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An Econometric Analysis of the Energy-Saving Performance of the Italian Plastic Manufacturing Sector

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Abstract: In a scenario characterised by mitigation concerns and calls for greater resilience in the energy sector, energy audits (EAs) emerge as an essential mean for enhancing end-use energy consumption awareness and efficiency. Such a tool allows us to assess the different energy carriers consumed in a productive sector, offering insight into existing energy efficiency improvement opportunities. This opens avenues for research to devise an econometrics-based methodology that encapsulate production sites and their environmental essentials. This paper contributes to the literature by exploiting the EAs received by the Italian National agency for New technologies, Energy, and Sustainable Economic Development (ENEA) in 2019 from the Italian plastics manufacturing sector, matched with Italian firm-based data extracted from the Analisi Informatizzata delle Aziende Italiane (Italian company information and business intelligence) (AIDA) database. In particular, we investigate how the implementation of energy efficiency measures (EEMs) is influenced by a set of contextual factors, as well as features relating to the companies and EEMs themselves. The empirical investigation focuses on the EAs submitted to ENEA in 2019, which was strategically chosen due to its unique data availability and adequacy for extensive analysis. The selection of 2019 is justified as it constitutes the second mandatory reporting period for energy audits, in contrast to the 2022 data, which are currently undergoing detailed refinement. In line with the literature, the adopted empirical approach involves the use of both the OLS and logistic regression models. Empirical results confirm the relevance of economic and financial factors in guiding the decisions surrounding the sector's energy performance, alongside the analogous influence of the technical characteristics of the measures themselves and of the firms' strategies. In particular, the OLS model with no fixed effects shows that a one-percent variation in investments is associated with an increase in savings performance equal to 0.63%. As for the OLS model, including fixed effects, the elasticity among the two variables concerned reaches 0.87%, while in the logistic regression, if the investment carried out by the production sites increases, the expected percentage change in the probability that the energy-saving performance is above its average is about 187.77%. Contextual factors that prove to be equally influential include the incentive mechanism considered and the traits of the geographical area in which the companies are located. Relevant policy implications derived from this analysis include the importance of reducing informational barriers about EEMs and increasing technical assistance, which can be crucial for identifying and implementing effective energy solutions.

Keywords: energy efficiency; energy audits; industry; plastics

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1. Introduction

The current policy environment in the European Union (EU) is witnessing numerous challenges affecting the stability of the macroeconomic framework of member countries, most notably the compelling need to address growing uncertainties regarding the reliability and affordability of energy flows while maintaining policy strategies in line with greenhouse gas emission reduction targets. For several years, the key institutions of the EU have shown a deep awareness of the combined benefits and urgencies associated with energy efficiency (EE), identifying energy demand moderation as a pivotal dimension of the European Energy Strategy. According to the text of Directive 2012/27/EU [1], and its 2018 [2] and 2023 [3] recasts, EE is a valuable tool whose advancements along the entire energy chain (including generation, transmission, distribution, and end-use of energy) would generate benefits directly attributable to the wellbeing of the EU population, such as those related to the environment, air quality and public health, and even positive impacts related to the energy security of member countries, by reducing their dependence on energy imports from outside the Union. As a result, energy costs for households and businesses would decrease, thus alleviating energy poverty, fostering business competitiveness and the dynamics of labour markets. In 2012, the European Energy Efficiency Directive 2012/27/EU (EED) [1] was therefore enacted, with the aim of regulating the matter and introducing additional stimulus mechanisms for the adoption of energy efficiency measures. The integrated approach used is reflected in the request to Member States to establish "national energy efficiency targets expressed through national action plans to be published every three years", and the complementary request to define and promote financing instruments or fiscal incentives that lead to the implementation of energy management practices and energy-efficient technologies or techniques. The legislation on the subject is, in fact, constantly evolving. On 10 October 2023, a new Directive on energy efficiency entered into force [3], containing updated norms on the matter to reduce final energy consumption at an EU level of 11.7% by 2030, which translates into an upper limit on the EU final energy consumption of 763 million toe and 993 million toe for primary consumption. The 2023 revision of the Directive is part of the EU Green Deal package, and the ambition of the 2021 initial proposal was strengthened in the REPowerEU plan. For the first time, the "energy efficiency first" principle takes on legal standing, meaning that EU countries must consider EE in all relevant policy and investment decisions. The present work aims to offer a method to analyse the impact of the existing mechanism of mandatory energy audits on the adoption of EEMs, applying it to a specific manufacturing sector, prior to the introduction of these new obligations.

In line with European commitments, Italy pursues a path to improve the country's energy security, environmental protection, and accessibility of energy services, recognising the benefits associated with energy efficiency and therefore identifying its strategic role through the Legislative Decree No. 102 of 2014 on energy efficiency [4]. The Decree establishes a framework of measures for the promotion and improvement of energy efficiency that contribute to the achievement of the national energy savings target indicated in Article 3 and to the implementation of the European principle that puts energy efficiency first. In detail, it sets a national obligation to save 20 Mtoe per year of primary energy, equivalent to 15.5 Mtoe per annum of final energy through mechanisms and tools outlined by the Legislative Decree itself. For what concerns these latter, as stressed by the Italian Action Plan for EE, Italy mainly refers to the White Certificates obligation scheme, accompanied by other support tools for energy efficiency enhancement measures such as tax deductions for the energy requalification of buildings and the renewable energy for heating and cooling support scheme (*Conto termico*), which incentivises interventions to increase energy efficiency and thermal energy production from renewable sources for small-scale plants. EE Directive 2012/27/EU [1] introduced the obligation for large enterprises to carry out an energy audit on their production sites, starting from December 2015 and subsequently every 4 years. Among the horizontal policies mentioned in the Decree, in line with the requirements of the Directive, EAs are recognised as a key tool capable of stimulating a conscious management of energy consumption within production activities, while identifying feasible efficiency measures and mechanisms for their implementation, breaking down some of the barriers associated with the adoption of EEMs.

In this study, we exploit the large potential offered by data collected through mandatory EAs, a crucial source of detailed and reliable information on energy-saving opportunities. The focus on the plastics manufacturing sector is motivated by its economic significance and the abundance of EEMs identified in the EAs. We adopt an econometric approach which involves the use of both OLS and logistic regression models to assess the contributions of economic, financial, and contextual factors to a firm's energy performance. Such econometric approach represents a significant starting point to explore firm dynamics in relation to EEMs. However, the unique nature of the EAs' data limits comparability to other studies.

This analysis aims to understand the broader influence of financial and managerial practices on EE. The main focus of this paper is the examination of how certain aspects of corporate productivity, including broader management practices not directly related to energy consumption behaviours, influence industrial energy performances. For instance, a specific area of interest is the role of debt-financed funding in implementing energy efficiency measures, as this could reveal key business strategies for long-term cost management and the impact of these financial decisions on energy efficiency of the sector.

Simultaneously, our investigation delves into the technical characteristics of the energy efficiency interventions. We aim to identify which specific measures and characteristics might lead to enhanced energy performance in the plastics manufacturing sector. This entails examining discrepancies in energy performance impact, attributable to the efficacy of interventions, cost–benefit ratios, adaptability to corporate needs, and technological innovations.

Furthermore, the study critically assesses existing incentives, with a particular focus on the Italian White Certificate scheme, and their effectiveness in supporting enterprises overcome economic barriers to implementing EEMs. Considering the several challenges that companies face in implementing EEMs, it should be considered how the specific characteristics of production realities influence their energy performance and their propensity to implement EEMs. In fact, a uniform approach to incentives may not be sufficient in addressing these challenges. Market-based incentives based solely on the level of energy savings achieved (such as White Certificates) may not be sufficient to achieve sector-specific EE targets, especially if there are discrepancies compounded by differences in energy behaviour related to the geographical location of companies. In acknowledging the inherent limitations of this study, including the nature of the EA information, the specific focus on the plastics manufacturing sector, and the heterogeneity in the energy audits, we emphasise the need for a cautious interpretation of our findings. These factors highlight the potential for further research, particularly in areas where data and methodological limitations currently constrain our understanding of regional disparities and sector-specific challenges in energy efficiency.

2. Literature Review

2.1. Energy Efficiency in Productive Activities

2.1.1. Barriers and Drivers of Energy Efficiency Interventions

The emphasis on incentive mechanisms and energy audits, as part of the European approach, is based on the imperative for Member States to reduce energy intensity of their production processes at an increasing pace. However, businesses, leading players in the clean energy transition, still face several obstacles in pursuing this path.

A distinctive branch of the literature attempts to gain an in-depth understanding of the forces (external and behavioural) that inhibit investment in energy-efficient technologies, i.e., barriers to adoption [5], with the aim of expanding the insufficient adoption of EEMs notwithstanding the benefits in terms of enhanced competitiveness and decreased energy costs. Multiple studies emphasise the crucial importance of financial elements.

In particular, access to capital appears to be one of the main impediments, strongly felt by small and medium enterprises (SMEs) [6–9]. Newell and Anderson [10] substantiates how the initial expenditure incurred by firms and the relative payback period are negatively correlated with the rate of EEM adoption. Therefore, economic incentives are particularly effective in the short term as they abate resistance stemming from implementation costs. However, there may be many benefits and risks that these financial measures do not capture. The specific features of an EEM can be an equally relevant factor for the purpose of implementation, shaping the difficulties faced by the company. In this regard, the authors of [11] identify macro-areas for defining these characteristics; the first deals with the relative benefit of the measure itself (including financial aspects and noneconomic benefits such as those related to the reduction in environmental damage), while the second area deals with the technical context of the intervention and thus with all the elements that characterise the type of EEM, such as its magnitude and duration.

An additional problem arises considering that these specificities can in turn acquire different degrees of relevance depending on the characteristics of the company in consideration and the market in which it operates; in fact, different sizes, market competitiveness, the organisational and knowledge management model adopted, etc., are all traits that can interact with the specificities of the intervention, thus widening or reducing existing barriers [8]. Finally, among the most frequently encountered reasons for insufficient adoption is the perception of the intervention itself, i.e., the priority assigned to it in relation to the corporate strategy adopted. Zhang et al. [12] suggests that whether an EEM is perceived as strategic depends not only on the characteristics of the intervention itself but to an even greater extent on the culture and priorities of the company.

