European Research Studies Journal
Volume XXVIII, Issue 4, 2025

pp. 1534-1560

The Relationship between the Gender of Top Management and the Adaptation of Energy Management Activities in an Enterprise

Submitted 13/10/25, 1st revision 05/11/25, 2nd revision 26/11/25, accepted 10/12/25

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Abstract:

Purpose: *The study investigates whether and how the gender of top managers differentiates the impact of the drivers behind the adoption of energy management actions aimed at reducing emissions, waste, and pollution in enterprises.*
Design/methodology/approach: *Based on survey data collected by the World Bank , covering 9,485 firms across 12 countries in Southern Europe, two separate multivariate logistic regression models were estimated for companies led by women and those led by men, respectively.*
Findings: *The results confirm that innovation activity, R&D engagement, and the possession of international quality certificates significantly foster the implementation of energy management practices in both groups. However, the magnitude and direction of these effects differ by gender. Firms led by women are more strongly motivated by process innovations and certifications, while product innovations may have a negative impact on their energy-related actions. In companies headed by men, R&D plays a more influential role. Company size and competitive pressure further differentiate the likelihood of adopting energy management systems: quantitative competition is more relevant for male-managed firms, whereas qualitative competition matters more for female-led businesses.*
Originality value: *The article fills a research gap regarding the impact of gender diversity in top management on companies' propensity to implement measures to improve energy efficiency.*
Practical implications: *The findings underscore the significance of gender-diverse leadership in shaping sustainable energy strategies and highlight the need for tailored policy support that encourages environmental initiatives across various management profiles.*

Keywords: *Energy Management Systems (EnMS), gender, top management, logit modeling.*

JEL Classification: *O30, J16, Q40.*

Paper type: *Research article.*

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1. Introduction

Growing climate requirements, regulatory pressures, and widespread digitization make energy management systems (EnMS) and ISO 50001 implementation important pillars of corporate transformation (Fuchs *et al.,* 2018; 2020; Damasceno *et al.,* 2024).

Empirical research shows that energy monitoring and management systems increase the quantitative and qualitative scope of energy performance improvement actions (EPIAs) (Marimon and Casadesús, 2017; Herce *et al.,* 2021; Šebo *et al.,* 2023).

Their effectiveness depends, among other things, on the maturity of processes, employee competence, and the capacity for knowledge absorption (Solnørdal and Thyholdt, 2019; Jin *et al.,* 2021; Kocot *et al.,* 2024).

At the same time, the literature on corporate governance suggests that the composition and characteristics of top management affect companies' environmental engagement and strategic choices (Onjewu *et al.,* 2024). This means that the demographic and social characteristics of leaders, including gender, may imply the adaptation of companies' energy management activities.

Based on a review of the literature on the subject, it can be concluded that there is a research gap regarding the impact of gender diversity in top management on companies' propensity to implement measures aimed at improving energy efficiency.

Previous studies have rarely comprehensively analyzed these relationships, combining aspects of man magement structure with technological, organizational, and market conditions, such as innovation, research and development activities, quality certification, and competitive pressure.

The research gap, therefore, lies in the lack of integrated analyses that simultaneously address both internal and external factors influencing the adoption of pro-energy measures, depending on the gender of managers.

This paper aims to fill this gap by empirically verifying the research hypotheses proposed in the paper (H0–H4) and analyzing the mechanisms shaping the implementation of solutions conducive to effective energy management in enterprises.

The primary objective of this article is to determine whether and how the gender of top management influences the impact of the variables considered on the adaptation of enterprise activities within energy management aimed at reducing emissions, waste, and pollution.

The structure of the paper includes the following sections: 1) literature review, 2) materials and methods, 3) research results, 4) discussion, and final conclusions.

2. Literature Review

Energy management within a company is a crucial element of the strategy for enhancing energy efficiency, reducing operating costs, and implementing the concept of sustainable development (Schulze *et al.,* 2016; Xavier *et al.,* 2024; Thollander, 2025). It involves monitoring, controlling, and optimizing energy consumption through the use of appropriate strategies, processes, and tools.

Adaptation, mainly through systematic actions in this area, enables the reduction of pollutant emissions and waste, as well as the minimization of negative environmental impact. At the same time, it contributes to the long-term growth of organizational efficiency and the company's sustainable competitiveness in conditions of dynamic economic changes and increasing regulatory requirements (Leszczyńska and Lee, 2016; Chu *et al.,* 2017; Fuchs, 2020; Lui *et al.,* 2021; Asgari *et al.,* 2025).

Measures aimed at reducing emissions and pollution include, among others, the implementation of innovative energy strategies, such as the use of renewable energy sources (e.g., biomass), which enable a significant reduction in CO_2 emissions by up to 85% compared to traditional fuels (Borowski, 2022).

Companies that adapt their activities to meet environmental requirements, including the principles of the circular economy, contribute to achieving climate goals and improving air quality (Yang *et al.,* 2022; Unegg *et al.,* 2023). The integration of energy management with waste management (e.g., waste-to-energy technologies, recycling) not only reduces the amount of waste sent to landfills but also recovers energy and raw materials, resulting in lower emissions and greater resource efficiency (Hernández-Romero *et al.,* 2024).

In addition, companies that implement energy management systems and invest in energy-efficient technologies achieve better results in terms of sustainable development. Thanks to the innovations they implement, they improve their operational efficiency and build a positive social image (Ali *et al.,* 2019; Bielski *et al.,* 2021).

As already mentioned, energy management and standardization, in the form of ISO 50001 and EnMS systems, are an essential component of companies' transformation towards energy efficiency and emission reduction. Empirical analyses indicate that the presence of developed energy monitoring and management systems significantly increases the number and quality of energy performance improvement actions (EPIAs), with this effect being particularly pronounced in industry and strengthening over time as processes are improved (Herce *et al.,* 2021; Šebo *et al.,* 2023).

