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Energy Efficiency Improvement in Polish Manufacturing Enterprises Participating in the EMAS Scheme

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Abstract:

Purpose: *The purpose of this paper is to present undertakings of Polish manufacturing enterprises participating in the EMAS scheme, implemented to improve their energy efficiency.*
Design/Methodology/Approach: *The theoretical part of the study presents the results of previous desk-research regarding the EMAS system, indicating a gap in the knowledge concerning particular activities implemented by the analysed companies in order to improve their environmental performance. The empirical part contains the results of individual research conducted in Polish manufacturing enterprises participating in the EMAS scheme. The grounds for the assumed research method was the analysis of secondary sources in form of environmental statements. The selection of sample was targeted, the research involved a complete analysis among 12 manufacturing companies from Poland, participating in the EMAS scheme. It should be noted that the analysis of environmental statements had been used as the grounds for the research in previous studies concerning the EMAS scheme, among others, describing the effects of EMAS implementation on the improvement of environmental performance.*
Findings: *The conducted analysis allowed to identify most common initiatives aimed at energy efficiency improvement and indicate examples of specific solutions in that area. The most common undertakings included, improvement of manufacturing processes, modernisation or replacement of lighting systems, energy recovery, using renewable sources of energy and rebuilding or retrofitting of buildings along with process installations and equipment.*
Practical Implications: *Specific solutions identified in the course of the analysis included both cheap and simple ones, as well as more expensive and time-consuming procedures, but all of them could inspire organisations of different size, with a large spectrum of activity profiles. This paper may be also important in the aspect of life quality, as it describes solutions aimed at reaching optimum energy efficiency.*
Originality/Value: *This study supplements previous research concerning the EMAS system, providing specific examples of activities undertaken by Polish manufacturing companies in order to improve their energy efficiency.*

Keywords: *Eco-management and audit scheme, energy and climate policy, energy management.*
JEL codes: *P18, Q42, Q54.*
Paper type: *Research article.*

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1. Introduction

One of the major problems discussed in the European Union is reducing the negative environmental impact related, among others, with air contaminants emissions. Improving energy efficiency in different industries is particularly significant in this area.

The results of such improvement might include reduction of greenhouse gas emissions, improvement of air quality and society health, introducing new technologies, increased innovative potential of the economy and competitiveness within the EU (measured by the GDP energy consumption) as well as reduction of energy costs for enterprises (Ministerstwo, Klimatu, and Środowiska, 2021; The European Parliament and the Council of the European Union, 2018).

Indirect effects might be related with energy security, due to reduced fuel and energy demand and import of raw materials (Ministerstwo Klimatu i Środowiska, 2021). As regards energy efficiency improvement, top-down initiatives, including European and national policies determining the legal framework and trends in this area, are equally important as bottom-up initiatives, consisted in taking voluntary actions to optimise energy consumption in household environment and individual organisations.

Enterprises should have a particular role in the fulfilment of investment projects in the field of energy efficiency improvement, including renewable sources of energy (Komisja Europejska, 2016).

One of the tools that may support organisations in taking voluntary environmental initiatives (including energy efficiency improvement), is the eco-management and audit scheme (EMAS). It is an instrument introduced by the European Union primarily to support organisations in permanent improvement of environmental performance. EMAS is currently considered the most credible and transparent environmental management system. The significance of EMAS in energy efficiency improvement has been described, among others, in one of the key legal documents concerning energy efficiency in Poland (Dz. U. 2016 poz. 831).

The purpose of this paper was to present undertakings of Polish manufacturing enterprises participating in the EMAS scheme, implemented to improve their energy efficiency. This paper is an attempt to supplement the knowledge concerning the activities undertaken or planned by Polish organisations participating in the EMAS scheme to reduce the negative impact or increase the positive impact of their operations in different environmental areas (e.g., energy consumption).

Presenting the outcomes of this research will be significant for the implementation of the EU and Polish energy and climate policies. It will also promote the EMAS scheme and supplement previous studies conducted in different countries, providing

examples of initiatives that could be taken in order to improve environmental performance, or maintain conformity with the EMAS requirements in enterprises already implementing this tool.

The grounds for the assumed research method was the analysis of secondary sources in form of environmental statements. The selection of sample was targeted, the research involved a complete analysis among 12 manufacturing companies from Poland, participating in the EMAS scheme.