These discussions highlight the importance of the regulatory instruments adopted in the EU to create an economic, legal, and social context capable of transforming corporate culture and strategies, while financially supporting companies in implementing EEMs. To this end, the role of financial, governmental, and non-governmental institutions in promoting energy efficiency in the various production sectors and/or end-uses and guiding financial markets is evident. Trianni and Cagno [8] demonstrates this role through an analysis of the factors capable of stimulating the adoption of energy conservation measures (i.e., energy efficiency drivers). Indeed, along with economic factors, the authors emphasise the influence of regulatory instruments. These can be distinguished between internal, such as voluntary agreements made by companies, and external, such as obligations and constraints imposed on companies, including those related to the performance of energy consumption audits. These obligations, together with the use of information tools and the necessary professional training, increase the efforts made by the production activities and the ease with which they are carried out, increasing awareness both on energy consumption and energy efficiency solutions for the production site, thus breaking down informational barriers.

In addition to internal business organisational factors, which can potentially hinder EEM implementation, it is crucial to address the influences of specific regulatory and policy environments on energy efficiency trajectories. By analysing the broader interconnections and systemic links between renewable energy consumption, financial development, and public health [11], and in particular by exploring the two-way influences and long-term linkages between these variables in different nations, the authors clarify how renewable energy consumption not only supports the reduction in environmental pollution, but also enhances public health. This tripartite relationship, explored through robust econometric methods, reinforces the need for policies that balance immediate financial incentives with long-term health and sustainability goals. From a business perspective, this causality relationship suggests that investment in renewable energy and prioritising financial growth may have more far-reaching implications. This could affect not only immediate operational costs, but also public welfare, and could potentially shape both market reception and competitive edge. When examining the effects of energy policies and their influence on corporate health, we can gain some fascinating insights. Through examining how China has intertwined different policy instruments in the field of energy conservation and emission reduction, Zhang et al. [12] enlightens us on the role of policy coordination in the broader framework of economic growth. When administrative and financial measures are coordinated, there is a positive knock-on effect on economic growth. It is as if these two forces, once aligned, not only serve the goal of energy conservation, but also give the economy a boost.

Zhang et al. [12] also presents a contrasting scenario where administrative measures are implemented alongside fiscal and taxation policies, or when they are aligned with broader policy orientations. In this case, the impact on economic growth goes in the opposite direction. The results suggest the need for a delicate balancing act when introducing policies; policy instruments must be rooted in the specific implementation context and work in harmony, simultaneously supporting sustainable energy goals and economic growth.

In conclusion, these studies shed light on the complexity and multidimensionality of energy efficiency in manufacturing sectors. They emphasise the central role of internal corporate culture and external policy frameworks, along with governmental coordination strategies, in influencing the adoption and effectiveness of EEMs. This interplay of factors accentuates the need for a holistic approach, complemented by an in-depth understanding of the unique green transition needs of the productive sectors, for the creation of customised policy instruments that meet sector-specific needs.

2.1.2. Empirical Analysis of Barriers and Drivers of Energy Efficiency Interventions

This section focuses on the literature on which this work is based, which relates to the use of econometric methods for the sectoral analysis of observed energy efficiency pathways. The use of such methodologies allows for the identification of the foundational traits of the company and the interaction between productive activities and the socioeconomic context capable of influencing the ability of production sites to implement EEMs. Sectoral studies in the field of energy efficiency mostly focus on the analysis of the benefits associated with the implementation of specific technology systems and behavioural measures [13,14]. Few empirical contributions, on the other hand, take a generalised approach aimed at estimating how various elements, inherent in multiple aspects of the company and the context, enable industries to move towards better energy-saving performances. A relevant strand of the literature consists of the studies conducted by Cagno and Trianni; the two authors, in collaboration with several researchers, have carried out multiple empirical works regarding the drivers and barriers that can influence the adoption of EEMs [15–18]. Although these contributions mostly adopt statistical approaches (correlation analysis) methodologically different from econometric models, there are important exceptions, such as [19,20]. The latter studies—in the context of SMEs in the Slovenian manufacturing sector—how salient the barriers and drivers are for EEM adoption in comparison to other contextual influences. Trianni and Cagno [8] constructed a linear probability and logit model to investigate the likelihood of EEM implementation by separately examining elements influencing past and future EE investment decisions. The authors found that companies' internal culture and their innovative capabilities raise the emphasis on energy conservation. Considering past investment decisions, they observed how greater leverage negatively affects the probability of introducing EEMs. They also show that businesses that have implemented awareness programs and performed an energy audit are much more likely to implement EEMs. As for the results related to future investment decisions, the firm's ability to innovate becomes central; research and development activities to achieve an energy-conscious corporate culture are an essential stimulus for EEM deployment. The deployment appears to be highly influenced by organisational and skill-related barriers. Finally, behavioural and technological barriers reduce the likelihood of future EEM introduction, showing once again how building internal awareness, while leveraging external linkages, can influence the energy conservation pattern of a manufacturing sector. In this regard, Hrovatin et al. [20] exploits panel data pertaining to actual investment decisions through two probit models and evaluate the probability for firms to carry out an environmental investment and then, separately, the probability associated with carrying out investments in clean technologies and in energy efficiency measures. Economic factors related to the characteristics of the enterprises as profitability (ROA), indebtedness (debt ratio), innovative capabilities (R&D activity), and energy costs were used in these approaches as predictors, together with market-driven elements and regulations. Regarding the results inherent in investments in EEMs, the authors suggest that both firm and sectoral characteristics can shape them; in particular, firm-specific and market-related economic factors are of crucial importance. For instance, firm size affects the level of EE investments due to the greater exposure to international competition and higher energy costs; consequently, these become necessary means for large enterprises to lower their manufacturing costs and enhance their competitive edge.

Finally, this type of investment is influenced by favourable expectations about future demand and to be relatively more resilient, during and after the 2008 financial crisis. The reason for this probably lies in the fact that EE investments are relatively cost-effective, which makes it easier "to obtain the corresponding financing despite the stringent banking regulations and scarce financial resources" [20]. In their groundbreaking 2014 study, Boyd and Curtis [21] employed a two-phase approach (which at first establishes a benchmark for plant-level energy intensity and subsequently analyses the impact of management practices on this relative energy intensity using a linear regression model) to delve into the impact of corporate management practices on energy performance in the U.S. manufacturing sector. The study incorporated plant-level fixed effects, allowing for the control of unique, invariant characteristics of each plant that could sway energy efficiency. The findings reveal a complex relationship between management practices and energy efficiency. Certain practices, such as effective monitoring and well-structured incentive systems, are linked to a decrease in energy usage. However, a focus on aggressive production targets can paradoxically lead to an increase in energy consumption. Following Boyd and Curtis's approach to examining the role of management in operational efficiency, Blass et al. [22] delves into how top operations managers within small and medium-sized manufacturing firms influence the adoption of energy-saving practices. By employing logistic and OLS regression models with fixed effects for multisite firms, Blass et al. [22] reveals that the engagement of operationally focused senior managers significantly boosts the implementation of recommended practices by 13.4% and increases the adoption of substantive process changes. These insights highlight the importance of managerial influence in enhancing EE for SMEs, aligning with, and expanding upon, the foundational findings of [21]. In parallel with the examination of policy and managerial influences on energy efficiency, the 2017 research conducted by Nicola Cantore [23] presents an in-depth analysis of 214 companies across diverse industries and countries. Cantore's study, utilising logistic regression models complemented by Principal Component Analysis, sheds light on the determinants of energy efficiency technology adoption within the manufacturing sector. Contrary to expectations, the study reveals that geographical location is not a significant factor in investment decisions related to energy efficiency. Instead, it emphasises the decisive roles of internal management, prior experience with EE projects, and microeconomic barriers such as capital constraints. These insights emphasise the importance of a company's internal organisational structure and management practices in the evolution of industrial energy trajectories, advocating for a tailored approach to energy conservation promotion that caters to the specificities of different manufacturing sectors and developmental contexts. Notably, the study uncovers a counterintuitive yet significant relationship where the adoption of certified management systems may deter further energy efficiency investments. From a management perspective, achieving certification might be perceived as an end-goal, potentially reducing the motivation for ongoing investment in EEMs. Further, another significant empirical contribution is [10] on the relevance of information programs for technology adoption. Specifically, the authors considered a set of potential energy-saving projects related to the U.S. manufacturing sector, recommended by auditors of the U.S. Department of Energy's Industrial Assessment Centre (IAC) program, therefore using data resulting from EAs. The utilisation of EA information in this study significantly enhances its contribution to the existing literature, offering a foundation upon which our article draws considerable inspiration. The authors exploited a logit model with plant-level fixed effects [24,25] to control for unobserved differences between plants in the propensity to adopt EE technologies. Newell and Anderson [10] found that adoption rates are higher for projects with shorter payback periods, lower costs, higher resulting annual savings, higher energy prices, and greater energy conservation; results also emphasised how installations are 40% more sensitive to upfront costs than to annual savings, identifying important policy implications, as subsidies appear to be more effective in promoting energy-efficient technologies than increases in energy prices. The study highlights that although numerous cost-effective energy-efficient projects are implemented by manufacturing plants, a significant number remain unadopted. This is mainly due to high implicit discount rates and overlooked factors such as project risks and internal barriers within firms. These findings indicate that decision-making within firms involves more than just financial calculations, encompassing a range of unquantified elements that influence the adoption of energy-efficient technologies.

The use of data from energy audits appears to be an under-used methodological choice, especially considering the econometric formulations. However, there is the extensive opportunity to extract relevant information from them, as demonstrated by [26]. This work is an effort to compute energy performance indices in the cement manufacturing sector, clearly framing the type of information that can be extracted and the methodology used in the analysis. An empirical analysis aimed at assessing the impact of energy monitoring and energy management systems (EnMSs) for implementing and planning actions to improve energy performance was also developed [27]. In particular, the studies emphasised the richness of the data retrieved from audits, which allow for a delineation of the characteristics of the analysed sectors (plastic and ceramic manufacturing), as well as the relevance of promoting energy monitoring and EnMSs as a pivotal part of energy efficiency policies.

The possibilities offered by the data contained in the audits, together with the wide range of applicable econometric approaches, provide the foundations for a broader research path aimed at identifying a standard methodology for analysing the energy performance of productive sectors.

2.2. The Italian Energy Audit System

For the purposes of this analysis, prior to proceeding with the discussion related to the data employed, it is crucial to provide a framework for a proper understanding of the tool used as a source of information, i.e., the EA, and ultimately how this is regulated in Italy.