This is also confirmed by other sources of motivation, such as the implementation of ISO 50001 standards. These are the result of the need to reduce energy costs, compliance requirements, growing stakeholder expectations, and the pursuit of competitive advantage. It is essential to emphasize that top management plays a crucial role in these initiatives (Fuchs, 2020; Marimon and Casadesús, 2017).

The literature on the subject emphasizes that the effectiveness of energy measures is determined not only by the scope of the techniques and tools implemented, but also by the manner in which they are implemented and the personal commitment of the team to the entire process. EnMS practices are based on mature quality and environmental management systems (e.g., compliant with ISO 9001/14001 standards), which support the development of a culture of continuous improvement and organizational learning (Tarí *et al.,* 2012).

From an operational perspective, guidelines for implementation and tools that help reduce organizational and cost barriers are of significant importance. Research conducted in Europe and beyond suggests that the effectiveness of the implementations discussed is strongly dependent on organizational and market conditions, which vary according to the size and nature of the companies. In the small and medium-sized enterprise (SME) sector, organizational barriers (lack of time, shortages of resources and skills) predominate, while the main drivers are cost reduction, participation in energy efficiency networks, and strong leadership (Jalo *et al.,* 2021).

In larger enterprises, on the other hand, economies of scale and better access to capital favor the implementation of energy recovery technologies (ERT) and the implementation of more complex programs (Šebo *et al.,* 2023). Similarly, the results of analyses of the motivations driving the implementation of energy management systems confirm that as organizations mature, they shift their focus from achieving quick savings to strategic energy learning and integration with ESG goals (Fuchs, 2020; Marimon and Casadesús, 2017).

The starting point for an organization's transformation towards adaptive knowledge utilization is absorptive capacity, understood as the propensity and competence to acquire, assimilate, and utilize new solutions. Research on industrial companies indicates that higher absorptive capacity (R&D involvement, staff qualifications, cooperation with science and competitors) increases the likelihood of implementing innovations and energy management programs (Solnørdal and Thyholdt, 2019), while the development of employee competencies strengthens the integration of green energy technologies and improves energy performance (Kocot *et al.,* 2024).

Data plays a crucial role at the intersection of technology and management: green innovations bring greater benefits when accompanied by HR practices that foster learning and the utilization of analytics, including Big Data (El-Kassar and Singh, 2019). In this context, product innovations expand the scope of low-energy solutions and facilitate the implementation of efficiency practices, while process innovations enable a permanent reduction in unit energy consumption through standardization and operational improvements (Gerstlberger, 2014; Tarí *et al.,* 2012; Fuchs, 2020).

The innovative perspective in energy management is closely tied to the issues of economic and environmental efficiency. Research indicates that investments in research and development (R&D) in the field of energy savings lead to improved CO_2 emission efficiency, with these effects potentially spreading spatially to neighboring regions (Chen *et al.,* 2023; Abudureheman and Yiming, 2024; Hai and Duong, 2024; Ahmed and Elfaki, 2024).

At the level of energy companies, the relationship between green R&D expenditure and financial performance is non-linear, with positive results occurring within certain intensity ranges, while excessive investment may worsen economic indicators in the short term (Song *et al.,* 2023).

The intensity of energy management system implementation is also influenced by central and regional regulations that set the direction and pace of innovation in the energy efficiency sector. Policies on energy saving regulations, standards, and certification are important incentives for investment and the implementation of pro-energy innovations (Yu, 2025).

Factors such as corporate governance and ownership structure are also important for business decisions in this area. European studies indicate that foreign ownership and board diversity promote greater environmental engagement (Calza *et al.,* 2016, Lagasio and Cucari, 2019; Onjewu *et al.,* 2024; Erben *et al.,* 2024).

Similarly, in the Chinese context, ownership identity influences the level of adaptation of environmental management systems (Wang *et al.,* 2023). Decisions made by top management—regarding the structure of R&D investments, the type of innovation, and the certification path—are a key mechanism for translating strategy into concrete pro-energy actions (Gerstlberger, Knudsen, and Stampe, 2013; Huang and Chen, 2020; Iqbal *et al.,* 2022).

Quality certificates and EnMS systems, including ISO 50001, provide a management framework that includes policy, objectives, indicators, and energy audits. The implementation of these systems stabilizes energy performance and promotes an increase in the number and quality of improvement measures (Fuchs, 2020; Marimon, 2017; Tarí, 2012; Herce, 2021). CO_2 emission monitoring and control systems strengthen the motivation to adopt low-carbon solutions and incorporate climate goals into investment decisions (Yu, 2025; Fuchs, 2020; Herce, 2021).

The effectiveness of these systems depends largely on human resources, in particular on the level of qualifications of those responsible for their implementation and maintenance. Technical, leadership, and analytical skills are of key importance in this respect, as they determine the effectiveness of the measures taken. A high level of qualifications facilitates the adoption of energy-saving technologies and enhances the effectiveness of their implementation (Solnørdal, 2019; Millán *et al.,* 2020; Carlander and Thollander, 2022; Samour *et al.,* 2024; Nguyen, 2024; Kocot, 2024).

In turn, participation in international markets increases pressure to meet customer requirements and environmental standards, promoting the adoption of EnMS and practices that reduce the carbon footprint (Wang *et al.,* 2023; Onjewu *et al.,* 2024).

In addition to human resources, the profile of a company's activities is also a significant determinant of the varying effects of implementing an energy management system. In energy-intensive sectors such as industry, the return on investment in EnMS is faster, while in services and construction, the integration of standards and operational optimization is more important (Iqbal *et al.,* 2022; Šebo, 2023). Large companies are more likely to implement advanced efficiency systems and technologies, while SMEs benefit from simpler interventions and network support (Jalo, 2021; Šebo, 2023).

The origin of capital is also important for the implementations discussed. Companies with foreign capital participating in global value chains are more likely to use advanced energy management practices and EnMS systems due to pressure from international investors and technology transfer (Onjewu *et al.,* 2024; Wang *et al.,* 2023).