2. Energy Efficiency Improvement and EMAS Requirements to Be Considered

Energy efficiency is one of the five closely related and mutually supporting measures of the energy union (The European Parliament and the Council of the European Union, 2018a). It is defined as the ratio of the usable effect of a given facility, technical device or installation, achieved under typical usage or operation conditions, to the amount of energy used by such facility, installation or technical device to achieve such effect, also by providing a service.

The usable effect shall be defined as the effect achieved through the delivery of energy to a given facility, installation or technical device, in particular to illuminate, ensure thermal comfort or perform mechanical work (Dz. U. 2016 poz. 831). Energy efficiency improvement may be beneficial in a broader perspective, beyond energy, including social and environmental aspects, not interfering with economic growth.

Positive environmental effects achieved through initiatives in this area may concern reducing emissions of airborne contaminants and waste management (by reducing the volume of waste or circularity). The economic significance of energy efficiency improvement (including the use of renewable energy) has been defined on the EU and Polish level (Dz. U. 2016 poz. 831; Komisja Europejska, 2011, 2014, 2016, 2021; Ministerstwo Klimatu i Środowiska, 2021; The European Parliament and the Council of the European Union, 2018, 2018b).

Initiatives that could be implemented among organisations to improve energy efficiency may differ depending on the type of activity. These are defined as activities consisted in modification or optimisation of the facility, installation or technical device in order to save energy (Dz. U. 2016 poz. 831).

In manufacturing companies, these may include: insulation of industrial installations; modernisation or replacement of lighting systems, installations and devices used in industrial processes, as well as vehicles used for transport; energy recovery; rebuilding or retrofitting of buildings along with technical installations and devices, and switching to heating or cooling systems based on renewable energy or waste heat from industrial processes (Dz. U. 2016 poz. 831).

Additionally, large enterprises (according to the Entrepreneurs' Law, Journal of Laws of 2021, item 162) are obliged to conduct energy audit every 4 years. Its purpose is to perform detailed and credible calculations concerning actions proposed to improve energy efficiency of the enterprise, and to provide information on potential energy savings that could be achieved as a result of the proposed actions (Dz. U. 2016 poz. 831).

One of the instruments that could support organisations in their activity to reduce the negative environmental impact and increase the positive environmental impact, is the EMAS system. This scheme imposes strict requirements that can be significant also in the field of energy efficiency improvement. These include the obligation to achieve continuous improvement of environmental performance, which stimulates organisations to seek solutions that facilitate environmental performance.

The organisations are also required to present and evaluate their performance in the environmental statement, based on the analysis of environmental performance measures. Six most important measures include the energy efficiency index (The European Parliament and the Council of the European Union, 2009).

Additionally, organisations must identify significant environmental aspects, defined as a part of activity, products or services that have or may have significant impact on the environment (The European Parliament and the Council of the European Union, 2009). If energy consumption is defined as a significant aspect, the organisation is obliged to set environmental goals and tasks to enable improvement in a that area.

Another significant requirement within the EMAS scheme is the conformity obligation. In this area, enterprises should monitor legislative changes on a regular basis and adjust their activity to ensure conformity. EMAS is currently considered one of the most credible environmental management systems. Its significance is reflected in the obligation for large enterprises to conduct energy audits. Companies participating in the EMAS scheme, having conducted an energy audit within its framework, can be exempted from that obligation (Dz. U. 2016 poz. 831).

3. Review of Previous Research Concerning EMAS

Activities undertaken in enterprises to improve their environmental performance are among the positive outcomes of the EMAS scheme implementation. It is also related with the aforementioned obligation of continuous improvement of environmental activity effects. The research indicates that most frequent benefits included systematisation and streamlining of previous environmental activity (Abeliotis, 2006; Bohne, 2000; Freimann and Schwaderlapp, 1996; Hillary, 1998; Hyršlova and Hajek, 2005, 2006; Kossler *et al.,* 2002; Ministerio De Medio Ambiente, 2006; Morrow and Rondinelli, 2002; Nycz-Wróbel, 2016; Steger, 2000; Umweltbundesamt, 2000).

In this connection, individual EMAS requirements that facilitated improvement of environmental performance were indicated. They concerned identification of significant environmental aspects, determining environmental policy and goals, and the requirement for constant improvement of environmental performance (Hyršlova and Hajek, 2005).