Article 8 on EAs and EnMSs of the EE Directive 2012/27/EU [1] imposes two major obligations on Member States: to promote the availability of EAs among final customers in all sectors, and to ensure that enterprises that are not SMEs conduct energy audits at least every four years.

Consequently, EAs become the most qualified tool in the EU for analysing the energy flows of production activities and their management, represented by a "systematic evaluation of energy uses from their point of entry up to their final uses, able consequently to track and quantify energy saving opportunities" [1]. On the one hand, energy audits constitute a tool to understand and represent the structure of energy consumption in the various functional areas of production activities; on the other hand, they support companies in identifying the possible reductions in energy consumption, economic costs, and carbon emissions.

In line with the EU requirements, the Italian Legislative Decree 102/2014 [4] identifies large enterprises and energy-intensive enterprises as the subjects obligated to carry out an EA at their production sites, excluding, however, large enterprises with a total annual energy consumption of less than 50 toe. In addition, the Decree entrusts ENEA as the entity in charge of establishing and managing a database of enterprises subject to audit, with the task of carrying out controls to verify the conformity of the audits with legal requirements.

The standard EN 16247.1 "Energy Audit–General Requirements" [28] and subsequent regulatory tools define the methodology for obtaining a good-quality energy audit of a production site. In this standard, the Italian approach to energy audit has been referred to; indeed, the guidelines for energy audit contents adopted in Italy have been considered to be the best practice in the EU. The audit process involves defining the professional prerequisites of the energy auditor and assigning the responsibility of gathering all information necessary and useful for gaining an understanding of the various areas of energy consumption, along with its supply sources. The role of the auditor is central due to the specific knowledge in managing energy and implementing potential interventions, and the potential to reduce resistance to adopting energy management practices by conducting analyses in the field.

Companies are required to send an audit report to ENEA every four years; the report should gather all the essential information to draw a complete picture of the company's funding characteristics, while also providing a summary of energy consumption and its deployment in the different functional areas. The section of the report aimed at describing the energy efficiency interventions already introduced and those implementable (as identified by the auditor) is particularly relevant. Table 1 lists all the information contained in an audit report.

Table 1. Information contained in the energy audits.

Audit Report Content
1. Note on who drew the energy audit.
2. General data of the company.
3. Data of the production site for which the audit is made.
4. The reference period of the audit.
5. The units of measurement adopted within the audit.
6. Energy consumption.
7. Raw materials used in production processes.
8. Production process description.
9. Description of finished products.
10. Reference energy indicators.
11. Information on data collection method.
12. Description of implementation of monitoring strategy.
13. Energy models.
14. Calculation of energy indicators.
15. Interventions carried out in the past.
16. Individuation of possible interventions.
17. Summary of identified interventions:
a. Net Present Value (NPV);
b. Investment (I);
c. Cash flow (FC);
d. Energy savings;
e. Payback period (TR);
f. IRR.

Source: ENEA, The Energy Audit Guidelines and Operating Manual.

3. Data and Methodology

3.1. Data

By receiving the information resulting from the energy audit obligation from a large number of companies every four years, ENEA manages a unique database, offering the opportunity for an in-depth analysis of the characteristics of the companies and their impact on the past and future evolution of EEMs in different sectors.

This work exploits a cross-sectional database, which consists of the information extracted from the 684 energy audits sent to ENEA in 2019 by over 600 obligated manufacturing enterprises pertaining to the Italian production of plastic articles. The year 2019 represents the starting year of the second obligation period for energy audit policy (after its introduction in 2015) and a significantly higher number of audits has been collected by ENEA relative to following obligation years (energy audits collected in December 2019 are relative to 2018; more information on the obligation years can be found in the report "Rapporto sull'attuazione dell'obbligo di diagnosi" drafted for the Ministry of Environment and Energy Security, available here https://www.efficienzaenergetica.enea.it/servizi-per/imprese/diagnosi-energetiche/pubblicazioni-e-atti.html (accessed on 23 December 2023)). In particular, the sample includes audits received from firms operating in the plastics sector, classified as ATECO 22.21.00, 22.22.00, and 22.29.09, equivalent to NACE C22.1.1, C22.2.2, and C22.2.9. (The ATECO and NACE codes mentioned here refer to specific classifications within the European system for categorising various types of economic activities; ATECO (Attività Economiche) is the Italian version, while NACE (Nomenclature statistique des Activités économiques dans la Communauté Européenne) is the broader European standard.) These codes predominantly include small and medium-sized energy-intensive enterprises, with a high share of multisite enterprises. An in-depth discussion of the business area under consideration will be provided in the next section. The uniqueness of the database is the informative scope of the energy audit, which allows us to capture data inherent to implementable EEMs as well as intrinsic to production sites.

With regard to the former, these cover the description, type, and energy saving of the identified energy efficiency measures, allowing us to consider the technical specificity of the interventions themselves. Accordingly, information is also disclosed on the different types of energy savings that could be attained: annual electric energy savings (toe), annual thermal energy savings (toe), other annual savings (toe), total annual savings (toe), primary electric savings (toe), total primary savings (toe), and annual fuel savings (toe). The database also incorporates details concerning the investment required for EEMs' implementation and the associated net present value, and payback period, calculated without incentives. Cost-effectiveness can thus be derived from the information in the database. In detail, the technical traits of the intervention are considered by classifying the energy efficiency measures into different areas of categorisation: HVAC (heating, ventilation, and air conditioning); building envelope; compressed air systems; engines, inverters, and other electrical installations; electric systems; general/managerial (monitoring, training, energy management system, ISO 50001 [29]); distribution networks; lighting; power factor correction; cold production unit; production lines; intake systems; thermal power plant/heat recovery; transport; production from renewable sources and cogeneration/trigeneration; and a miscellaneous category of measures not elsewhere classified.

With regard to the variables tied to enterprises, ENEA collects information concerning the company name and the ID code for the identification of production sites associated with the same VAT (multi-site companies); the region and province in which the production sites are located; the presence of energy consumption monitoring systems; and the presence of ISO 50001 certification. Finally, it is possible to make a distinction between the obligated parties, i.e., to assess whether the company considered is a large company or an energy-intensive company. Table 2 summarises the different information included in the database.

Table 2. Information obtained from the energy audits.

Information Related to the Firm	Information Related to EEMs
Company name	Investment level
ID code	Payback period (PBP)
VAT	Cost-effectiveness
Region and province	Area of categorisation
Energy monitoring mechanism	Realizable energy savings
ISO 50001 [29]	Net present value
Energy intensity	
Dimension	
Energy consumption level	

Source: Authors' own elaboration based on ENEA data.

Furthermore, for the purposes of this work, energy consumption levels of the production sites considered were included as well (primary electric consumption (toe), total primary consumption (toe), total final consumption (toe), thermal energy consumption (toe), and gas consumption (toe)). This information can be derived from the ENEA energy audit database, as described in [27], in terms of electrical, thermal, and gas consumption levels.

Given that this information for three NACE C22 sectors has never been processed before, considerable effort was required to validate the data. The adjustments that were made to the source database are listed in detail in Table 3.

Table 3. Adjustments applied to the database.

Data Validation Steps
Energy efficiency interventions with missing total energy savings were removed as they were not relevant for the purposes of the analysis.
Interventions resulting from audits not relevant to the investigated obligation period were removed from the database.
Energy savings and investments values, associated with interventions, which were particularly distant from their average (with reference to both tails of the distribution) were checked by directly verifying the contents of the energy audits.
Adjustments were made, where necessary, to the values of energy savings by applying due conversions.
Where investment and cost-effectiveness levels were missing, the energy audits were inspected and, if necessary, the database was integrated on the basis of the content of the audits.
Payback periods were included where missing if related information was present in the energy audits.

Source: Authors' own elaboration.

Finally, to broaden the lens on business attributes that are capable of influencing energy-saving performance, ENEA EA data were merged with data extracted from AIDA (Informed Analysis of Italian Companies) database. More specifically, through the identification code of the companies, information on productivity and sector characteristics was extracted. These turned out to be available for about 400 of the companies subject to the obligation. The merge, in combination with the previous data preparation phases, resulted in a narrower number of observations: 1304 implementable EEMs constituted the sample analysed.

3.1.1. Variable Description

The selection of suitable econometric methods reflected the recognition that the database includes variables connected to the company rather than only to individual EEMs, such as energy consumption or those obtained from the AIDA database. As a result, if more than one intervention is proposed for a company based on the energy audit, then the values of the company-level parameters are reiterated for each intervention. This peculiarity of the data was evaluated along with the possibility that multiple production sites (therefore multiple interventions) are tied to the same enterprise, thus generating the presence of specific uncontrolled elements common to different production sites, able to affect the energy-saving performance.

Based on the previous description of the information that could be extracted from an EA, the predictors used in the models are summarised in Table 4.

Table 4. Summary of the variables included in the logistic and linear regressions.

Predictor Names ($X_1, X_2 \ldots X_k$)	Variable Description	Logistic Regression	Pooled OLS	Pooled OLS (FE)
INVESTMENT	Investment level (EUR) associated with the EEM.	✓	✓	✓
NPV	Net present value of the investment (EUR).	✓	✓	✓
PBP	Payback period associated with the investment (Years).	✓	✓	✓
MONITORING	Dichotomous variable = 1 if the EEM considered comes from a production site subjected to monitoring.	✓	✓	

Table 4. *Cont.*

Predictor Names (X_1, X_2 . . . X_k)	Variable Description	Logistic Regression	Pooled OLS	Pooled OLS (FE)
ISO 50001	Dichotomous variable = 1 if the EEM considered comes from a production site owning a system for managing energy vectors.	✓	✓	
FIXED EFFECTS	N-1 dummy for each production site having the same ID code, so pertaining to the same firm.			✓
NORTH–EAST	Dichotomous variable = 1 if the intervention considered comes from a production site located in the northeastern area of Italy.	✓	✓	✓
NORTH–WEST	Dichotomous variable = 1 if the intervention considered comes from a production site located in the northwestern area of Italy.	✓	✓	✓
SOUTH	Dichotomous variable = 1 if the intervention considered comes from a production site located in the southern area of Italy.	✓	✓	✓
	AIDA variables related to firms' productivity			
REVENUES	Company revenues from sales in 2018 (EUR).			
EMPLOYEE	Company number of employees in 2018.			
DEBT_RATIO	Debt ratio indicating the company's total debt, as a percentage of its total assets in 2018.	✓	✓	✓
CAPITAL_TURNOVER	Denotes the number of times the invested capital has returned in the form of sales in 2018.	✓	✓	✓
REVENUES_PROCAP	Company revenues per employee in 2018 (EUR).	✓	✓	✓

Source: Authors' own elaboration based on ENEA and AIDA data.