The level of competition in the market environment of companies is also an important factor shaping the intensity of energy management system implementation. An increase in the number of competitors generates stronger pressure, motivating companies to implement EnMS systems and other energy efficiency practices more quickly in order to improve cost efficiency and maintain a market advantage.

The greater the number of competitors in the sector, the higher the likelihood of implementing energy management systems and environmentally friendly practices, which is particularly evident in highly competitive industries. Conversely, with few competitors, the pressure to adapt is lower, and the pace and scope of energy solution implementation remain limited (Chu *et al.,* 2017; Lui *et al.,* 2021; Jakaša *et al.,* 2022).

An additional factor differentiating the degree of adaptation in energy management activities is the import of raw materials, which increases companies' sensitivity to risks related to supply security and the carbon footprint of transportation. Companies that are strongly integrated into global value chains (GVCs) are more likely to implement sustainable energy practices, as they remain under the influence of regulatory pressure and the expectations of international partners (Huang, 2020; Khoshnevisan *et al.,* 2022; Agostino *et al.,* 2023; Osabohien *et al.,* 2024).

As a result, effective management of raw materials and energy is becoming strategically important in the context of growing import dependence and global raw material challenges.

The effectiveness of energy management systems is the result of the interaction of technological, organizational, and institutional factors, including innovation, staff competence, corporate governance quality, emissions control, and integration into global value chains. Consistent management of these areas promotes sustainable improvement in energy efficiency and strengthens the competitiveness of enterprises.

The literature emphasizes the complementarity of three dimensions of effective EnMS implementation: process formalization (including ISO 50001, audits, and monitoring), organizational and human capabilities (competence and learning culture), and strategic conditions (corporate governance and market pressure).

This approach explains the varying pace of adaptation of energy measures in different companies and sectors (Tarí *et al.,* 2012; Marimon and Casadesús, 2017; Jēkabsone *et al.,* 2020; Fuchs, 2020; Guo 2022; Šebo, 2023; Gomes *et al.,* 2024).

The literature review also points to the need for further research on the role of senior management characteristics, including gender diversity, as moderating factors in the relationships between innovation, certification, and the adoption of energy management measures.

3. Materials and Methods

Empirical data for this article were sourced from the World Bank (collected April 2023–March 2025), covering 2022–2025 and focusing on companies from southern European countries. Table 1 lists these countries, their company counts, and geographical distribution.

Table 1. *List of countries from which the companies included in the study originated*

No	Country	Number of companies	Structure [in %]
1	Portugalia	1 007	10,6
2	Hiszpania	1 456	15,4
3	Włochy	1 216	12,8
4	Chorwacja	480	5,1
5	Macedonia	354	3,7
6	Bośnia i Hercegowina	360	3,8
7	Słowenia	402	4,2
8	Serbia	502	5,3
9	Grecja	598	6,3
10	Rumunia	971	10,2
11	Bułgaria	723	7,6
12	Turcja	1 416	14,9
Total		9 485	100

Source: *Own study based on data from the World Bank.*

The structure of the surveyed companies in terms of their size and the gender of their top management is presented in the following Table 2.

Table 2. *Structure of the surveyed companies in terms of their size and gender structure of senior management*

Gender of top manager Size of of company	Female	Male	Total	Structure
Mikro	501	1659	2160	22,8%
Small	689	3399	4088	43,1%
Medium	310	2254	2564	27%
Large	70	603	673	7,1%
Total	1570	7915	9 485	100%
Structure	16,6%	83,4%	100%	

Source: *Own study based on data from the World Bank.*

The selection of entities for the survey involved stratified random sampling, in which the population of enterprises from the surveyed countries was first divided into nonoverlapping groups, called strata. Secondly, respondents for the study were randomly selected within each stratum. The World Bank typically uses three levels of stratification simultaneously, which include: business sectors, company size, and country regions.

The business sectors included in the survey covered manufacturing (ISIC 4.0 codes: 10-33) and services (ISIC 4.0 codes: 41-43, 45-47, 49-56, 58, 61, 62, 69-75, 79, 95). EU country regions were selected based on NUTS 1 statistical divisions, while for non-EU countries, the selection was based on the administrative divisions of those countries.

The calculations in the next part of the article were performed using multivariate logit modeling. The use of this method was dictated by the binary nature of the dependent variable (0 or 1). This variable concerned the company's implementation over the last three years of procedures, technical and organizational solutions, and other energy management measures aimed at reducing emissions, waste, and pollution. If such activities occurred within the company, then this variable was assigned a value of 1. In the absence of such activities, the dependent variable was assigned a value of 0.

For the independent variables, their selection for modeling was based on a review of the relevant literature. As a result of this review, four groups of independent variables were accepted for the study. The first group of variables included the occurrence of broadly understood innovative activity in the company, such as: product and process innovations, the company's R&D activities, the acquisition of international quality certificates, and the purchase of new or used machinery, vehicles, and equipment.

The second group of variables described the market situation of the company, with particular emphasis on: sales range (local, national, international), the number of competitors known to the company (broken down into: no known competitors, 1 to 7 identified competitors, 8 to 20 competitors, more than 20 known competitors), the dynamics of competition in the sector served by the company (increase and decrease in competition or no change in competition in the sector).

The variables included in this group also took into account the export of products or services offered by the company and the import of raw materials necessary for the manufacture of finished products. The third group of variables were those that constitute the basic characteristics of the company, i.e., they determine: the size of the company in terms of the number of employees (micro, small, medium, and large companies); the form of owners-hip of the company (domestic, foreign, and mixed companies); the type of activity conducted (industrial, construction, or service activities).

The last group of variables concerned personnel issues in the company and its approach to environmental issues. Within this group, variables were identified concerning staff qualifications (high, medium, low), training in the company, and the monitoring of CO_2 emissions into the atmosphere.

The result of logit modeling is the determination of odds ratios, which provide information about the probability of the dependent variable occurring. If the odds ratios were greater than one, it meant that the probability of the expected event occurring for a given independent variable was higher than the probability of that event occurring for the other independent variables in the same group of variables. If the odds ratio was less than 1, the interpretation of the probability was reversed.