Another benefits reported in the course of the research concerned limiting the negative environmental impact, mostly through the reduction of waste and consumption of resources and energy (Braun and Grotz, 2002; Bültmann and Wätzold, 2000; Hyršlova and Hajek, 2006; Nycz-Wróbel, 2016a; Schucht, 2000; Umweltbundesamt, 2000; Vernon *et al.*, 2009; Wenk, 2004).

The analysed organisations also reported improvement of environmental efficiency (Daddi *et al.*, 2011; Hillary, 1998, 2004; Merli *et al.*, 2014; Morrow and Rondinelli, 2002; Nycz-Wróbel, 2016a). The research conducted among French and German enterprises indicated that technical improvements of existing facilities or installations, optimising or implementation of new processes, improvement of environmental impact of existing products or replacement of problematic materials, were among the activities planned or taken for this purpose (Bültmann and Wätzold, 2000; Schucht, 2000).

There were also organisations in which implementation of EMAS scheme resulted in technical innovations (Braun and Grotz, 2002; Nycz-Wróbel, 2016; Rennings *et al.*, 2006) and product innovations (Hoffmann *et al.*, 2003; Nycz-Wróbel, 2016; Salomone, 2008), related with the environment. Additionally, certain studies indicate savings among major benefits of the EMAS scheme implementation, due to improvement of energy efficiency.

These studies were conducted among entrepreneurs from Great Britain (Strachan *et al.*, 1997), Spain (Ministerio De Medio Ambiente, 2006), Greece (Abeliotis, 2006), Czechia (Hyršlova and Hajek, 2005, 2006) and Germany (Freimann and Schwedes, 2000; UBA, 2013; Umweltbundesamt, 2000). A study concerning Polish enterprises with different profiles of activity lists individual initiatives taken to improve energy efficiency. Most of them had replaced or modernised equipment or installations, streamlined their production processes and installed energy-saving lighting systems.

One of the most common practices was using additional indexes or systems for power utilities consumption monitoring, implementing an energy management system according to ISO 50001 standard, conducting energy audits and raising awareness among employees and customers (Nycz-Wróbel, 2020).

The analysis of the previous research related with the implementation and maintaining the EMAS scheme in organisations indicates that environmental benefits were the most frequently reported effects.

However, studies presenting specific exemplary activities that enterprises could take in order to improve their environmental performance in different areas (including energy efficiency), have not been conducted so far. This study is an attempt to fill this gap.

Supplementing that knowledge will be fundamental for the presentation of specific solutions put into practice to improve energy efficiency or planned by organisations with different activity profiles, with the aim to improve their environmental performance. It is important both for those organisations and the improvement of the overall quality of life in the society.

4. Purpose and Methodology

The purpose of this paper was to present undertakings of Polish manufacturing enterprises participating in the EMAS scheme, implemented to improve their energy efficiency. The theoretical part describes the benefits that can be obtained as a result of energy efficiency improvement in the power engineering, environmental and social perspective. It also lists the types of activities that could be implemented in manufacturing enterprises to reduce energy consumption.

Additionally, the results of previous desk-research regarding the EMAS system have been presented, indicating a gap in the knowledge concerning particular activities implemented by the analysed companies in order to improve their environmental performance. The empirical part contains the results of individual research conducted in Polish manufacturing enterprises participating in the EMAS scheme.

The assumed research method was based on the analysis of secondary sources in form of environmental statements. Environmental statement is a type of an environmental impact report that is obligatory for organisations participating in the EMAS scheme, that must be regularly published and updated.

According to the EMAS Regulation, environmental statements must contain sufficient information for the public and other stakeholders of the organisation, including the description of conducted activity, identified significant environmental aspects, environmental goals and tasks, as well as effects achieved in different environmental areas, among others, in form of calculated values of environmental indexes (The European Parliament and the Council of the European Union, 2009).

Information presented in environmental statements must be regularly assessed by a third-party environmental verifier in terms of correctness, reliability, credibility and conformity with the EMAS Regulation, which ensures they are credible source of data for the analysis (The European Parliament and the Council of the European Union, 2009). It should be noted that the analysis of environmental statements had been used as the grounds for the research in previous studies concerning the EMAS scheme, among others, describing the effects of EMAS implementation on the

improvement of environmental performance (Daddi *et al.*, 2011; Heras-Saizarbitoria *et al.*, 2020; Matuszak-Flejszman *et al.*, 2019; Nycz-Wróbel, 2020). They can also provide information concerning possible technical innovations to be transferred in other enterprises (Rennings *et al.*, 2006).

