process (André and Goepp, 2024).

If, in general management theory, KPIs are designed to iteratively improve the efficiency of the organization and thus influence its future success, as illustrated in Figure 7, then in the heat and energy field we are dealing with energy EKPIs whose goal is analogous to KPIs but limited to energy efficiency and reducing its consumption. In this approach, however, the basic indicators, i.e. those that show, for example, the total heat and energy consumption per year or per product, provide information that is too general. They lack precision and transparency, i.e. they will not be useful enough to indicate, for example, the factors responsible for the current situation (May et al., 2015).

Figure 7. KPI creation/development loop (Andersson and Thollander, 2019)

Therefore, different types of KPIs work, depending on the area they are designed to monitor and influence, thereby improving their effectiveness. There are examples of KPIs specific to whole sectors of the economy (May et al., 2015), e.g. the paper industry in Vietnam (Le-Anh, 2023), at board level, e.g. of companies with different industrial plants in their portfolio, a single factory or a specific production line and process (Andersson and Thollander, 2019), a machine or even a component (May et al., 2015), which is particularly important from the point of view of energy efficiency, e.g. an engine. This diversity arises from the fact that general KPIs are usually insufficient to accurately monitor the process and draw conclusions about the changes that need to be introduced (May et al., 2015). What is more, a well-configured KPI at the right depth in the process can also be used to identify disturbances in the process itself, in addition to the decision-making function described above. For example, an increase in energy consumption that does not correlate with an increase in production may be caused by premature wear of one of the elements, parts or machines in the production line (Andresson et al., 2021).

Conclusions

Maintaining competitiveness in industrial production depends on a number of factors. One important factor is the share of energy in production costs. This is closely linked to EU and national regulations that require both a reduction in the amount of energy consumed in production processes and a switch to renewable energy sources. These generally costly measures have an impact on the price of the main industrial refrigerant for heat and energy. In this context, the position of automotive companies in Poland has historically been burdened by high energy consumption, which is gradually improving with new investments. A serious challenge to the competitiveness of the automotive industry is, and will remain in the near future, the high-emission commercial power industry, which in Poland is still largely based on coal.

The way to improve competitiveness and more efficient use of heat and energy in industry is to increase the energy efficiency of processes. One of the possibilities is the use of EMS management systems, which enable the continuous analysis of key indicators – energy KPIs. Implementing such a system at the level of the entire company or an isolated production process, down to a single machine, allows the most accurate targeting of modernization investments. Thanks to such tools, it is possible to implement and verify the most effective solutions for reducing heat and energy consumption. The use of KPIs, repeated iteratively in a loop, combined with the development of indicators best suited to the specifics of production, will determine whether or not to embark on the path of rapid optimization. The alternative is to remain in an increasingly unfavourable position in the face of strong and growing competitive pressure from producers in markets outside the European Union.

Acknowledgement

The topic was presented during the Scientific Conference "Water and fires – planning, suppression, management" on April 22–24, 2024 in Żyrardów. The conference is financed by the Minister of Education and Science as part of the "Excellent Science" programme, the "Support for scientific conferences" module (project no. KONF/SP/0311/2023/01*).*

Funding

This research received no external funding.

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