Statistica 13 software (TIBCO Software Inc., Palo Alto, CA, USA, 2017) was used for the analyses. It should be emphasized that not all variables included in the study met the condition of statistical significance. The variables used in the estimation process in the model are presented in Table 3.

Table 3. *Definitions of variables used in equations*

Zmienne	Opis
Dependent variable	
Sys_EnMS_Wom	1: occurrence of energy management activities aimed at reducing emissions, waste, or pollution in companies managed by women; 0: no such activities;
Sys_EnMS_Men	1: occurrence of energy management activities aimed at reducing emissions, waste, or pollution in companies managed by men; 0: no such activities;
Independent variables	
	Broadly understood manifestations of innovative activity:
Inn_prod	1: occurrence of product innovations; 0: no such innovation;
Inn_proc	1: occurrence of process innovations; 0: no innovation of this type;

B+R	1: R&D activities are present; 0: no such activity;
QC	1: acquisition of an international quality certificate by the company; 0: no such certificate;
Invest_fix_a	1: investment in machinery, equipment, and vehicles; 0: no such investments;
	Market situation of the company
Sal_loc	1: local sales coverage; 0: sales range other than local;
Sal_nat	1: national sales coverage; 0: sales coverage other than national;
Sal_inter	1: international sales coverage; 0: sales coverage not extending beyond national borders;
Num_com_0	1: no known competitors; 0: number of competitors is known;
Num_com_1-7	1: number of competitors between 1 and 7; 0: number of competitors other than 1-7;
Num_com_8-20	1: number of competitors between 8 and 20; 0: other number of known competitors;
Num_com_over 21	1: number of known competitors above 20; 0: number of known competitors below 20;
Inc_comp	1: increase in competition in the sector; 0: no increase in competition in the sector;
Dec_comp	1: decrease in competition in the sector; 0: trends other than a decline in competition in the sector;
Stab_comp	1: stable competition in the sector; 0: no stabilization of competition in the sector;
Exp	1: Export of goods; 0: no export of goods
Imp	1: Import of raw materials; 0: no import of raw materials
	Characteristics of the enterprise (size, form of ownership, and type of activity)
micro	1: micro enterprise; 0: enterprise larger than micro;
small	1: small enterprise; 0: other than small enterprise;
medium	1: Medium-sized enterprise; 0: other than medium-sized enterprise
large	1: large enterprise 0: smaller than large enterprise
dom_cap	1: domestic form of enterprise ownership; 0: other than domestic form of enterprise ownership
for_cap	1: foreign form of enterprise ownership; 0: other than foreign form of ownership
mix_cap	1: mixed form of ownership; 0: other than mixed form of enterprise ownership;
NACE_C	1: industrial activity of the enterprise; 0: non-industrial activity of the enterprise;
NACE_F	1: company in the construction sector; 0: company from a sector other than construction;
NACE_G-S	1: company in the service sector;

	0: company from a sector other than services;
	Personnel and environmental issues:
high_qual	1: highly qualified staff;
	0: low or medium staff qualifications;
med._qual	1: medium qualifications of personnel;
	0: high or low staff qualifications;
low_gual	1: low staff qualifications;
	0: medium or high staff qualifications;
train	1: The company organizes training for its employees;
	0: no training for employees;
CO_2	1: the company monitors CO_2 emissions;
	0: the company does not conduct this type of monitoring;

Source: *Own work.*

$$Sys\_EnMs\_Wom = \alpha_0 + \alpha_1 Inn\_prod_i + \alpha_2 Inn\_proc_i + \alpha_3 B{+}R_i + \alpha_4 QC_i + \alpha_5 CO2_i + \alpha_6 low\_gual_i + \alpha_7 high\_qual_i + \alpha_8 Sal\_loc_i + \alpha_9 NACE\_F_i + \alpha_{10} Inc\_comp_i + \alpha_{11} micro_i + \alpha_{12} medium_i + u_i \tag{1}$$

$$Sys\_EnMS\_Men = \alpha_0 + \alpha_1 Inn\_prod_i + \alpha_2 B{+}R_i + \alpha_3 QC_i + \alpha_4 high\_qual_i + \alpha_5 Num\_com\_1\text{-}7_i + \alpha_6 Num\_com\_8\text{-}20_i + \alpha_7 Imp_i + \alpha_8 dom\_cap_i + \alpha_9 NACE\_F_i + \alpha_{10} micro_i + \alpha_{11} small_i + \alpha_{12} medium_i + \alpha_{13} large_i + u_i \tag{2}$$

In the context of the above literature review, the research hypothesis was formulated as follows:

H0: *The gender of top management has a different impact on energy management activities in a company aimed at reducing emissions, waste, or pollution.*
For the purposes of verifying the main hypothesis, partial hypotheses were also formulated:
H1: *Innovative activity, R&D, and international quality certificates have a positive impact on energy management activities in a company aimed at reducing emissions, waste, or pollution.*
H2: *Innovative activity, international quality certificates, and R&D have a stronger impact on the adaptation of energy management activities in companies where top management is represented by women than by men.*
H3: *As the size of a company increases, so does the likelihood of energy management activities aimed at reducing emissions, waste, or pollution.*
H4: *As competition increases, so does the likelihood of energy management activities in a company aimed at reducing emissions, waste, or pollution.*

4. Results

The calculations resulted in two logit models that characterize the impact of various independent variables on the occurrence of energy management activities aimed at reducing emissions, waste, or pollution. The first model was established for companies where women held top management positions, while the second was established for companies where men held top management positions. These models are presented in Tables 4 and 6.