Environmental statements were downloaded from the Polish EMAS website. The selection of sample was targeted and the research involved a complete analysis among 12 manufacturing companies from Poland, participating in the EMAS scheme, according to the register dated 8 May 2023. The characteristics of individual enterprises in terms of size and offered products is presented in Table 1.

Table 1. *Characteristics of enterprises participating in the study*

No.	**Products**	**Size of enterprise**	**Designation for study purposes***
1	Cement and clinker	Large	A
2	Construction materials (in particular cement, ready-mixed concrete and aggregates)	Large	B
3	Portland clinker as an intermediate product; Portland and mixed cement	Large	C
4	Graphic and offset paper	Large	D
5	Meat and poultry products	Medium	E
6	PVC coated, varnished and extruded materials	Small	F
7	Equipment for power engineering industry, chemical industry and environmental protection systems	Large	G
8	Polyester and woollen yarn	Medium	H
9	Utility vehicles	Large	I
10	PVC and aluminium windows, aluminium fire protection doors and windows	Large	J
11	Aerosol products, esp. cosmetics, medical products, household chemicals	Medium	K
12	Gypsum construction materials	Medium	L
**In order to present the results of the study, companies participating in the study have been coded with letters A, B, C, D, E, F, G, H, I, J, K, L*			

Source: *Individual research based on the analysis of environmental statements.*

Considering the size of organisations, the structure of the analysed population included 7 large, 4 medium enterprises, and 1 small enterprise. The analysis encompassed a group of manufacturing enterprises where 4 dealt with the manufacture of construction materials, while other organisations offered different types of products.

The study started on 8 May 2023 and ended on 31 May 2023. An in-depth analysis of entire environmental statements of individual companies participating in the study has been conducted. Based on the analysis, all types of activities implemented by the study participants in order to improve their environmental efficiency, were

identified. Next, the identified activities were listed and grouped. The outcome has been presented in form of a chart. Table 2 presents the most frequently performed activities. Tables 3 through 8 present detailed solutions used by the study participants in individual groups of initiatives listed in Table 2.

5. Outcomes of Empirical Research

Table 2 lists types of undertakings implemented in Polish manufacturing enterprises in order to improve their energy efficiency.

Table 2. *Most frequent activities performed in Polish manufacturing enterprises to improve their energy efficiency*

Actions taken to improve energy efficiency	**Number of enterprises**
Streamlining production processes (including retrofitting or replacement of equipment or systems)	8
Retrofitting or replacement of lighting systems	6
Energy recovery	6
Renewable energy sources	6
Reconstruction or retrofitting of buildings along with technical systems and devices	5
Other	12

Source: *Individual research based on the analysis of environmental statements.*

The most frequent activities performed in order to improve energy efficiency include: streamlining production processes (including retrofitting or replacement of equipment or systems) (8), retrofitting or replacement of lighting systems (6), energy recovery (6), use of renewable energy sources (6) and reconstruction or retrofitting of buildings along with technical systems and devices (5). The group of other activities included solutions that could not be classified under the major identified categories (12).

Table 3 presents solutions implemented by the study participants as part of streamlining production processes.

Table 3. *Solutions implemented to improve energy efficiency of manufacturing processes*

Activities implemented to improve production processes	**Enterprise**	**Number of enterprises**
Using energy efficient technologies/techniques	A, E, I,	3
Modernisation of kiln at a single cement plant Rescheduling energy-consuming processes beyond peak energy consumption periods Increasing mill efficiency by storing clinker at a roofed site	B	1
Launching dry manufacturing kilns	C	1
Choosing energy-efficient machines while designing new	I	1

processes Eliminating leakages within the pressurised air installation Buying additional pumps for the main paint shop		
Building a system of silos to store products and raw materials Building a modern mixing plant and a warehouse	L	1
Heat exchanger and closed water circulation in Formax machines	E	1
Eliminating production faults Increasing unification of product series Significant product quality improvement Stabilising and optimising production processes Slight modification of machines	F	1
Taking energy performance into account while designing or modernising existing installations	H	1

Source: *Individual research based on the analysis of environmental statements.*

Activities aiming at the improvement of energy efficiency within manufacturing processes had been implemented in 8 enterprises. Four of them were manufacturers of construction materials. The analysed enterprises focused on using most energy efficient technologies (3) and optimising the used technology (e.g. by using power-saving machines, buying additional machines, which eliminated the necessity to work extra hours, or machine replacement to increase production efficiency and achieve larger production output).