With the intent of mirroring in the models the impact undertaken by the technical characteristics of the interventions, dichotomous variables indicating the area of categorisation of the energy efficiency measures were introduced (see Table 5). It is thereby possible to verify whether investing in certain areas negatively affects energy-saving performance.

Table 5. Summary of the constructed dummies for intervention areas.

Dummy Variables for Intervention Areas	
HVAC	Dichotomous variable = 1 if the intervention belongs to the Air conditioning area.
Cogeneration/Trigeneration	Dichotomous variable = 1 if the intervention belongs to the Cogeneration/Trigeneration area.
Compressed air systems	Dichotomous variable = 1 if the intervention belongs to the Compressed air area.
Engines/Inverters	Dichotomous variable = 1 if the intervention belongs to the Engines/Inverters area.
Electric systems	Dichotomous variable = 1 if the intervention belongs to the Electric systems area.
General/Managerial	Dichotomous variable = 1 if the intervention belongs to the General/Managerial area.
Other	Dichotomous variable = 1 if the intervention belongs to the Not elsewhere classified area.
Cold production units	Dichotomous variable = 1 if the intervention belongs to the Cold production units area.
Production from renewables sources	Dichotomous variable = 1 if the intervention belongs to the Production from renewable source area.
Production lines	Dichotomous variable = 1 if the intervention belongs to the Production lines area.
Intake systems	Dichotomous variable = 1 if the intervention belongs to the Intake systems area.
Thermal power plant/Heat recovery	Dichotomous variable = 1 if the intervention belongs to the Thermal power plant/Heat recovery area.
Transport	Dichotomous variable = 1 if the intervention belongs to the Transport area.

Source: Authors' own elaboration based on ENEA data.

3.1.2. The Energy Performance

The methodology adopted in this study encompasses various econometric techniques; hence, this section will scrutinise the response variable and its transformations as employed across the distinct methodologies implemented. The response variable investigated here is measured as the ratio between the potential energy savings related to the identified EEMs and the total consumption of energy carriers in the production site considered. In particular, for each individual intervention identified (potential), the total achievable energy savings—expressed as an aggregate of electric, thermal, and other savings—is measured in tons of oil equivalent (toe). This conversion allows us to jointly evaluate the different types of interventions. These primary savings in toe are then divided by the overall level of energy consumption (again considered in terms of primary energy consumption) of the enterprise. Hence, we obtain, overall, the energy performance of the sector that would occur if these interventions were implemented (information on actual implementation will be available through the refinement of data from the 2022 energy audits). Therefore, factors capable of increasing or reducing the sector's potential energy performance are explored. The dichotomous version of the variable, investigated trough the logistic regression, reports a value of 1 if the observed energy performance for a given production site exceeds the average of its distribution. On the other hand, in the OLS model, the response variable is not exhibited as dichotomous, but as a continuous variable; and by examining its distribution graphically, we observed that there is a concentration of observations for values lower than 0.25. This means that the energy performance of companies in the sector is predominantly below this threshold. Consequently, to reduce the incidence of extreme values related to large-scale energy self-production interventions (cogeneration/trigeneration), a logarithmic transformation of the variable has been introduced for the OLS regressions.

3.1.3. The White Certificate Variable

In order to verify the extent to which the presence of policies that encourage the adoption of EE interventions can boost energy-saving performances, a special dichotomous variable was constructed, related to the White Certificate scheme. As highlighted in the introduction, this incentive tool is one of the main policy instruments employed to foster the implementation of energy efficiency measures in the Italian industry. Thanks to the White Certificate guidelines issued by the Gestore Servizi Energetici (GSE) [30], it was possible to detect which EEMs were eligible for this support policy. According to the guidance offered by the GSE and the reported background information, the White Certificate variable was built as detailed in Table 6. NA has been attributed to Building Envelope since no intervention in this area can be associated with the White Certificate policy. Other energy efficiency incentive mechanisms are applicable, namely tax deductions.

For the cogeneration/trigeneration and the production from renewables areas, there are some clarifications to be made. Regarding the former, high-efficiency cogeneration (CAR) under the White Certificate scheme are regulated by the Directive 2004/8/EC, transposed in Italy by Legislative Decree 20/2007, which stipulated that, as of 2011, the condition for which the combined production of electricity and heat can qualify as "High-Efficiency Cogeneration" is based on the primary energy saving (PES) parameter. White Certificates for cogeneration are therefore assigned annually by the GSE, if the PES value is at least 10% or, in the case of micro-cogeneration units (<50 kWe) or small cogeneration units (<1 MWe), when it takes any positive value. In this study, the set of cogeneration interventions benefiting from the White Certificates is thus underestimated, as the information available has not always made it possible to evaluate access to the incentive. Regarding incentives for the installation of energy production plants from renewable sources in Italy, in continuity with Ministerial Decree 06/07/2012 and Ministerial Decree 23/06/2016, from which part of the structure is inherited, the Ministerial Decree 04/07/2019 promotes, through economic support, their diffusion. The plants eligible for incentives under the Decree are described in different categories, including newly built photovoltaic ones. Eligible to apply for incentives will be only those plants that were placed in a useful position in the rankings of one of seven competitive registry or downward auction procedures on the value of the incentive, drawn up by the GSE based on specific priority criteria.

Table 6. Description of the construction of the White Certificate variable.

Intervention Areas	White Certificate Variable
HVAC	1 if the intervention concerns a heat recovery and/or refrigeration system; 0 otherwise.
Building envelope	NA
Cogeneration/Trigeneration	1 if the audit reveals PES greater than 10% and/or if the plant capacity < 50 kWe or <1 Mwe; 0 otherwise.
Compressed air	1 for intervention on compressed air/compressor replacement; 0 otherwise.
Engines/Inverters	1 for motor/inverter replacement if savings > 5 toe; 0 otherwise.
Electric systems	1 only for power quality interventions 0 otherwise.
General/Managerial	1 per each introduced management and monitoring system; 0 otherwise.
Lighting	1 for LED introduction if energy savings > 5 toe; 0 otherwise.
Cold production units	1 per replacement/introduction of refrigerant system; 0 otherwise.
Production from renewables	1 if the intervention entails the installation of a new plant; 0 otherwise.
Production lines	1 only in case of press replacement excluding hydraulic presses; 0 otherwise.
Intake systems	0 for all the interventions.
Thermal power plant/Heat recovery	1 for any registered heat recovery and for EEMs referring to process chiller; 0 otherwise.
Transport	0 for all the interventions in light of the fact that the interventions in question are not eligible for a White Certificate.

Source: Authors' own elaboration based on ENEA data.

3.2. Methodology

Econometric Approach and the Energy-Saving Performance

The literature reviewed in the previous section has revealed a prevalence of the use of nonlinear regression models that exploit a binary response variable that is equal to 1 in the case of the implementation of the EEM, and 0 otherwise [8,10,17,18]. In parallel to these perspectives, the present paper involves the use of a logistic regression model. In the current study, the primary variable of interest is quantified as the proportion of potential energy savings attributable to the proposed EEMs relative to the aggregate energy carrier consumption at the production facility in question. Thus, the main purpose of this modelling choice is to assess the presence and impact of relevant factors (inherent to both the interventions and the companies themselves) capable of stimulating above-average energy-saving performance.

To carry out the analysis, the RStudio software (version 2023.09.1) was utilised. RStudio is a widely used statistical software used to perform various statistical tasks. The sensitivity of the logit models to the choice of threshold for the dichotomous response variable was tested relative to the alternative option of a binary variable, which assumes a value of one if energy performance is greater than the median of its own distribution. Although the obtained significances are in line, the latter have a much lower goodness of fit.

The logistic regression is compared with an ordinary least squares (OLS) linear regression model, an embryonic approach chosen for its capacity to shed light on future analytical directions, especially in the absence of benchmark studies using similar datasets. In adopting this approach, we align with the methodologies utilised by the authors of [21], who demonstrated the efficacy of linear regression in elucidating the influences on energy-saving performance within manufacturing sectors. Indeed, we introduce fixed effects for the site identification code in our linear regression formulation to account for the presence of multisite enterprises, a decision that echoes Curtis and Boyd's considerations of uncontrolled common characteristics among production activities that can potentially influence energy-saving performance. To ensure the robustness of the OLS model, as fixed-effects control for common factors of production sites belonging to the same company, the variables related to monitoring and ISO 50001 are removed. Finally, for the latter model, logarithmic transformation is applied to the response variable (the performance) in order to reduce the incidence of extreme values related to large-scale energy self-production facilities. Based on the results in terms of goodness of the models, the fixed effects were removed from the logistic regression and kept instead in the OLS model.

In detail, the logistic regression model is formulated as shown in Equation (1):

$$P(y_i = 1|X_i) = \frac{e^{\beta_0 + B_1 X_1 + B_2 X_2 \ldots B_k X_k}}{\left(1 + e^{\beta_0 + B_1 X_1 + B_2 X_2 \ldots B_k X_k}\right)} \tag{1}$$

where $P(y_i = 1 \mid X_i)$ is the odds that, given the set of explanatory variables ($X_1, \ldots, X_k$) described in the previous section (investment, PBP, White Certificates, etc.), the intervention i will result in an above-average energy-saving performance (y), which can be written as follows:

$$Performance_{\ i,f\ \left(x = \frac{Total\ savings\ (toe)_i}{Total\ consumption\ (toe)_i}\right)} = \begin{cases} 1;\ x > mean(x) \\ 0;\ x \leq\ mean(x) \end{cases} \tag{2}$$

In which i represents the index of the i-th intervention and f represents the f-th firm.

While the OLS model is depicted by Equation (3), Equation (4) illustrates how the regression differs when we introduce fixed effects for the enterprise ID code, where the X stands for the chosen predictors, β for the associated coefficients, ϵ is the residual error term, while γ denotes the fixed effects, a set of unobserved variables that are constant over time for each observed unit, but vary between different companies f.

$$Log\left(Y_{i,f}\right) = \beta_0 + \beta_1 X_1 + \beta_2\ X_2 \ldots + \beta_k X_k + \varepsilon \tag{3}$$

$$Log\left(Y_{i,f}\right) = \beta_1 X_1 + \ldots + \beta_k X_k + \gamma_f + \varepsilon \tag{4}$$

In the OLS models, the response variable is not exhibited as dichotomous but as a continuous variable to which we applied the logarithm. The reference period for each variable was not detailed in the formulation of the model since the data only refer to the year 2018. All the models are estimated using maximum likelihood (ML) estimation method.