Table 4. *Determinants influencing energy management activities aimed at reducing emissions, waste, or pollution in companies where women hold top management positions*

Variable	OR (95% CI: LL - UL)
Inn_proc	1,99 *** (1,35 – 2,94)
Inn_prod	0,53 ** (0,32 – 0,89)
B+R	1,57 ** (1,06 – 2,33)
QC	3,26 *** (2,56 – 4,15)
CO_2	6,21 *** (4,26 – 9,05)
Low_gual	1,44 ** (1,03 – 2,00)
High_gual	0,75* (0,57 – 1,00)
Sal_rande_loc	0,74 ** (0,58 – 0,94)
NACE_F	0,48*** (0,29 – 0,79)
Inc_comp	1,23 * (0,98 – 1,55)
small	1,46*** (1,13 – 1,89)
medium	1,40 * (1,00 – 1,99)
Sample	1 570
Likelihood ratio	387,31
AIC	1795,46
BIC	1865,07
R^2 Cox-Snell	0,22
R^2 Nagelkerk's	0,29
ROC curve	0.77
Hosmer-Lemeshow	
chi-square	2,64
p-value	0,95

where:
**** - significance level below 1%, ** - significance level between 1-5%, * - significance level in the range of 5-10%.*
Source: *Own study based on data from the World Bank.*

The above model shows that companies managed by women with a CO_2 emission control system are more likely to implement energy management measures to reduce emissions, waste, or pollution. For this group of companies, the likelihood of energy management activities is more than six times higher than in companies that do not have such a CO_2 control system.

The occurrence of energy management activities is also strongly and positively influenced by the company's possession of international quality certificates. In such cases, the likelihood of these activities occurring is more than three times higher than in companies that do not have such certificates.

Certain forms of innovative activity, such as process innovation and R&D, also have a positive impact on a company's energy management activities. In the case of companies where process innovations occur, the likelihood of undertaking energy management activities is almost twice as high as in companies where such innovative activity is not present. For companies that conduct R&D activities, the likelihood of undertaking energy management activities is 57% higher than for companies that do not conduct R&D activities.

In companies where a woman holds a top management position, small and medium sized companies also experience a positive impact on energy management activities. In companies of this size, the chances of undertaking activities related to the energy management system are 40 to 46% higher than in companies of other sizes.

A similar likelihood of energy management activities occurring is found in companies where low-skilled employees predominate. In this group of companies, the likelihood of activities related to energy management is 44% higher than in companies where medium or high-skilled employees predominate.

The last factor identified in this article that has a positive impact on energy management activities is strong competition in the sector in which companies managed by women operate. When competition in the sector becomes increasingly fierce, the likelihood of energy management activities occurring is 23% higher than in companies operating in sectors not exposed to increased competition.

In the model discussed, which identifies the conditions affecting energy management activities in companies managed by women, there are also determinants that negatively affect the above-mentioned variable.

The variable that has the strongest negative impact on the occurrence of energy management activities is the company's business activity related to NACE F – construction. In companies engaged in this type of activity, the likelihood of energy management activities occurring is 52% lower than in companies with a different business activity.

A less obvious conclusion can be drawn from the analysis of another variable, which concerns product innovation. It turned out that in companies that implemented product innovations, the likelihood of energy management activities occurring is 47% lower than in companies that did not carry out this type of innovative activity. It is therefore clear that different forms of innovation have different effects on energy management activities in companies aimed at reducing emissions, waste, or pollution.

The last two barriers concern highly qualified personnel and companies serving only the local market. In the first case, the likelihood of energy management activities occurring is 25% lower than in companies where medium or low-skilled employees predominate.

In the second case, the likelihood of such activities occurring is 26% lower than in companies that serve larger markets, i.e., national or international markets.

To assess the accuracy of assigning individual observations to the appropriate categories related to the occurrence or non-occurrence of energy management activities, Table 5 presents a case classification matrix.

Table 5. *Matrix of case classification*

Real Belonging of Objects	Classification of Objects Based on the Logit Model		
	Predicted: 0	Predicted: 1	Correct (%)
Observed: 0	669	178	79,27
Observed: 1	281	442	60,92

Source: *Own calculation based on questionnaire research.*

The above classification matrix shows that the calculated model explains slightly over 79% of observations concerning the absence of energy management activities, while observations concerning the occurrence of energy management activities are explained in almost 61% of cases. This means that the obtained model was slightly more effective in recognizing cases classified as "0", i.e., those with no energy management activities.

To assess the model's ability to correctly distinguish between cases belonging to classes "1" and "0," the ROC curve and AUC coefficient were presented.

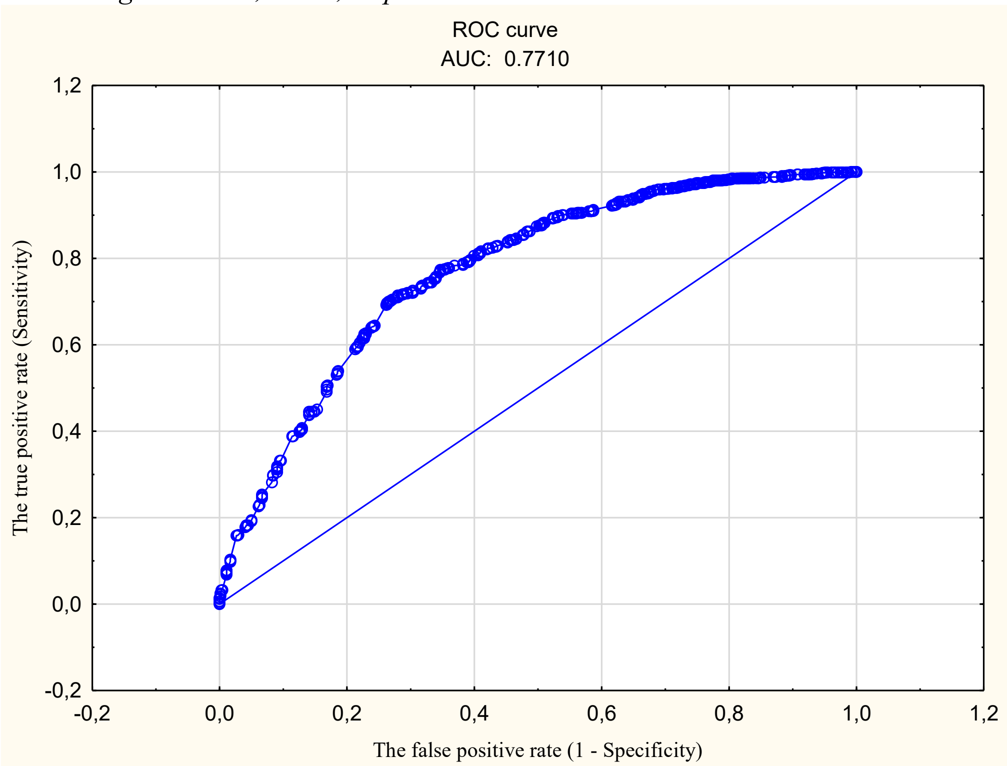
The obtained AUC value of 0.77 indicates the good quality of the model and its ability to distinguish between observations belonging to different classes. A result in the range of 0.7 to 0.8 indicates effective identification of positive and negative cases.

