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Empirical Evidence on Pro-Environmental Activities of Companies in Times of Energy Transformation: A Case Study of Poland

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Abstract: This article addresses a topic of critical importance globally, particularly in the context of the ongoing energy crisis, climate change, and efforts to transition towards sustainable energy systems. A growing environmental awareness among consumers, along with changing regulations on energy efficiency, forces companies to adapt their products and services to meet new market demands. Eco-innovations, such as energy-efficient technologies and environmentally friendly materials, can respond to the increasing demand for products with a lower carbon footprint and reduced energy consumption. Using structural equation modelling, our study aimed to evaluate the significance of selected determinants of enterprise activities aimed at innovations that yield environmental benefits. The analysis focused on the scale of the benefits obtained due to these innovations (e.g., reduced material or water use per unit of output, reduced energy use, reduced CO_2 footprint, reduction in pollution, or recycling of waste) and during the consumption or use of goods or services by the end user (e.g., energy savings, facilitated recycling, or extended product life). The empirical data source was a database of anonymised individual data from Statistics Poland. The database comprised 8544 industrial enterprises employing 10 or more people, of which 2714 introduced eco-innovations. To verify the hypothetical relationships between variables, we proposed a structural equation modelling method. The structural model estimates indicated that requirements arising from current and future regulations, pressure from high operational costs and administrative formalities, and reputation and incentives had a positive and statistically significant impact on the scale of benefits obtained due to these eco-innovations. The assessment of the importance of factors determining the introduction of eco-innovations differed slightly between companies of different sizes. For large enterprises, the key determinants were incentives, reputation, and law requirements. For medium-sized enterprises, incentives and reputation were the most influential. For small enterprises, reputation was the primary determinant, followed closely by pressure and incentives at a similar level.

Keywords: energy transformation process; energy efficiency; resource efficiency; eco-innovations

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1. Introduction

The European Union has set itself the objective of becoming a smart, sustainable, and inclusive economy, with a set of policies and actions aimed at making it a low-carbon and

resource-efficient economy. In the context of the increasing focus on the implementation of EU climate and energy legislation, all Member States must step up their efforts to ensure the achievement of collective energy and climate targets for 2030. These include reducing greenhouse gas emissions by at least 55% compared to 1990 levels [1], achieving a 42.5% share of renewable energy in gross final energy consumption [2], and improving energy efficiency by at least 11.7% in 2030 compared to the 2020 level [3]. As a member of the EU, Poland is tasked with contributing to these overarching objectives. Research and innovation remain key to enhancing energy and resource efficiency, reducing GHG emissions, and ensuring the competitiveness of EU companies. Through continuous research and innovation, the transformation of production and consumption patterns, and adaptation to new challenges, the economy strengthens resilience and protects the well-being of present and future generations.

As part of the energy transformation process, not only is the way energy is sourced undergoing significant change, but its utilisation and management are also undergoing a fundamental restructuring. This transformation involves the development and integration of new technologies that enable the generation, storage, and distribution of energy in a more sustainable manner. The transformation also impacts the way energy is consumed. Energy efficiency has become a central focus, with the aim of reducing overall consumption. New technologies enable consumers and companies to manage their energy use more effectively, thus reducing costs and minimising environmental impact. Policy and regulatory frameworks are also adapting to support the transformation of energy use and management. Governments are implementing policies that encourage energy efficiency, support renewable energy adoption, and incentivise innovation. Such policies include subsidies for renewable energy technologies, carbon pricing mechanisms, and regulations that mandate energy efficiency standards for buildings and industries. These changes are also influencing business practices, with companies increasingly adopting sustainable energy practices to reduce operational costs and comply with regulatory requirements.

One of the central aspects of energy transformation is the adoption of eco-innovations. Eco-innovations, which are technological advancements and innovative processes aimed at reducing environmental impacts, are pivotal in the transition towards sustainable energy systems. These innovations are crucial for meeting both national and EU climate targets. As companies in Poland adopt eco-innovations, they can simultaneously improve their operational efficiency and lower their environmental impact, contributing directly to the EU's objectives for 2030.