4. Empirical Results

4.1. Descriptive Analysis of the Italian Plastic Production Sector

As for the economic magnitude of this industrial branch, according to the Italian National Statistic Institution [31], in Italy in 2019, the entire plastic processing sector involved almost 10,000 enterprises with more than 175,000 employees. The companies also show increasing levels of profitability with a dependence on imports higher than their contribution on exports. There is a clear concentration of production activities in the northern regions of the peninsula, accounting for more than half of the total. The sampled businesses account for about 5 percent of the total number of production sites belonging to NACE code 22.

For the 453 companies included in the final sample obtained after the merge, AIDA data highlighted that in 2018, they employed 35,527 individuals for an average revenue per employee that reached EUR 370.664. Total turnover exceeded EUR 11 million. The companies also displayed a turnover rate of invested capital of 1.14, interpretable as an efficient ability to achieve high levels of revenue by rationally deploying available resources, confirming the dynamism of the sector itself.

The energy consumption levels of these enterprises reiterate the importance of the sector in terms of energy efficiency potential. Electricity constitutes most of the energy uses of the Italian plastic manufacturing sector, followed by thermal and gas consumption, indicating a strong electrification of the entire production system.

The energy savings flows are equally relevant: 70,231.97 toe are the primary savings that can be achieved through EEMs, which are inherent in the implementation of energy self-production interventions (renewable energy production and cogeneration/trigeneration plants) and 13,003.85 toe of final energy savings achievable by deploying all the other EEMs. These stylised facts relate to a period prior to the economic contractions caused by the COVID-19 pandemic, which, together with the current energy crisis hampering production, increased the uncertainty associated with production activities. Uncertainty pertains also to the potential future progression of taxation on plastics (currently applied only to single-use products). More information is included in Tables 7 and 8. In the first table, potential savings are calculated in final energy for all areas except for two of them; for these two areas, involving self-production of energy, potential savings are shown in the second table in primary energy.

Table 7. Summary of identified interventions pertaining to final energy savings.

	Interventions	Interventions, %	Energy Savings (Final Energy Savings, Toe)	Savings, %	Average Cost-Effectiveness	Investment (EUR)
HVAC	46.0	1.76	1247.0	1.77	4043.66	5,751,737.00
Building envelope	7.0	0.27	177.2	0.25	10,634.08	946,274.00
Compressed air	248.0	9.51	8414.8	11.96	5345.02	22,365,921.38
Electric system	127.0	4.87	3229.0	4.59	6673.73	10,723,177.41
General/Managerial	166.0	6.37	16,086.0	22.86	4861.37	22,510,741.31
Lighting	298.0	11.43	16,533.7	23.50	6276.83	35,104,974.62
Other	6.0	0.23	127.7	0.18	4468.71	557,059.00
Cold production units	44.0	1.69	2695.4	3.83	8215.31	5,643,930.00
Productive lines	117.0	4.49	8150.3	11.58	6693.79	21,466,966.53
Intake systems	16.0	0.61	116.2	0.17	6476.49	610,861.00
Thermal power plant/Heat recovery	37.0	1.42	4068.2	5.78	4609.74	8,095,459.00
Transport	30.0	1.15	100.9	0.14	5959.97	490,400.00

Source: Authors' own elaboration based on ENEA data.

Table 8. Summary of identified interventions pertaining to primary energy savings.

	Interventions	Interventions, %	Energy Savings (Primary Energy Savings, Toe)	Average Cost-Effectiveness	Investment (EUR)
Cogeneration/Trigeneration	68.0	2.61	3465.3	6162.90	12,219,494.44
Production from renewable sources	171.0	6.56	10,215.2	6973.03	25,159,500.59

Source: Authors' own elaboration based on ENEA data.

Focusing on the different areas of energy efficiency interventions, the values reported in Table 7 show the high numerosity of interventions concerning the lighting system, which constitute 11.4% of the total, followed by those aimed at improving compressed air (9.5% of the total) and those concerning the general/managerial area (6.4% of the total). Slightly less numerous are instead the EEMs associated with production lines (4.5%), signalling opportunity for companies to review production processes to improve the efficiency in the use of resources, including energy vectors. The terminology of the above areas should not mislead readers, as EEMs could refer to extensive and complex operations as well as to simpler ones. For example, energy efficiency in production lines could be attained through the replacement of a melting furnace with another one with a higher energy efficiency. In contrast, energy efficiency in the compressed air area is often associated with leak detection, which is a relatively simpler form of intervention. The production of energy from renewable sources, on the other hand, includes 171 interventions (6.6% of the total), many of which refer to installing photovoltaic panels, which increases the company's independence from the purchase of energy flows. Many efficiency measures have adaptable characteristics. For example, heat recovery can also be implemented by referring to compressed air or production lines equipment, making it relevant not only to the thermal power plant/heat recovery area, but also for the others. Therefore, the absence of such measures does not necessarily imply that there are no identified interventions that could affect the above areas.

The replacement of lighting equipment with LED is a widely identifiable and feasible intervention that would lead to the saving of 16,533.7 toe. However, it is necessary to underline how an excessive emphasis on such interventions would prevent the delineation of more efficient technological trajectories pertaining to the production processes; such emphasis is already supported by the relatively low cost of such interventions.

Concerning the extent to which the concept of innovation is extended to the introduction of new organisational forms, the general/managerial area interventions provide a better understanding of the current management of energy flows; by broadening the knowledge base, the search for new rationalisation mechanisms is stimulated. The 166 interventions identified in relation to the introduction of new organisational practices, energy management tools, and the adoption of ISO 50001 certification (general/managerial area) would allow for a reduction in consumption by 16,086.0 toe, confirming that there is large room for improvement when a more organised and careful management of energy sources is implemented within the company.

The greatest source of savings is identified instead in the area pertaining to the installation of cogenerators and trigenerators. In recent years, these systems have been the subject of in-depth studies within the European Union with the objective to identify new ways of achieving energy efficiency in buildings and industry, as they allow for the combined and simultaneous production of electrical and thermal energy, thus increasing the efficiency of installations and optimising energy self-sufficiency. This type of intervention is characterised by its criticality, relatively large scale except for micro-cogenerators, and long technical life and payback period. As a result, such measures may be implemented with resistance, which is exacerbated by the current economic conditions.

However, the implementation of the above measures would lead to a reduction in consumption of 3465.3 tons of oil equivalent for an equally important investment of EUR 12,219,494.44. Similarly, production from renewable energy sources involves a high level of initial investment, equivalent to EUR 25,159,500.59, and relatively long payback periods, which could be shortened using existing incentives. Accordingly, the associated energy savings reach 10,215.2 toe. These EEMs offer significant benefits, not only in terms of reduced consumption, cost reductions, and productivity improvements, but also in terms of competitiveness and the ability of the companies to meet their social and environmental commitments. As highlighted in Figure 1, electricity flows not only account for most of the consumption in the three NACE sectors considered, but also have the most significant savings potential; in fact, the total energy savings is given by the sum of electrical savings, which accounts for more than half of the total (75%), thermal savings, fuel savings, and other savings.

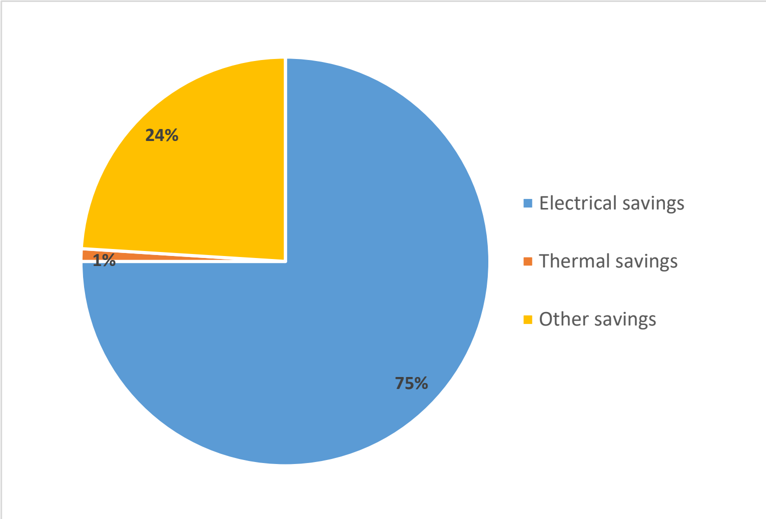

Figure 1. Breakdown of energy savings (%, calculated on savings expressed in toe). Source: Authors' own elaboration based on ENEA data.

The observations obtained from the audits also display a concentration of identified interventions related to low levels of investment and savings; overall, the companies subjected to energy audits with an investment of EUR 193,525,069.46 would be able to obtain 13,680.5 toe of primary energy savings, associated with the areas cogeneration/trigeneration and production from renewables, and 70,361.2 toe of final energy savings, relative to all other intervention areas. These savings represent an upper threshold, since not all the EEMs identified in the energy audits will be chosen for implementation.

Furthermore, given the relevance of the cost-effectiveness to business decisions regarding the adoption of EEMs, it is possible to see, as shown in Figure 2, how most interventions display levels of such indicators around EUR 5001 and 15,000, signalling a positive economic performance for many of the interventions (this comparison excludes those sectors where the financial characteristics of the investments are not comparable on a large scale, such as production of renewable energy and CHP/trigeneration.