The following Table 6 presents a model illustrating the impact of selected variables on energy management activities in companies where the top managers were men.

The model presented in the table above indicates that the size of the entities is the most significant factor in determining the occurrence of energy management activities aimed at reducing emissions, waste, or pollution in companies managed by men. The likelihood of such activities occurring increases with the size of the enterprise, reaching 6.7 times higher in the largest entities.

The possession of international quality certificates by a company also has a significant impact on its energy management activities. In such a situation, the chances of undertaking the afore-mentioned activities are 158% higher than in companies without international quality certificates. The implementation of R&D projects by a company has a slightly weaker impact on the occurrence of the discussed activities. In such a situation, the chances of undertaking energy management activities are more than twice as high as in companies that do not carry out R&D activities.

Figure 1. *ROC curve for a model describing the determinants influencing the occurrence of energy management activities in companies managed by women aimed at reducing emissions, waste, or pollution*



Source: *Own work*

Table 6. *Male top managers and expenditure on EnMS*

Variable	OR (95% CI: LL – UL)
Inn_proc	1,90 ** (1,67 – 2,15)
B+R	2,04 *** (1,75 – 2,38)
QC	2,58 *** (2,33 – 2,87)
high_qual	0,55 ** (0,49 – 0,61)
Num_com_1-7	1,28 *** (1,14 – 1,44)
Num_com_8-20	1,39*** (1,18 – 1,64)
Imp	1,21 *** (1,06 – 1,36)
dom_cap	0,58 *** (0,49 – 0,69)
NACE_C	1,26*** (1,14 – 1,39)
micro	4,00 *** (2,31 – 6,92)
small	4,55*** (2,66 – 7,80)
medium	5,38 *** (3,16 – 9,17)
large	6,73 *** (3,93 – 11,51)
Sample	7 915
Likelihood ratio	1520,68
AIC	9406,17
BIC	9503,86

R^2 Cox-Snell	0,17
R^2 Nagelkerk's	0,23
ROC curve	0.74
Hosmer-Lemeshow Chi-square p-value	 6,48 0,59

Source: *Own study based on data from the World Bank.*

The implementation of innovative process-related projects also has a positive impact on a company's undertaking of energy management activities. The occurrence of in a company implementing product innovations means that the chances of undertaking energy management activities are 90% higher than in entities that do not implement product innovations.

The growing number of entities that compete with the surveyed company also has a stimulating effect on the occurrence of energy management activities. With a significant number of competitors (8 to 20), the chances of energy management activities occurring are 39% higher than in companies with fewer competitors.

The type of activity carried out, which relates to industrial activity, also has a positive im-pact on the implementation of energy management measures. The likelihood of energy management measures being implemented in industrial companies is 26% higher than in companies from other sectors of the national economy, such as construction or services.

The last determinant that positively influences the implementation of energy management measures by a company where the top manager is a man is the import of raw materials necessary for producing finished products.

When a company imports raw materials for the production of finished products, the likelihood of undertaking energy management activities is 21% higher than in companies that do not import raw materials from abroad.

In the model presented in Table 6, two variables had a disincentive effect on energy management activities. The first variable concerned the high qualifications of the staff, while the second was related to the origin of the company owners.

In the case of companies that employed highly qualified staff, the likelihood of implementing energy management measures was as much as 45% lower than in companies where the majority of staff had medium or low qualifications.

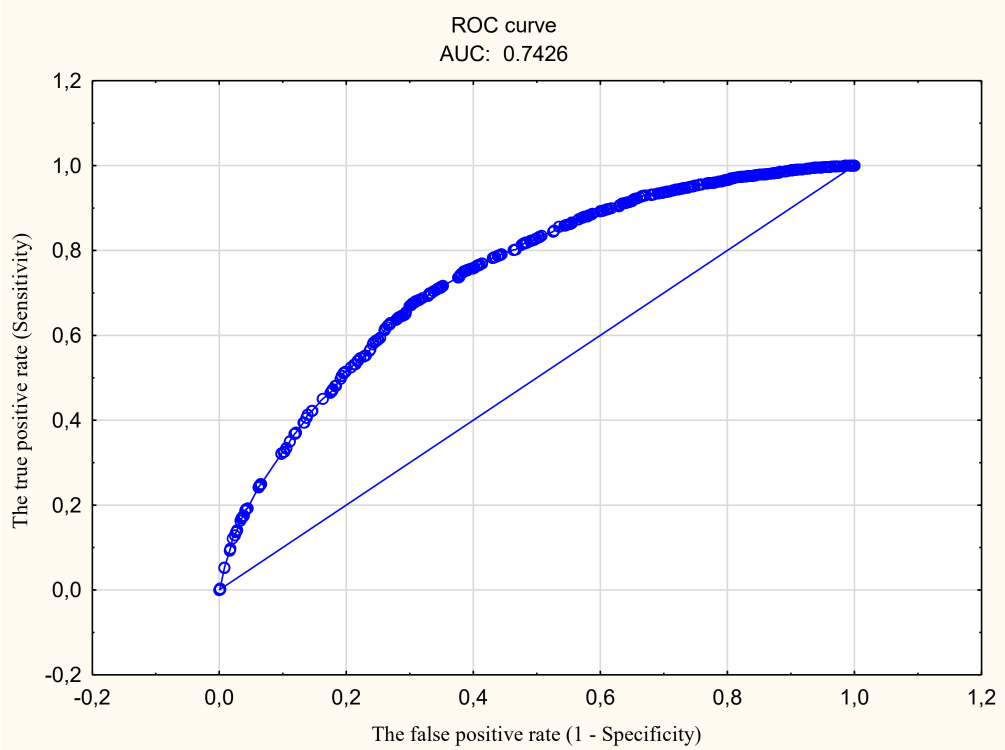
On the other hand, the likelihood of energy management activities being undertaken in companies owned by domestic entities is 42% lower than in companies where foreign entities have at least a minimum share.