The relationship between eco-innovations and broader energy transformation is not limited to technological advancements but also extends to changes in consumption patterns. Eco-innovations are integral to shaping the behaviour of both producers and consumers, as sustainable solutions foster more energy-conscious consumption habits. For instance, energy-efficient products adopted by Polish consumers lead to reductions in energy demand and GHG emissions throughout their lifecycle, promoting a sustainable consumption culture. Additionally, such innovations help consumers make informed choices, which can result in a systemic shift toward a low-carbon economy. Government-supported initiatives like the Clean Air Programme (Polish: Czyste Powietrze) incentivise homeowners to upgrade insulation, replace outdated heating systems with heat pumps or modern gas boilers, and install photovoltaic panels. These measures significantly reduce household energy consumption and carbon emissions, while also fostering a mindset shift toward more responsible and efficient energy use in everyday life. The dynamic nature of these changes requires ongoing research. Innovation and environmental issues are two key areas shaping the development trends of the European Union. They are viewed as opportunities to enhance European enterprises' competitiveness and address modern challenges arising

from mass production and resource consumption, as well as the resulting environmental threats. The adoption of innovative technologies that improve energy efficiency, reduce emissions, and contribute to decarbonization is central to the country's ability to meet its climate and energy goals. In this way, Poland not only aligns with the EU's broader energy transformation agenda but also positions itself as a key player in the development of sustainable energy solutions for the future.

Eco-innovations can lead to multiple advantages, with benefits realised both within the enterprise (e.g., reduced material or water use per unit of output, reduced energy consumption, reduced CO_2 footprint, less pollution, substitution of materials with less polluting or hazardous alternatives, use of renewable energy instead of fossil fuels, and recycling of waste, water, or materials for internal use or sale) and during the consumption or use of goods or services by the end user (e.g., reduced energy consumption, reduced CO_2 footprint, less pollution, facilitation of product recycling after use, and extended product life through increased durability). Therefore, it is of particular interest to explore the following questions: What motivates Polish industrial enterprises to engage in innovations that benefit the environment? What factors influence the increase in the environmental performance of eco-innovations?

This study aimed to assess the significance of factors motivating enterprises to engage in eco-innovation activities. The factors were considered from the perspective of their obligatoriness and were divided into the following: (1) formal requirements, (2) incentives from future demand or available funds, (3) the enterprise's image (reputation), and (4) pressure from high costs and formal requirements in public tenders. The study utilised data from 2714 industrial enterprises (small, medium, and large) operating in Poland in 2020.

Despite the growing interest in eco-innovation at both national and EU levels, a significant research gap persists in the comprehensive identification of the conditions that facilitate its implementation—particularly in the context of Central and Eastern European countries.

The Community Innovation Survey (CIS), coordinated by Eurostat, serves as a key data source for analysing innovation activities among enterprises across the EU. The most recent iteration of the survey, conducted in close cooperation with member states, enables a more detailed examination of knowledge flows, external drivers of innovation, and—most notably—eco-innovation. Nevertheless, CIS data still fall short of providing a comprehensive understanding of the determinants driving eco-innovation implementation, especially in less-developed contexts.

Our research seeks to address this gap by providing empirical evidence on the specific factors that promote eco-innovation. The analytical model we developed has enabled the identification of the most influential determinants supporting eco-innovation activities. This study contributes to the existing literature by offering new insights into eco-innovation, based on unique individual-level data that is not publicly available, while also underlining the need for further, in-depth analyses that account for national contexts and structural disparities among EU member states.

Beyond theoretical contributions, it is important to emphasise the broad and representative nature of our dataset, which constitutes a key methodological strength of this study. This article builds upon and expands the conclusions drawn by previous research using the PNT-02 dataset (in the context of Poland) and the Community Innovation Survey (in other countries). It provides additional empirical evidence by distinguishing the specific drivers of eco-innovation from those of other innovation types, thereby enriching the ongoing academic discourse.

By examining the factors that influence eco-innovative behaviour, our study enhances our understanding of the unique mechanisms underpinning environmentally focused innovation. Furthermore, the findings contribute to the broader debate on the extent to which

the drivers of eco-innovation are context-dependent and shaped by national institutional, regulatory, and economic conditions. Ultimately, this research advances the academic discussion by concentrating specifically on eco-innovation—a subject underrepresented in previous empirical studies using the PNT-02 dataset. We propose a refined model that isolates key eco-innovation drivers, particularly those related to environmental regulation and company-level behavioural change, which have not previously been jointly analysed within the Polish context.