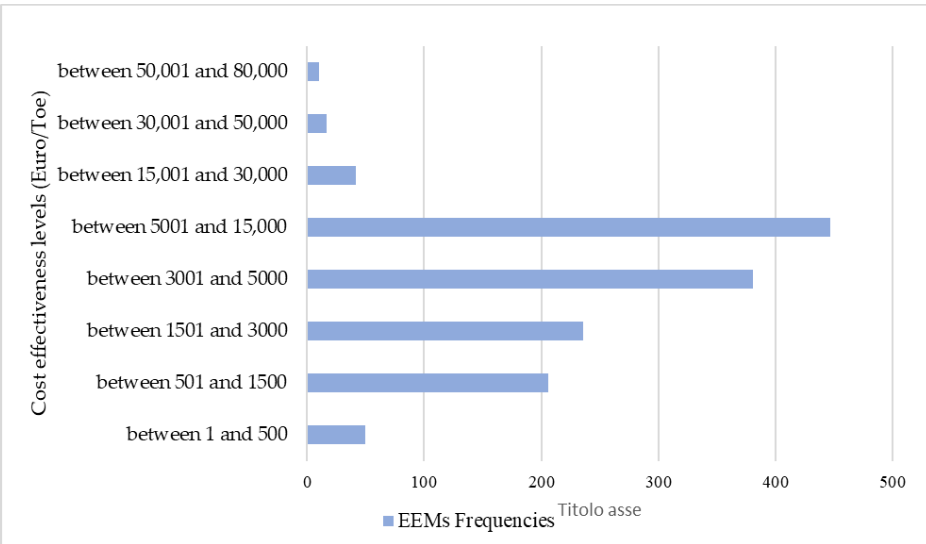

Figure 2. Cost-effectiveness levels (EUR/toe) associated with identified EEMs. Source: Authors' own elaboration based on ENEA data.

Turning our attention to the relationship between energy savings and the payback period of the investments necessary for their realisation, the weight assumed for the total savings by cogeneration/trigeneration measures and those related to the self-production of energy through production from renewables prompted us to exclude them from Figure 3. In Figure 3, we can observe a clear concentration of the achievable savings on investments characterised by medium–long payback periods (up to 5 years), which may constitute a potential constraint for the propensity to adopt the efficiency measure and for the realisation of the savings themselves. At the same time, about 26.84% of the potential savings can be achieved through less risky investment options from the point of view of business decision makers and thus characterised by shorter payback periods (up to 3 years).

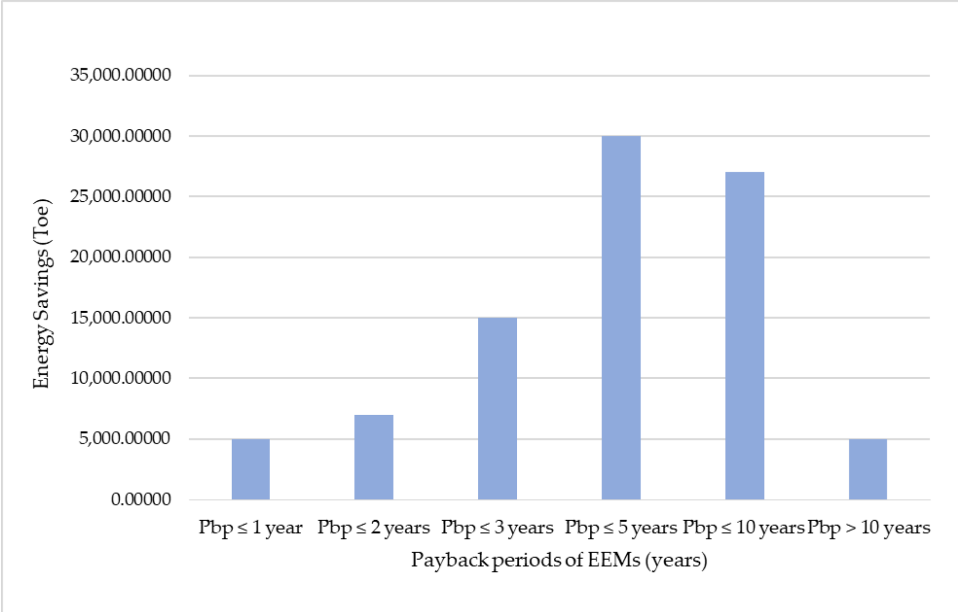

Figure 3. Payback periods associated with identified EEMs. Source: Authors' own elaboration based on ENEA data.

The regional distribution of the identified EEMs (the regional distribution refers to all energy efficiency interventions identified by the energy audits received by the plastics sector in 2019) (Figure 4) reflects the location of examined companies in the most industrialised regions of the Peninsula, namely in Northern Italy.

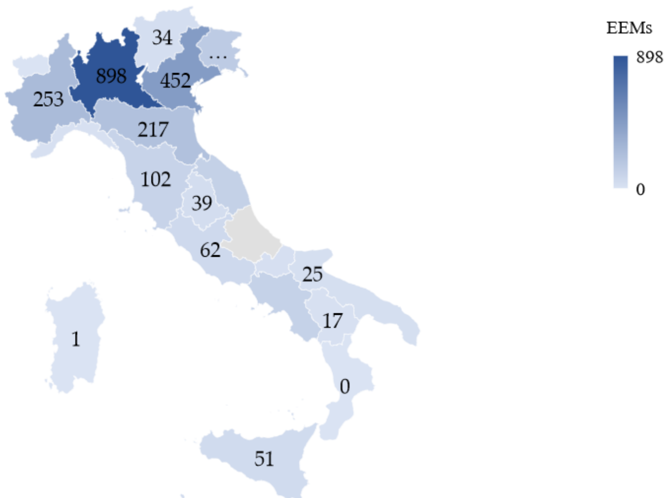

Figure 4. Regional distribution of identified EEMs. Source: Authors' own elaboration based on ENEA data.

Indeed, the analysis shows a clear concentration of identified interventions in Lombardy, Piedmont, and Veneto. Such EEMs could be implemented or not depending also on the commitment of regional governments to promote the ecological and energy transition and the consequent reduction of environmental impacts. No interventions and therefore savings are found instead for the regions of Calabria and Val D'Aosta, from which no energy audits belonging to the examined sectors were received.

4.2. Econometric Results

This section is dedicated to the discussion of empirical findings obtained through the application of the methodologies described in Section 2. The approaches employed have confirmed the great potential of the analysis of EA information, combining elements associated with the intrinsic characteristics of companies and information on measures to achieve energy savings, capable of driving the energy performance of the plastics manufacturing sector. Results are shown in Table 9. In the field of econometrics, the Breusch–Pagan (BP) test is utilised to examine the presence of heteroskedasticity, which refers to the situation when the variance of the residuals is not constant, within a linear regression model. The test is conducted in order to evaluate the null hypothesis of homoskedasticity. In this specific case, the BP test is applied to the pooled OLS model, resulting in a BP value of 42.532, accompanied by a *p*-value of 0.01124. Consequently, we reject the null hypothesis of homoskedasticity and reach the conclusion that heteroskedasticity does exist in our pooled OLS model. Considering the potential limitations of the OLS model identified through the BP test, we opt for the adoption of a nonlinear logistic regression model, incorporating a binary response variable. The results also report the mean values of the variance inflation factor (VIF) for the ordinary least squares (OLS) model. These metrics are used to gauge the degree of multicollinearity among the predictor variables. In this particular case, the low VIF values observed (1.460, 1.398, and 1.390) suggest that the variables included in the model exhibit a significant degree of independence from one another. In all models, the potential savings are calculated as primary energy savings for all interventions areas.

Table 9. Summary of econometric results.

	Pooled OLS	Pooled OLS Fixed-Effects	Logistic Regression
n (Investment)	0.626 *** (0.025)	0.870 *** (0.018)	1.057 *** (0.118)
White Certificate	0.161 ** (0.077)	0.053 (0.048)	0.224 (0.307)
PBP	−0.081 *** (0.012)	−0.103 *** (0.009)	−0.101 ** (0.046)
Cost-effectiveness	−0.00003 *** (0.00000)	−0.00004 *** (0.00000)	−0.0001 *** (0.00004)
MONITORING	−0.437 *** (0.069)		−1.070 *** (0.247)
ISO 50001	0.098 (0.169)		0.147 (0.685)
NORTH–EAST	0.036 (0.092)	−4.829 ** (2.239)	0.331 (0.329)
NORTH–WEST	0.159 ** (0.075)	−9.790 *** (1.342)	0.125 (0.271)
SOUTH	−0.143 (0.131)	−7.698 *** (2.640)	0.554 (0.407)
DEBT_RATIO	0.008 *** (0.002)	−0.086 ** (0.034)	−0.003 (0.009)

Table 9. *Cont.*

	Pooled OLS	Pooled OLS Fixed-Effects	Logistic Regression
CAPITAL_TURNOVER	−0.027 (0.082)	−4.782 *** (1.494)	−0.146 (0.287)
HVAC	0.350 * (0.179)	0.264 ** (0.111)	0.757 (0.752)
Compressed Air	0.559 *** (0.096)	0.558 *** (0.059)	0.417 (0.660)
Cogeneration/Trigeneration	1.568 *** (0.179)	1.057 *** (0.118)	3.653 *** (0.818)
Thermal Power Plant/Heat Recovery	1.108 *** (0.203)	1.456 *** (0.127)	2.957 *** (0.650)
Engines/Inverters	−0.130 (0.114)	0.073 (0.071)	1.039 * (0.569)
Electric Systems	0.460 *** (0.165)	0.084 (0.104)	1.778 *** (0.527)
General/Managerial	0.747 *** (0.111)	0.630 *** (0.069)	1.294 ** (0.554)
Production from Renewables	0.675 *** (0.132)	0.033 (0.087)	2.167 *** (0.502)
Cold Production Units	0.337 * (0.178)	0.252 ** (0.110)	1.492 ** (0.582)
Production Lines	0.486 *** (0.121)	0.326 *** (0.076)	2.000 *** (0.512)
Intake Systems	−0.284 (0.267)	−0.064 (0.173)	−11.192 (577.260)
Transport	−0.241 (0.204)	−0.187 (0.119)	2.544 ** (1.030)
CONSTANT	−10.129 *** (0.309)		−12.283 *** (1.272)
Observations	1320	1320	1320
R2	0.627	0.992	
Adjusted R2	0.620	0.988	
Akaike Inf. Crit			52.000
Residual Std. Error		1.070 (df = 1294)	0.541 (df = 891)
F-Statistic		87.110 *** (df = 25; 1294)	248.279 *** (df = 429; 891)
Studentised Breusch–Pagan Test	BP = 42.532, (df = 24, p-value = 0.01124)		
Average VIF Value	1.460	1.398	1.390

Notes: *, **, *** represent, respectively, statistically significance levels of 0.05, 0.01, and 0.001; a dot (.) represents a significance level of 0.1. These markers provide a quick visual cue to assess the statistical robustness of the findings. Source: Authors' own elaboration.