Modification of warehousing processes allowed to increase mills efficiency operated by the manufacturer of cement, ready-mixed concrete and aggregates, while in another company, manufacturer of gypsum construction materials, it allowed to secure the stock and extend the production cycle. In both cases, the major result were energy savings. One of the listed solutions, consisted in kiln modification at a cement plant, obtained White Certificates amounting to 16,505 toe, which confirmed the achieved energy savings. Other activities identified in the course of the environmental statements analysis involved modernisation or replacement of lighting systems. Specific solutions in this area had been reported by 6 enterprises (Table 4).

Table 4. *Solutions in the field of modernisation or replacement of lighting systems*

Modernisation or replacement of lighting systems	**Enterprise**	**Number of enterprises**
Installation of LED lighting or replacement of other systems with LED lighting	B, D, E, I, L	5
Modernisation of factory room lighting	G	1
Innovative lighting concepts Repair of lighting in the sub-assembly and storage halls Implementing an illumination schedule in the warehouse docking area	I	1
Lighting system of the building	E	1

Source: *Individual research based on analysis of environmental statements.*

The most frequently reported solutions included installation of LED lighting systems. These solutions were implemented in five enterprises. Certain organisations indicated specific locations where lighting systems had been modernised or optimised. These were mostly manufacturing shops and warehouses. Another solution reported in the analysed environmental statements was the introduction of intelligent lighting systems. Energy recovery solutions reported by the study participants are presented in Table 5.

Table 5. *Energy recovery solutions implemented in the Polish manufacturing enterprises*

Energy recovery	**Enterprise**	**Number of enterprises**
Construction of a dryer/mixer system with a vertical roller mill (heat recovery from the clinker cooler)	A	1
Rotary dryer construction, using clinker cooler off-heat for alternative fuel drying Recovery of waste heat (from clinker cooler of kilns No. 13 and 5, and waste gas from kiln No. 5) to dry the stone in the raw product mill Recovery of energy from the combustible fraction of non-recyclable municipal waste	B	1
Using waste thermal energy for production and welfare purposes Using heat from burning alternative fuels in the Portland clinker production process	C	1
Retrofitting of the MP1 heat recovery tower (heat recovery from fumes exhausted from the dryer) Construction and launch of the MP2 processing line energy recovery systems (heat recovery from MP2 turbofans) Construction of a energy recovery system for the MP1 processing line vacuum turbofan	D	1
Heat recovery system for the entire building Heat pump	E	1
Heat distribution with manufacturing process heat recovery	I	1

Source: *Individual research based on the analysis of environmental statements.*

Energy recovery solutions have been found in environmental statements of 6 enterprises. Specific solutions in this field included the use of waste thermal energy. That solution had been used in one of the cement plants (cement and clinker production) where clinker firing process used hard coal and alternative fuels that replaced conventional fuel.

According to the integrated permit, it is waste reusable in the R1 recovery process, where incineration heat is used in the production of Portland clinker. Another manufacturer of construction materials (cement, ready-mixed concrete and aggregates), intending to increase energy efficiency of the clinker firing process, added a rotary dryer at a cement production plant, using off-heat from the clinker

cooler to dry alternative fuels. Firing conditions were improved by reducing fuel moisture, which lowered heat demand of the production process.

A graphic and offset paper manufacturer introduced three solutions to improve the energy efficiency. First, consisted in a modification of the heat recovery tower, aimed at increasing the amount of energy recovered from exhausted fumes (dryer exhaust air) and reducing steam consumption for heating fresh drying/ventilation air.

The purpose of the second solution, consisted in the construction and launch of a MP2 processing line energy recovery system, was heat recovery from MP2 turbofans. Waste energy comes from air exhausted by turbofans used to produce vacuum, while recovered energy is used for heating clean water and to support the drying and ventilation system on the MP2 line. The third solution enabled the recovery of energy used for heating ventilation/drying air and clean water.