2. Research Background

2.1. Determinants of Eco-Innovation

Research on eco-innovations is developing dynamically [4–14]. Implementing eco-innovations involves numerous activities and requires a broader perspective on the factors influencing them. Various ways of classifying eco-innovations' determinants can be found in the literature Table 1. Šūmakaris, Korsakienė, and Ščeulovs [15] classified energy-efficient innovation determinants into three levels: micro (e.g., cost savings, prior experience, technological and green capabilities, organisational innovations, financial resources), meso (e.g., competitive pressure, customer and supplier expectations, social pressure), and macro (e.g., government subsidies, regulatory frameworks).

Table 1. Determinants of eco-innovations.

Level	Determinants	Source
Macro	Government subsidies, regulatory frameworks	[4,15]
Meso	Market dynamics (e.g., new customer needs and market segments), pressure groups, competitive pressure, customer and supplier expectations, and social pressure	[4,15]
Micro	Cost savings, prior experience, technological and green capabilities, organisational innovations, financial resources, owner/manager values, firm performance and competences related to eco-innovation, as well as firm reputation and talent attraction	[4,7,15]

Source: own elaboration.

Some authors divide eco-innovation determinants into internal and external factors. External factors include environmental regulations [16,17], ecological awareness, the pro-ecological expectations of consumers, and market linkages with information and technology partners [18]. Internal factors include cost savings [4], managerial environmental awareness [19], corporate environmental policy [20], flexibility and ability to respond quickly [21], better adaptation to customer needs and providing them with greater added value [22], and professional skill development for long-term competitive advantage [5]. The proposed dependency models include factors such as technological factors, financial factors, organisational factors, informational resources, research and development activities [23], quality, cost, and life cycle assessment [24].

Scientists strive to identify dependencies and look for moderators and mediators of these processes. Despite extensive research, there is no consensus on how these factors influence eco-innovation, with variations depending on the industry [8,25], type of innovation (products eco-innovations vs. process eco-innovations) [26], company size [8], sectors (ICT vs. industry) [27] and cultural influences [28].

2.2. Policy Instrument Pressure

State regulations play a significant role in environmental protection, often stemming from international commitments. A prominent example of globalisation's influence is the

standardisation of laws. One of the basic environmental protection directives is the "polluter pays" principle. In this respect, Poland's course of action in the area of environment is consistent with its international legal obligations. In Poland, the principle of "the polluter pays" is embedded in the Art. 7 of Environmental Protection Law. This principle states that entities causing pollution bear the costs of remedying its effects.

The primary goal of regulations is to mitigate human activity's negative environmental impact while encouraging the development and enforcement of environmentally friendly technologies and practices. Increasing environmental risks drive the introduction of new laws and incentives regulating product design, production, and disposal. These regulations may impose constraints or offer benefits, such as tax reliefs and grants, encouraging eco-friendly investments.

However, the regulator and its addressee (the enterprise) assess a legal act differently. From the enterprise's perspective, the following seem particularly important: overregulation, frequent changes in legal regulations, possible loopholes in the law, and difficulties in implementing legal provisions. From a business perspective, regulatory compliance is often seen through financial and operational impacts. By adapting their strategies and activities to regulatory requirements, companies can meet legal obligations and gain a competitive advantage in the market [29–31]. While regulations can compel or encourage enterprises to innovate [20,32–34], they can also restrict competition or slow innovation diffusion. For example, a study of Chinese industrial companies from 2005 to 2015 found a U-shaped relationship between environmental regulations and technological innovations. Initially, regulations impose costs and have an offsetting effect on the research and innovation capacity of the industrial sector, but as they intensify, companies improve their technological capacities to reduce pollution (a compensatory or promoting effect) [35,36].

Public procurement in Poland plays a key role in implementing green development policies, serving as an essential tool in achieving sustainable development goals and driving the energy transition. Poland has adopted four National Action Plans for Sustainable Public Procurement, and since January 2022, the National Procurement Policy for 2022–2025 has been in force, promoting the procurement of innovative and sustainable products and services (e.g., high-quality food, energy-efficient devices, and eco-friendly equipment) by public institutions. The Interministerial Team for Green Public Procurement is initiating actions aimed at the broader incorporation of environmental considerations in public procurement.