First, the coefficients related to the economic dimension of the energy efficiency measures show very encouraging results. All the specifications used led us to observe a significant and positive role of the investment level in influencing the future level of energy performances in the sector of plastic production: the greater the initial expenditure made for the implementation of the measures, the higher the likelihood of businesses experiencing a higher energy performance. In the pooled OLS model without fixed effects, the impact of the investment level on the dependent variable can be interpreted in terms of elasticity, as the logarithm is applied to this predictor (to reduce the impact of observations particularly distant from the mean). Therefore, a one-percent variation in investments is associated with an increase in savings performance equal to 0.63%. As for the OLS model including fixed effects, the elasticity among the two variables concerned reaches 0.87%, while in the logistic regression, if the investment carried out by the production sites increases, the expected percentage change in the probability that the energy-saving performance is above its average is about 187.77%.

Moreover, if the payback period (PBP) increases, the financial concern for the company decision makers increases as well, discouraging the implementation of EEMs. In the OLS without fixed effects, we observe a 0.08% reduction in the dependent variable related to a unit increase in the predictor, while once we control for firms' characteristics, this percentage reduction is equal to 0.10%. Considering the logistic formulation, the same alteration of PBP leads to a higher expected percentual change of the odds ratio, consisting of 10.62%. Overall, the outcomes relating to PBP are in line with the empirical findings of [10], confirming a role of the risk level of EEMs, therefore inherent to their different technical nature and in some cases to their economic dimension. Thus, the control effectively acts as a barrier to the adoption of EEMs.

The existing relationship between costs faced by companies and the attainable benefits proves to be a widely explored relation in the literature on energy efficiency, with the objective of reducing the resistance to the adoption of EEMs. This study, using the information extracted from the audits, contributes to empirically demonstrate the beneficial impact, albeit small, that increases in cost-effectiveness produce on energy-saving performances. All the econometric models considered confirm the significance of this parameter.

Moving on to the variables inherent to the firm's traits, in the OLS without fixed effects and in the logistic regression, it is possible to recognise the role played by the parameter monitoring, which brings a reduction in energy-saving performance (0.44% in the OLS, 191.53% in the odds ratio), although minor with respect to the other company attributes examined. Nevertheless, this does not directly imply that the monitoring of production activities is detrimental to the development of energy efficiency pathways. On the contrary, this could be related to the fact that companies already having a monitoring system have more accurate estimations of the potential savings associated with identified EEMs. For this reason, the saving potential and the performance could be adversely impacted, resulting in a means that is more "realistic".

The dummy variables representing the geographical location of the firms from which the audits, and so the relative interventions, have been received, assume distinct roles in the models considered. In the linear regression formulation with fixed effects, we clearly see the significance of all the three geographical macro areas. In the northeast, compared to all other locations, including those referring to the central part of Italy used as the reference area, a 4.83% decrease in energy performance is observed. The drop is even higher when considering the southern regions of the peninsula instead. In fact, the south parameter resulted in a 7.7% reduction in the level of energy-saving performance, compared to the other macro regions. Finally, for the north–west variable, the highest relative decrease in the dependent variable was found to be around 9.8%. Alternatively, when examining the model without fixed effects, only one macro area assumes significance, namely the northwest area, while no significance is observed for the geographic areas in the logistic modelling choice.

It is interesting to note that all these variables become significant only when we include a component that allows us to account the fact that the production sites belong to the same company, and thus the existence of common strategies and elements. Nonetheless, the contradictory results obtained by the various econometric models suggest the possibility of refining the approach to better reflect the role of the geographical location of firms and the consequences of their geographical proximity, by relying on spatial econometric methods.

Moving to the variables obtained from the AIDA database, the related parameters assume relevance exclusively for the linear regression models. Regarding the outcomes achieved, including the firm's fixed effects, we observe that the coefficients associated with the variables debt ratio and capital turnover are statistically significant; in particular, this result indicates that the greater the number of times in which the company can recover the capital invested in management through sales and revenues, the lower the rate of achievable energy-saving performance. Despite the general expectation that firms with higher profitability—and in this case, a higher aptitude for dynamic cash flows—face fewer financial constraints and thus are more inclined to adopt EEMs, the empirical evidence in several contributions, especially for manufacturing SMEs, did not confirm this hypothesis. The analysis detects a clear negative role of capital turnover, indicating how an efficient management is not necessarily linked to increases in energy efficiency: in fact, a percentage reduction of the performance equal to 4.78% has been found for the capital turnover unitarian variation.

Shifting our attention to the impact of the financial liabilities of firms (debt ratio) in the literature, this impact is generally assessed in terms of whether the availability of financing affects energy efficiency pathways, alternatively measured by considering the company's profitability. Companies encounter numerous challenges related to debt servicing due to a relatively higher share of liabilities, which discourages the adoption of the measures. Regardless, the contributions on the issue once again offer opposing propositions; for instance, the authors of [32] found that profitability has a deleterious influence on energy efficiency investments, while the authors of [33] did not find that the debt-to-equity ratio behaves as a real barrier. Concerning the finding obtained here for indebtedness, the variable debt ratio assumes relevance in both OLS approaches, but once again, conflicting results are found. In the modelling choice without fixed effects, a unit increase in liability leads to a slight percentage increment in the dependent variable (0.008%). In the alternative modelling choice, controlling for factors common to the production sites examined, the coefficient of this variable becomes negative, although it remains particularly low (−0.086%). These results suggest that the influence of an increase in the amount of debt-financed assets has a different impact on energy-saving performance depending on the characteristics of the firm.

As for the results inherent to fixed effects themselves (OLS model), since these dummies are constructed by exploiting the site ID code, they cannot be explicitly listed in this analysis as particularly sensitive information would be displayed; therefore, here, we simply confirm that they are significant for the majority of the sites considered, validating the existence of specific features, not controlled by the other predictors, common to sites belonging to the same VAT. These findings open the way for further investigation of the characteristics capable of generating better energy performances.

The intervention areas show different behavioural patterns, although most areas are significant in all the models exhibited. Beginning with the OLS model without fixed effects, we observe how, relative to all the other intervention areas and to the baseline area (represented by lighting, not incorporated in the modelling), cogeneration/trigeneration, thermal power plant/heat recovery and general/managerial assume the highest positive impact on the response parameter. Regarding the first area, such a result is not surprising given the magnitude of the measures themselves. However, it is interesting to observe the role played by the thermal power plant/heat recovery area; in fact, despite gathering 1.4% of the total identified EEMs and corresponding to 5.78% of the potential energy savings, the performance variation associated with its own unit variation is relatively high and equal to 1.11%. With regard to the general/managerial area, to quantify the associated 0.71% increase in energy performance, it is necessary to consider that the total number of interventions in this area would allow us to achieve 22.86% of potential energy savings. Production from renewable sources, similarly to the other areas, also positively affects the response variable. In the case of the fixed-effects OLS model, the findings are reasonably close to the previous ones, while in the logit model, the intervention areas where very interesting behaviours can be observed are production lines, transport, and cold production units. The last two areas account only for 1.15% and 1.69% of the total interventions individuated and are associated with an expected change in odds ratio of about 1173.05% and 344.59%, respectively.

No significance was found, in any of the model specifications considered, for the NPV associated with the energy efficiency interventions and for the per capita revenue of the production sites.

Finally, regarding the incentive policy tool included (White Certificate), its significance is detected only in the OLS formulation (without fixed effects); in particular, the coefficient suggests a performance change of 0.16%. It is, however, necessary to say that these outcomes are influenced by the assumptions underlying the construction of the White Certificate variable, which leads to an underestimation of the interventions incentivised. Moreover, the information content of the variable itself is relatively poor: more information on the economic dimension of these incentives would enrich the analysis. In addition, the literature on the subject still seems far from including instruments reflecting national and/or regional policies, but the results obtained confirm the need to broaden the prospects for the adoption of EEMs.

5. Discussion

This paper leverages a comprehensive and unique database, comprising information gathered from energy audits, a pivotal tool currently utilised for assessing energy consumption across productive sectors. The database specifically focuses on energy consumption and potential EEMs based on audits received by ENEA from the plastic production sector in 2019. The empirical methodology is anchored in econometric techniques, aimed at identifying the characteristics of companies, the socioeconomic context, and EEMs that are likely to yield above-average energy savings. The study critically examines the role of incentive policies, albeit limited to the introduction of a singular instrument, the White Certificates, at a national level. This presents an opportunity to enhance the approach by broadening the spectrum of incentive mechanisms in the model and acknowledging the influence of regional policies common across various production sites, potentially resulting in varying energy-saving performances. Moreover, the information encapsulated in the White Certificate variable could be enriched by considering the economic magnitude of such political support, rather than its mere presence or absence. This, however, necessitates comprehensive information and a data management process; indeed, it should be verified for each EEM if the White Certificate amount is included in the business plans developed in the energy audits, and then a new variable should be added to the database.

The research investigates the existence of barriers and driving factors for the adoption of measures aimed at reducing energy consumption, employing both logistic regression and linear models, resonating with the findings highlighted in the literature review. The latter model is distinguished by the inclusion of fixed effects for site identification codes, exploring potential shared characteristics among production sites within the same corporate entity. Despite testing different methodologies, the empirical results can be synthesised by acknowledging that characteristics at both the company and EEM levels significantly influence the energy efficiency trajectories of production sites. The presence of energy monitoring mechanisms, interestingly, exhibits a negative impact on the response variable. These results, however, must be contextualised considering that our dependent variable is a ratio, with the denominator representing the companies' consumption flows. This variable has greater weight than the potential savings constituting the numerator, particularly since a considerable portion of the EEMs in the database, individually, do not project exceedingly high savings in tons of oil equivalent. This indicates that monitoring mechanisms enable more precise energy savings estimates, thus enhancing the diagnostic information's quality.