Table 7. *Matrix of case classification*

Real Belonging of Objects	Classification of Objects Based on the Logit Model		
	Predicted: 0	Predicted: 1	Correct (%)
Observed: 0	3348	1019	76,7
Observed: 1	1454	2101	59,1

Source: *Own calculation based on questionnaire research.*

Figure 2. *ROC curve for a model describing the determinants influencing the occurrence of energy management activities in companies managed by men aimed at reducing emissions, waste, or pollution*



Source: *Own work.*

The obtained AUC value of 0.74 indicates good model quality and the ability to distinguish between observations belonging to different classes. A value in the range of 0.7 to 0.8 indicates effective identification of positive and negative cases.

5. Discussion and Conclusion

The implementation of solutions aimed at reducing energy consumption is of significant importance in the context of achieving sustainable development goals and the energy transition of enterprises. Understanding the factors that favor the adaptation of energy management measures is, therefore, a key element in building the competitiveness and resilience of organizations in the face of growing climate and regulatory requirements.

The statistical study conducted in this work, preceded by an in-depth analysis of the literature on the subject, enabled the authors to empirically verify the research hypotheses adopted in the work and assess the factors that determine the phenomenon under study. The results obtained enabled the identification of a relationship between the organizational characteristics of companies and their commitment to reducing emissions, waste, and pollution.

The results of the analyses confirmed that, regardless of the gender composition of a company's top management, the implementation of process innovations has a positive impact on energy management activities. This conclusion is consistent with the findings of Introna *et al.* (2024), who pointed out that the integration of Industry 4.0 and 5.0 innovations supports the development of advanced energy management systems.

Similar results were obtained by Borowski (2021) and Segun-Falade *et al.* (2024), demonstrating that process innovations enhance the energy and environmental efficiency of companies. The study's results revealed that in companies managed by women, product innovations hurt energy management activities. This may be because these innovations are more focused on market, social, or aesthetic aspects, rather than on the energy and environmental efficiency of products.

This conclusion aligns with the views presented by Gerstlberger *et al.* (2014), who argued that not all forms of product innovation lead to increased energy efficiency, particularly when the priority is the functional and social characteristics of new products rather than their environmental characteristics.

The results also confirmed that conducting research and development (R&D) has a positive impact on the development of energy management activities. This result is consistent with the conclusions of Serrano-García *et al.* (2023), who emphasized that the development of technological competencies and green technologies through R&D activities contributes to improving energy efficiency and the overall environmental performance of companies.

The study confirmed that the possession of international quality certificates (such as ISO 9001 or ISO 14001) by companies promotes the development of energy management activities.

This result is consistent with the findings of Tarí, Molina-Azorín, and Heras (2012) and Haddaden and Altarazi (2024), who demonstrated that these certificates support the implementation of environmental management systems, resulting in improved energy and environmental performance.

Except for product innovation in women-managed companies, the results confirm hypothesis H1, which posits that innovation, R&D, and international quality certifications have a positive impact on energy management activities in companies that are aiming to reduce emissions, waste, and pollution.

The analysis showed that in companies where the top management is female, the impact of process innovation on energy management activities is more substantial than in companies managed by men. This result confirms the conclusions of Kuzey *et al.* (2022), who pointed out that gender diversity on boards promotes pro-environmental initiatives and greater environmental sensitivity.

The results of this study therefore confirm hypothesis H2, which posits that the innovative activity of companies has a more substantial impact on the adaptation of energy management activities in companies led by women.

In addition, it was found that the impact of quality certificates on energy management activities is more substantial in companies managed by women than in those managed by men. This result suggests that women leaders are more likely to perceive formal quality standards as a tool that supports sustainable development and transparency of environmental activities.

The analysis revealed that R&D activities have a more substantial impact on energy management activities in companies led by men than in those led by women. This may be due to different approaches to technological investments and diverse innovation strategies—men tend to focus more on technical and efficiency aspects.

At the same time, women place greater emphasis on organizational and social innovation. This result indicates that the leadership profile and decision-making structure of the company partly determine the effectiveness of R&D activities in the energy context.

The above conclusions regarding international quality certificates partially confirm Hypothesis H2, which posits that international quality certificates and process innovations have a more substantial impact on energy management in companies with female management, while R&D activities have a stronger impact in companies with male management.

The implementation of solutions to reduce energy consumption is important in the context of achieving sustainable development goals and the energy transition of companies. Understanding the factors that favor the adaptation of energy management activities is, therefore, a key element in building the competitiveness and resilience of organizations in the face of growing climate and regulatory requirements.

The results of available studies suggest that larger companies with greater financial resources and, consequently, better-developed technological and human resources are more willing to invest in energy management systems (EnMS) and ISO 50001 certification. Economies of scale and organizational maturity favor the implementation of comprehensive pro-energy solutions and reductions in emissions.

Meanwhile, SMEs tend to implement simpler efficiency measures, which are mainly cost-driven, explaining their moderate level of activity in this area (Šebo, 2023; Jalo *et al.,* 2021; Fuchs, 2020). Similar conclusions were also drawn from the empirical study conducted in this work, particularly regarding companies managed by men.