2.3. Customer Pressure

Changes in consumer behaviour result from various social, economic, and environmental factors. Environmentally conscious consumers often support the idea of sustainability for future generations [37]. Research shows that rising ecological awareness influences product and service markets [38], with consumers seeking environmentally friendly options [39,40]. However, these trends mainly apply to highly aware consumers [41].

Recognising evolving market trends, such as rising consumer awareness, is crucial for building a competitive advantage. Customers are vital sources of market information and can influence efficient resource management [42,43]. Customers can exert influence by purchasing a new organic product or boycotting a non-organic product [44]. Based on a study of 239 manufacturing companies, Awan, Arnold, and Gölgeci found that customer-oriented strategies have a more substantial positive impact on green product innovations than process innovations [45]. In turn, a study conducted on a sample of 223 Slovenian companies shows that customer demand is one of the factors facilitating the implementation of eco-process innovations [46].

Introducing eco-innovations is also considered to result in a good company image in customers' eyes [47–49]. However, stakeholder pressure does not always yield significant results—some companies adopt minimal environmental innovations solely for image purposes [50,51]. Porter and van der Linde [52] observed that companies often implement eco-innovations to justify higher prices, enter new markets, or attract eco-conscious consumers. However, if customers are unwilling to pay a premium, companies may hesitate to invest in green innovations [53].

2.4. Enterprise Size

In light of the existing literature, enterprise size appears to be a key characteristic influencing the capacity to implement eco-innovation. According to Pereira and Vence [54], larger enterprises are more likely to engage in such innovation due to their greater access to financial, human, and technological resources. Large firms also benefit from economies of scale, which further facilitates the adoption of green practices [55,56]. In contrast, small and medium-sized enterprises tend to lag behind in terms of eco-innovation performance. These disparities highlight the need for tailored support mechanisms that address the specific challenges faced by SMEs in the eco-innovation landscape. Axenbeck [57] explored the relationship between environmental innovation and firm profitability, with particular emphasis on the firm's size. The study revealed that small and medium-sized enterprises may derive greater relative benefits from eco-innovations than large enterprises, especially in terms of improvements in resource efficiency. This finding suggests that, while larger firms often have more capacity to invest in innovation, SMEs may experience more pronounced gains when implementing environmental solutions.

2.5. Other

Among the determinants of eco-innovation, other factors also play an important role in influencing business decisions. These include the sector in which the enterprise operates, its location, and the potential for cooperation with other companies, suppliers, or the scientific community, which serves as a source of knowledge and new technologies. Unfortunately, due to a lack of available data, these factors were not included in the model presented in the following part of our study.

Cooperation between companies, research institutions, governments, and NGOs fosters the exchange of technical knowledge, best practices, and innovative ideas. Such collaboration helps overcome knowledge barriers commonly associated with the development of green technologies. By working together, stakeholders can share costs, infrastructure, and skilled personnel—thereby reducing financial risk and accelerating innovation. Eco-innovation often requires behavioural change, and collaboration with community groups, NGOs, and local stakeholders is essential in building public awareness and support, which is critical for widespread adoption. Cross-sector partnerships, in particular, can spark novel solutions that might not emerge within a single discipline or firm.

In the context of eco-innovation, collaboration between scientific institutions and businesses plays a particularly important role. Some studies suggest that R&D cooperation is more prevalent among environmental innovators compared to other types of innovators. This supports the idea that environmental innovations are inherently more reliant on external partnerships due to their systemic nature, complexity, and the difficulty in assessing their benefits [58].

At the same time, evidence shows that effective cooperation between science, industry, and government often encounters considerable barriers—especially in the implementation of low-emission technologies. Without adequate R&D funding and government support, initiatives to deploy low-carbon technologies frequently fail to succeed [59].