The analysis also incorporates parameters pertaining to the economic productivity of the companies from which the audits were sourced, utilising an additional database on Italian companies, AIDA. A specific focus was placed on the role of companies' indebtedness;

an increase in a company's financial liabilities impacts energy performance positively in a general context but negatively when the unique characteristics of the company are considered. The interaction among companies' traits and substantial indebtedness may alter their business strategies, diverting focus from energy efficiency investments to other areas, driven by the need to manage the financial burden of debt, including interest payments and debt repayments. This shift potentially diminishes their capacity to invest in energy efficiency projects, with companies possibly prioritising debt management and creditor repayments over EE investments, adversely affecting their overall energy performance. These findings suggest the importance of technical assistance to companies, for example, in the form of energy consulting or industrial expertise, and the useful role of one-stop shops in supporting the identification and implementation of effective energy solutions, mitigating reliance on indebtedness for competencies or resources. Concurrently, encouraging the sharing of best practices among companies enhances learning and may improve EE without necessitating significant investments. In this context, the significance of Article 14 of the Decree-Law n. 17/2022 becomes apparent, promoting EEM investments in Southern Italy under specific conditions. Although a modest allocation of EUR 145 million has been earmarked for 2022 and 2023 in the form of a tax credit, the impact assessment of these policies opens avenues for future research. Since 2016, several regional calls have also been issued to finance energy audits in SMEs and sometimes also in large enterprises; in some cases, the financing was also granted for implementing EEMs identified in the energy audit. The access to such calls has been relatively limited as well as their effective results [34]. Both types of policies could not be included in the examined database.

Regarding capital turnover, an indicator of managerial efficiency, it paradoxically exerts a negative influence on our response variable. This is counterintuitive to the expectation that more dynamic companies, with fluid cash flows, would be predisposed to invest more substantially in energy efficiency measures. This anomaly could stem from prioritisation in investment choices, with companies having higher capital turnover possibly favouring investments in non-energy efficiency areas.

Another consideration relates to the investment payback period; companies with high capital turnover might gravitate towards investments with shorter recovery durations, seeking swift financial returns. Investments in energy efficiency, conversely, might necessitate longer recovery times due to higher initial costs and the gradual accumulation of energy savings. Simultaneously, per capita revenues seemingly do not influence the energy behaviour of companies, underscoring that the decision to implement measures is derived from evaluating multiple aspects, not necessarily correlated to the company's profitability.

Contrary to the findings of [23], the presence of certification related to the implementation of an energy management system (ISO 50001) did not yield conclusive results in this study. The paper also aligns with the findings of [10,22], emphasising the economic/financial dimension linked to EEMs in determining energy trajectories: higher investment levels lead to enhanced energy-saving performances. Generally, an extended period required for companies to recoup the initial expenditure acts as a deterrent to implementing EEMs. The associated risk with a longer payback period thus emerges as a significant barrier, its impact varying based on the technical nature of the measure. These findings resonate with [35]: "The probability of an investment being made decreases as the payback time in years increases, while sensitivity to these increases".

Regarding the categorisation of intervention areas, the results seem particularly noteworthy. The general categorisation area reveals that modifying energy consumption behaviours is not only broadly implementable in the sector, but also capable of affecting substantial improvements in energy performances. This mitigates concerns about the sector's future energy trajectory, particularly considering the significance of economic barriers. Furthermore, the challenge in estimating benefits associated with this intervention type affects the analysis, necessitating a nuanced evaluation of payback periods information, considering these limitations.

Geographical location, delineated by administrative divisions, exhibits distinct "genetic" traits, such as local policies, existing industrial clusters, and perceptions of necessary actions to combat climate change. These factors either directly or indirectly foster or impede future energy efficiency trajectories. Consequently, geographical variables were integrated into the models developed in this study. These variables were derived by assessing the origin of the identified measures, controlling for the macro-regional area of the companies using dichotomous variables. In summary, based on the coefficients obtained, firms in the northwestern region exhibit the lowest average energy performance, followed sequentially by those in the south and the northeast. These results validate our anticipation of regional disparities, pinpointing relatively inferior performance in the northwest. Such discrepancies are not explained by the quantity and scope of energy efficiency interventions or the number of companies, suggesting the presence of unaccounted factors in this context that might hinder the adoption of energy efficiency measures in northwestern companies. The significance of these indicators stresses the potential for further refinement of the methodology to capture the role of these spatial components more accurately, i.e., the attributes that define the genetic makeup of a specific geographical location in determining the energy performance of companies.

Furthermore, the White Certificate variable is observed to have a positive, albeit small, impact on performance. This finding necessitates an interpretation mindful of the inherent limitations of the variable. Our available data allowed only for an assessment of the obtainability of the White Certificate, not its economic value. Acquiring comprehensive information on the incentives received by companies, especially those influenced by regional policies, is a difficult task; data are scarce and elusive to ascertain. While this analysis underscores the need for more detailed and refined incentive data, it also tentatively supports the hypothesis that an incentive model based on achieved savings might not realise the anticipated impact. When the unique characteristics of companies are factored in through fixed effects, the incentive ceases to significantly influence performance. This highlights how pathways to energy efficiency can differ markedly across companies in this sector, an insight that this differentiation should inform the design of targeted policies. The heterogeneity observed at the sectoral level, as underscored by the authors of [23], reinforces these considerations, although it lies outside the current analysis's scope.

The literature published on EE improvements encompasses a diverse array of insights and conclusions. Yet, few studies venture into the realms of spatial and political contexts, integrating diverse contextual elements beyond market conditions and competitive dynamics into their analyses. The application of econometric models to evaluate viable pathways for energy efficiency is an area ripe with potential, particularly regarding the incorporation of models capable of recognising spatial correlations. Such approaches could broaden the contextual elements typically considered in models, providing enhanced opportunities to leverage robust data maintained by agencies tasked with managing energy audit databases. This study not only showcases some of the feasible analyses that can be conducted using these rich data, but also introduces a broad spectrum for future research endeavours.

6. Conclusions

Our research employs a range of econometric approaches, including three distinct models, to thoroughly examine the influence of economic, technical, and contextual factors on energy performance in the Italian plastics sector. This paper is rooted in data extracted from the 2019 energy audits of a representative sample of companies in the Italian plastics industry, encompassing over 600 enterprises. These data were further combined with management-related information extracted from the AIDA database. The analysis highlighted in multiple phases how the quality and homogeneity of EAs are crucial for the future use of these data, which possess significant analytical potential.

However, we faced significant challenges in accessing detailed information on policy tools, particularly concerning the companies that benefit from such incentives. The clarity and completeness of this information are critical for effectively assessing the efficacy of energy policies. Additionally, despite the presence of regional incentives and calls for proposals, we identified a lack of comprehensive data on these policies and their economic scope, suggesting the need for a more uniform and transparent approach to energy policies at the regional level.

Regarding company characteristics, our investigation shed light on how corporate indebtedness significantly affects their energy performance. An increase in debt can negatively impact a company's energy behaviour in relation to its unique characteristics. The presence of certain specific traits might lead highly indebted companies to reprioritise investments, shifting from energy efficiency to other areas due to financial burden. In this context, reducing informational barriers about efficiency measures could lead to a revaluation of the associated benefits and a revision of corporate strategies; technical assistance, such as energy consultancy and access to industrial expertise, can be crucial for identifying and implementing effective energy solutions, reducing dependence on indebtedness. Our study also highlighted that per capita revenues do not seem to significantly influence the energy behaviour of companies, suggesting that the decision to implement energy efficiency measures is based on the interaction of multiple factors, not necessarily linked to a company's profitability. Regarding capital turnover, we observed a negative impact on energy performance, which might also be linked to the priority assigned to investments in energy efficiency and the pursuit of rapid financial returns.

Considering these results, the authors emphasise the importance of behavioural modifications for reducing energy consumption. Although this topic has been addressed on several occasions, it tends to be underestimated, even though the implementation of such measures is generally more feasible than others. Greater promotion of efficient energy practices would lead to extensive energy conservation, especially considering the relatively lower level of investment and shorter payback periods, although difficulties in estimating the associated benefits might lead to an underestimation of the same. Furthermore, we confirmed the importance of the economic/financial dimension related to EE interventions in determining energy trajectories: higher levels of investment lead to better energy-saving performances. A prolonged payback period acts as a deterrent to the implementation of EEMs, a risk that varies depending on the technical nature of the measures. In summary, these results suggest that economic incentives aimed at reducing the resistance associated with initial investment, technical assistance, and the sharing of best practices are fundamental to stimulate the adoption of energy efficiency measures.

Turning our gaze onto the technical characteristics of the identified EEMs, our analysis displays that specific intervention areas, such as cogeneration/trigeneration and thermal power plant/heat recovery, have a more pronounced impact on the energy performance. This result underscores the potential benefits of focusing on the promotion of specific types of interventions to achieve significant energy savings in the plastics manufacturing sector. Additionally, given the relevance of energy self-production, namely cogenerators/trigenerators and plants using renewable sources, there is a need to develop ad hoc models for these intervention areas to understand the most appropriate strategy to stimulate their implementation.

From a policy perspective, our work underscores the need for tailored incentives and support mechanisms that address the specificities of companies and achievable energy savings to effectively promote energy efficiency in the plastics production sector. The current approach, which mainly design incentives based on achievable energy savings, may not be sufficiently effective in reducing the resistance associated with the implementation of measures, as evidenced by the variable impact of different EEMs and the influence of company-specific factors. Therefore, policy measures should consider the unique characteristics and needs of the specific industrial sector to facilitate the adoption of energy-efficient technologies.

Looking to the future, the analysis conducted in the plastics sector can be extended to other industrial sectors, providing insights into the specific needs of different industries and tools to compare them. The robustness of the models and results also implies the possibility of expanding the characteristics of the companies and interventions considered to obtain a comprehensive and detailed picture of the barriers and drivers to energy efficiency present in the analysed sector.

In addition, a future path for research opens, considering the possibility of exploring localised energy dynamics and the interaction between companies, foreseeing the implementation of econometric approaches capable of capturing the spatial impact of corporate behaviours; mechanisms of interaction and spillover that enhance or inhibit industrial energy performance could be identified and promoted. The process of refining data related to the third cycle of EAs (2023) will also allow us to assess which interventions have been implemented, analysing the factors that influenced the process. This approach will enable us to reach even more precise conclusions on the path to follow to stimulate the adoption of energy efficiency interventions in the considered sector.

Further research opportunities would also be possible thanks to continuous efforts of the ENEA for the promotion of high-quality energy audits and the future changes in the subjects obligated to perform EAs, an evolution that the recent legislation in this matter leaves us to suppose. In conclusion, our study provides a significant contribution to the understanding of energy efficiency in the Italian plastics manufacturing sector. Our findings offer insights for formulating effective policies and indicate promising directions for future research in the field of energy efficiency and sustainable development. By highlighting key drivers and barriers to energy efficiency, we aim to inform more effective policy decisions and encourage continued research in this vital area, emphasising the importance of tailored incentives and the need for greater transparency in information on business access to existing incentives.

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