This allowed to reduce the volume of steam used for heating. Reported solutions also included heat pump usage to recover off-heat from the ammonia refrigeration system (manufacturer of meat and poultry products). Waste heat from refrigeration system compressors is used for heating of building interior, domestic water and ground under the freezers and also for HVAC units. Table 6 presents renewable energy sources used by the survey participants in order to improve their energy efficiency.

Table 6. *Solutions based on renewable energy*

Renewable energy sources	**Enterprise**	**Number of enterprises**
Switching to electric energy generated in 100% using renewable sources (PV cells) Building a 50kW PV farm	B	1
Switching to renewable energy (photovoltaic cells, wind turbines)	E	1
Signing two new contracts related with production of green energy Commissioning of a fluidised bed boiler fired only with biomass Launching a new power unit in a cogeneration system using biomass	G	1
Access to alternative sources of energy	H	1
Powering the plant (since 2018) using electric energy obtained in 100% from renewable sources	I	1
Installing a PV plant	K	1

Source: *Individual research based on the analysis of environmental statements.*

The analysis of environmental statements indicated that solutions employing renewable energy had been implemented in 6 enterprises. The most common renewable energy solution were photovoltaic panels. Polish enterprises also reported

usage of biomass and wind turbines. As part of that activity, manufacturers of equipment for power engineering and chemical industry and environmental protection systems provided technologies allowing the use of biomass by its business partners. An innovative project is worth mentioning in this aspect, that involved commissioning of a fluidised bed boiler fired only with biomass. Previous units were fired with coal or a combination of coal and biomass.

Some research participants also reported certain measurable indexes related with the use of renewable energy. In one of the construction materials manufacturing enterprises (in particular: cement, ready-mixed concrete and aggregates), energy generated with PV cells covered 99.4 percent of total electric energy demand in all plants of the company in 2021, while for its cement manufacturing plants, its coverage reached 100 percent. That company also built a 50kW PV farm at one of their concrete production plants.

All energy produced using that system had been used for the purposes of the plant with the expected coverage of 20 to 25 percent of energy demand. For the meat products manufacturer participating in the research, 100 percent of green energy they produced, was used internally. Utility vehicle manufacturer reported that their plant had been powered with electric energy obtained in 100% from renewable sources since 2018. They also intended to produce energy on their own and supply heat for the entire production plant using boilers fired with wood pellet, which would cover 90% of yearly demand for central heating and processing heat. Another type of activities taken to improve energy efficiency was rebuilding or retrofitting of buildings along with technical systems and equipment (Table 7).

Table 7. *Solutions to improve building energy efficiency*

Reconstruction or retrofitting of buildings along with technical systems and devices	**Enterprise**	**Number of enterprises**
Triple-glazed windows in the office area Double-panelled walls Special ventilation system of production and office areas Modern gas boilers Building Monitoring System Use of rainwater and deep well water for the cooling process Water-saving faucets	E	1
Improvement of buildings insulation Energy-efficient air conditioning Modification and modernisation of energy supply systems	I	1
Installation of earth gas consumption meters on the heating system supply connections Installation of heating water flow controllers on radiators	F	1
Regular technical inspection of gas installations and tightness check	G	1
Launching an electronic platform for energy management	B	1

Source: *Individual research based on the analysis of environmental statements.*

Building modernisation and retrofitting solutions were implemented in 5 enterprises. In most cases, they aimed at the reduction of energy consumption for heating or cooling building interior (e.g., energy-saving air conditioning, use of rainwater and deep well water in the cooling process to reduce energy consumption, installation of water flow controllers on radiators to optimise heating of office spaces, installation of modern gas boilers as a backup for a heat pump) and improvement of building thermal insulation efficiency (improvement of thermal insulation of windows and walls). Table 8 presents other solutions implemented in Polish manufacturing enterprises to improve energy efficiency.

Table 8. *Other activities performed in Polish manufacturing enterprises to improve their energy efficiency*

Other	**Enterprise**	**Number of enterprises**
Raising environmental awareness among employees and stakeholders	B, C, D, E, F, I, J, K, L	9
Additional analysis, measurement and reporting of energy usage	A, B, C, F, H,	5
Rational usage of energy and gas	C, E, F,G,	4
Offering energy-efficient products	B, G, J	3
Energy audits	B,C, I	3
Project energy efficiency assessment	A, D	2
ISO 50001 energy management system	B, I	2
Purchase of energy-saving products and services	H, I	2
Switching to more restrictive cleaning and disinfection procedures Introducing synergy in process demand for heat/cooling/steam (BAT b12)	E	1
Appointment of an energy management group Introducing employees' ideas as part of the Kaizen process	I	1
Investing in energy-efficient solutions	B	1
Producing electric energy with the use of gas turbines and as a result of steam pressure reduction in two steam turbines	D	1

Source: *Individual research based on the analysis of environmental statements*.