Logit models indicate that in companies where top management is represented by men, the likelihood of implementing pro-energy measures increases significantly with company size, reaching up to 6.7 times the probability in large companies compared to other size classes.

In companies managed by women, this relationship is also positive, although the strongest effect was observed in small and medium-sized enterprises, where the likelihood of implementing such measures increased by 40-46%. This relationship is inversely proportional; i.e., as the size of the company increases, the likelihood of implementing pro-energy measures decreases. These observations confirm hypothesis H3 in the case of companies managed by men, while the results of the analysis do not confirm it in the case of companies managed by women.

When considering the impact of competition intensity on the phenomenon under study, an analysis of the available literature suggests that competitive pressure serves as a stimulus to enhance energy efficiency, reduce costs, and establish a market advantage. Companies operating in a more competitive environment are more likely to implement energy and environmental innovations, viewing them as integral to their brand and ESG strategy.

Especially in industrial and export industries, energy management is becoming an instrument for increasing international competitiveness (Chu *et al.* 2017; Fuchs, 2020; Lui *et al.,* 2021; Onjewu *et al.,* 2024). Similar observations are also made in an empirical study, with reservations regarding the differences between the analyzed groups of companies.

In companies where top management was represented by women, increased competition in the sector increased the likelihood of implementing energy measures by 23%. In contrast, in companies managed by men, a larger number of competitors (8–20) increased the likelihood of such measures being implemented by 39%. The above arguments therefore confirm Hypothesis 4, which states that: H4 - As competition increases, so does the likelihood of energy management measures being implemented in a company with the aim of reducing emissions, waste, or pollution.

However, it should be emphasized that in the case of companies managed by men, quantitative competition has a more significant impact on the adaptation of the systems in question, while in companies run by women, qualitative competition plays a more important role. This means that, with the number of competitors remaining unchanged, the attractiveness (or quality) of their offer increases.

Referring to variables related to staff qualifications, the empirical analysis revealed that, contrary to the prevailing assumptions in the literature, high employee qualifications significantly weaken the propensity of companies to undertake energy management activities, both in companies managed by women and those managed by men.

At the same time, it was found that the predominance of low-skilled employees increases the likelihood of such activities. These results are somewhat at odds with the findings of studies indicating that the development of technical competencies and absorption capacity promotes the implementation of energy innovations and the integration of low-carbon technologies (Solnørdal and Thyholdt, 2019; Millán *et al.,* 2020; Iqbal *et al.,* 2022; Carlander and Thollander, 2022).

In light of the literature presented, this conclusion can be interpreted as the result of a shift in strategic priorities—highly skilled personnel tend to focus more on technology and market development, while energy activities are treated as a secondary area for improvement. In turn, low-skilled employees are more strongly motivated by the simple and direct cost savings that come with improving energy efficiency, which drives organizations to implement basic pro-energy measures more quickly.

Empirical analysis has shown clear differences between sectors of activity in terms of their propensity to implement energy management measures. Companies belonging to the NACE_F sector (construction) were significantly less likely to implement pro-energy solutions. Limited process standardization, high project variability, and a dominant cost orientation may mean that energy management is not a strategic priority in construction. This result is consistent with the literature, indicating that less energy-intensive sectors are slower to adopt EnMS systems and more complex efficiency measures (Iqbal *et al.,* 2022; Šebo *et al.,* 2023).

The opposite relationship was observed for NACE_C (industry). Belonging to this sector increased the likelihood of implementing energy measures. This is due to the fact that the industry is characterized by significant energy intensity in its processes, which means that investments in energy efficiency lead to rapid cost reductions and increased competitiveness. The result confirms earlier findings that industry benefits most from the implementation of energy management systems and energy-saving technologies (Thollander *et al.,* 2025; Herce *et al.,* 2021; Šebo, Prester and Šebová, 2023).

The results obtained therefore confirm the validity of the main research hypothesis H0, which draws attention to the diverse impact of the gender of top management on energy management activities in a company aimed at reducing emissions, waste, or pollution. At the same time, the research results emphasize the need for further study of the role of gender in management in shaping the pro-environmental strategy of companies.

In light of the results obtained, it is important to determine what consequences for management practice may be brought about by the identified differences conditioned by the gender of leaders. The presented results not only broaden theoretical knowledge, but also indicate specific courses of action that can increase the effectiveness of energy management system implementation in companies. Therefore, the key practical implications of the analyses are presented below.

The results indicate that the gender structure in top management should be treated as an important factor in shaping corporate energy strategies. Both companies and public decision-makers can put this into practice by:

• Strengthening the representation of women in management, especially in energy-intensive sectors, as female leaders show a stronger focus on formalizing and standardizing pro-energy activities.
• Tailoring support instruments to the leadership profile—in companies managed by women, tools based on quality certification and process innovation development may be more effective, while in companies led by men, strategies based on R&D and technological investments may be more effective.
• Building gender-diverse management teams to combine different decision making styles — focused on both standardization and environmental responsibility as well as technological innovation — thereby increasing the effectiveness of energy management system implementation.
• Designing public policies and support programs that take into account the different ways in which women and men respond to competitive and regulatory incentives, increasing the effectiveness of interventions that accelerate the energy transition of companies.

Despite the valuable results obtained, the study has several limitations that should be considered when interpreting the findings. First, the analysis was conducted on data relating exclusively to companies from Southern European countries, which limits the possibility of fully generalizing the conclusions to other regions with different economic structures, levels of technological development, and regulatory pressure.
Second, the data used is cross-sectional, which makes it impossible to assess the long-term effects of implementing energy management systems and cause-and-effect relationships.

Third, the variables used in the models are based on respondents' declarations, which may involve the risk of perceptual errors and declarative responses. Additionally, although numerous organizational and market conditions were taken into account, more complex cultural, behavioral, and psychological factors that may influence managers' energy decisions were not examined.

Therefore, it is reasonable to conduct further research with a broader geographical and temporal scope, also covering the qualitative aspects of managers' attitudes and motivations, in order to deepen the understanding of the role of gender in the energy transition processes of enterprises.

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