This group lists examples of other solutions implemented in each of the 12 enterprises participating in the research. The most frequently reported practices included raising environmental awareness among employees and other groups of stakeholders (cooperating parties, visitors, families of employees, persons employed on behalf of the company). This solution was employed in 9 enterprises, of which 7 did not specify particular scope, while two companies, manufacturers of utility vehicles and construction materials, indicated that trainings concerned, among others, energy management.

Other initiatives to raise environmental awareness included informative campaigns, e.g., Environmental Protection Day, accompanied by a contest and info event, and introductory trainings for new employees. Additional analysis, measurements and reporting energy usage (of equipment or production phases) was another frequently reported activity. In one of the enterprises participating in the research (polyester and woollen yarn manufacturer), additional energy efficiency indexes have been introduced (energy savings index, environmental benefits related with energy savings).

Another solution that is worth mentioning, introduced in 3 enterprises, was offering energy-saving products, including: boilers with supercritical parameters, energy-efficient windows with 5 or 6 chambers and construction materials, including foamed concrete (increasing thermal insulation efficiency of buildings), liquid anhydrite subfloor (increasing thermal conductivity) and concrete (reducing heating and cooling energy demand). Other activities aimed at improving energy efficiency included energy audits (3) and project energy efficiency assessment (2).

In total, four undertakings were subject to energy efficiency assessment (three in a paper manufacturing company and one in a cement and clinker manufacturing enterprise). All of them concerned heat recovery systems. Projects initiated in two enterprises (manufacturers of utility vehicles and construction materials) concerned the implementation of an energy management system according to ISO 50001 standard. One of the projects, run by the manufacturer of utility vehicles, would be continued.

6. Discussion

This article presents solutions implemented mainly in large and medium enterprises, which is determined by the structure of the analysed population. Specific actions performed by the analysed enterprises to improve their energy efficiency differed, depending on the products supplied by particular research participants. However, the analysis enabled specification of major groups of activities, namely: streamlining of manufacturing processes (with equipment and installations), modification or replacement of lighting systems, energy recovery, usage of renewable energy sources and modification or retrofitting of buildings along with technical systems and devices.

This means that the analysed Polish manufacturing enterprises most frequently employed solutions listed in the fundamental legal document concerning energy efficiency in Poland (Dz. U. 2016 poz. 831). It is also a cue for other manufacturing enterprises, that indicates the areas in which solutions should be sought in order to improve environmental performance.

What is worth noticing is the fact that among the solutions identified in this study were both expensive and time consuming activities (e.g., related with modernisation

or modification of installations used in the manufacturing process and factory buildings), as well as less expensive and easier tasks (also feasible for small and micro enterprises), e.g., training of employees, informative actions concerning environmental initiatives important for the organisation, additional systems to analyse and measure energy consumption, appointing an energy management group, gathering employees' proposals for improvement activities, modification of lighting systems or optimising washing and disinfection procedures.

As far as the analysis and measurement of energy consumption is concerned, a set of indexes to provide measurable data and help control energy consumption is worth considering. Organisations participating in the EMAS scheme are obliged to calculate and analyse environmental efficiency indexes on a regular basis.

However, the EMAS Regulation suggests using only one energy efficiency index. As seen in the case of one company from the analysed group, organisations are not restricted only to meet the EMAS requirements in this field, and can use their own set of indexes. This solution can be implemented in organisations with various activity profiles, also small and micro enterprises, with limited financial resources that would not allow taking more expensive initiatives.

The analysis also indicated that three large enterprises (manufacturers of utility vehicles and construction materials) conducted regular energy audits. However, as far as large organisations are concerned, it is a statutory obligation (Dz. U. 2016 poz. 831) rather than a voluntary bottom-up environmental initiative. The cases of three following analysed enterprises did not provide data to determine if energy audits had been conducted. It might be due to the lack of relevant information in their environmental statements, or the exemption from the statutory obligation following the EMAS scheme implementation, which entails an energy efficiency audit (Dz. U. 2016 poz. 831).

Another two large enterprises (cement/clinker and paper manufacturers) had conducted energy efficiency assessments, regarding heat recovery projects in each case. That type of audit, along with related White Certificates of energy efficiency, issued by the Chairman of the Energy Regulatory Office, serve as an additional support mechanism for organisations intending to take actions focused on the improvement of energy efficiency. They facilitate access to additional funds for completed modernisation which resulted savings in the consumption of electric energy, heat or earth gas.

A number Polish manufacturing enterprises participating in this study decided to implement energy recovery solutions. Using alternative fuels (waste) in the cement industry is worth noticing in this aspect. It is particularly beneficial due to the character of the cement clinker production process and firing equipment in use. The cement kiln recovers energy from alternative fuel that can be efficiently used in the clinker production process.

Additionally, waste is utilised, which can bring positive environmental results in at least two areas (energy efficiency and waste management). What is also worth considering, is using renewable energy. Several enterprises reported measurable indexes which confirmed that the used solutions could largely cover organisation's energy demand, and apart from that, were environmentally-friendly.

The activity of manufacturing enterprises is particularly important in the field of environmental protection, including energy efficiency improvement. Some of them can consider environmental aspects at the product development stage, to help their users protect the environment. In the case of the analysed enterprises, it concerned, among others: power engineering and chemical industry equipment, environmental protection devices, windows and construction materials.

However, other types of product can also help protect environment, not only in the energy efficiency aspect, but also in the area of emissions of airborne contaminants (e.g., utility vehicles). Particular importance of manufacturing enterprises can be attributed to their capability to offer product or technologies, help their users protect the environment, and also implement internal actions to reduce the negative impact, or increase positive impact on the environment.

Considering the small scale of previous research indicating specific solutions implemented by enterprises participating in the EMAS scheme, it is difficult to compare particular activities, However, we can identify two types of activities most frequently implemented to improve environmental performance. These include implementing or optimising technological processes considering environmental aspects and introduction of technical improvements within the existing plants or installations.

This type of activity has been performed by the Polish manufacturing enterprises participating in this research, as well as French and German companies, participating in previous studies. When comparing the outcomes of this study with previous research concerning energy efficiency improvement activities of various enterprises from Poland, it may be inferred that the type of initiatives taken in that field is quite similar within the whole spectrum of business activity.

This leads to a conclusion that exemplary solutions presented herein can be used not only in organisations with the same profile as those participating in the study. In one case, the reported project was quite innovative (fluidised bed boiler fired only with biomass), which confirms the outcomes of the previous research, indicating that EMAS scheme stimulates organisations to search for innovative solutions in the area of used technologies or products, etc.

As it has already been mentioned, the results of this study may supplement previous research on the environmental impact of EMAS implementation, providing specific examples of solutions implemented in order to improve energy efficiency of

manufacturing enterprises. A certain limitation of the research is the fact that data in environmental reports are not uniform, which makes them difficult to analyse. It is also difficult to determine if all or only selected activities were presented. However, the described analysis allowed to identify exemplary activities that could be implemented in enterprises of different size, with various profiles of activity (not only manufacturers), and also in different countries.

Additionally, certain solutions could also be used in other environmental areas, apart from energy efficiency. Beside that, some activities having significant impact in terms of energy efficiency, could be introduced in households. These include modification of lighting equipment, individual training and searching for information, using energy-efficient devices, renewable energy and also controlling energy consumption within the household.

7. Conclusions

The purpose of this paper was to present undertakings of Polish manufacturing enterprises participating in the EMAS scheme, implemented to improve their energy efficiency. The major benefit of the described study is the identification and presentation of exemplary activities that could inspire and be implemented in organisations with different size and profile of activity (not only manufacturing enterprises), in order to improve their performance in the energy consumption area.

The analysis of data presented in environmental statements (serving as the basis for the research method), is difficult and time consuming, due to the differences in the method of data presentation and document volume (usually several pages).

Therefore, systematisation and clear presentation of reported data should be particularly important for the management staff (seeking ideas for solutions to be used in their organisation), allowing to save time that would otherwise be spent on reading through these documents. The results of this study will also supplement the previous research concerning the EMAS system and the implementation of EU energy and climate policies.

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