The sector in which a business or organisation operates also significantly influences eco-innovation, shaping the type, scale, and adoption of sustainable innovations. As research conducted by Świadek, Gorączkowska, and Godzisz indicates [27], among 3000 Polish enterprises from both the industrial and ICT sectors, ICT companies tend to follow a different eco-innovation path compared to industrial firms. ICT enterprises typically pursue a narrower route, which includes innovation cooperation with suppliers, the development of loan funds and training/advisory centres, and conducting research on innovative competitor technologies and consumer preferences. Journals and magazines are an important source of knowledge for ICT firms. In contrast, when it comes to the industrial sector, although companies may be influenced by a wide range of factors, the impact of any individual condition tends to be weaker than in the ICT sector. Thus, the industry can be described as taking a more horizontal approach—where many different conditions are present, but each has a relatively low influence on eco-innovation.

3. Methods and Data

3.1. Structural Model of Eco-Innovation Activities in Polish Enterprises—Assumptions

The following question arises: What motivates enterprises to engage in eco-innovation activities? Are coercive measures the primary factor driving environmental protection efforts, or does the importance of reputation, meeting customer expectations, and pursuing ambitious development goals play a more significant role? Or, perhaps, are cost factors are critical? Studies suggest that environmental regulations and customer pressure (and consequently, a company's reputation and adherence to good practices) are important drivers for adopting eco-innovations.

We sought answers to these questions based on data analysis focused on medium and large enterprises operating in Poland. To address the research problem, the following hypotheses were formulated:

H1: Requirements (REQ) arising from environmental regulations and current or anticipated tax solutions significantly influence the implementation of eco-innovations in industrial enterprises.

H2: Reputation (REP)-building significantly influences the implementation of eco-innovations.

H3: Incentives (INC) related to future demand or available financial resources are critical for implementing eco-innovations.

H4: Pressure (PRE) resulting from high costs (e.g., materials, water) and formal requirements related to public procurement significantly contribute to environmental benefits stemming from implemented solutions.

A structural equation modelling (SEM) procedure was applied to test these hypothetical relationships between the variables. The SMART PLS 4 software [60] was used to estimate individual parameters and evaluate the model's fit. The models underwent a two-step statistical validation process:

1. Measurement Model Evaluation: This included analyses of theoretical validity and tool reliability, using the following tools:
    - Cronbach's alpha, with a minimum required value of 0.6;
    - Convergent validity, assessed via AVE (Average Variance Extracted), with desirable values above 0.5;
    - A statistical significance level of 0.05;

- A critical value of 0.5 to assess indicator weights and their importance in shaping higher-order constructs.

2. Structural Model Evaluation: This included assessing the significance of relationships between the constructs defined in the model.

3.2. Data

The primary source of empirical data used in this study was a database of anonymised individual data provided for this research. The data were derived from the Statistics Poland (GUS) survey "Innovations in Industry" (PNT-02), conducted in the 2018–2020 period. This public statistics survey, based on OECD and Eurostat methodologies (Community Innovation Survey), examines innovation activities in enterprises.

The database included 8544 industrial enterprises with at least 10 employees, covering specific sectors (B—Mining, C—Manufacturing, D—Electricity supply, E—Water supply and waste management). Out of these, 2714 enterprises (31.8%) introduced at least one eco-innovation. These enterprises became the focus of analyses using structural equation models.

According to Statistics Poland methodology, eco-innovations refer to new or improved products or business processes that generate positive or reduce negative environmental impacts compared to previous solutions and are made available to users or implemented in operations. Environmental benefits can arise during production or usage phases and include the following:

- Reduced material or water consumption;
- Lower energy intensity or CO_2 emissions;
- Reduced pollution of soil, water, air, or noise;
- Use of less polluting or hazardous materials;
- Increased reliance on renewable energy sources;
- Recycling of waste, water, or materials;
- Extended product lifespan.

The motives for implementing eco-innovations were grouped into four categories for this model (Table 2).

It was assumed that recognising opportunities or necessities from external factors should translate into implementing eco-innovations. The high importance given to these factors correlates with the higher environmental benefits of eco-innovations, which stimulate increased activity. The relationships may vary depending on enterprise size.

Table 2. Groups of analysed variables.

Group of Factors	Description
Requirements (REQ)	Factors beyond enterprises' direct control include current or future environmental regulations, taxes, or penalties. These regulations often serve as climate policy tools. In Poland, there are about 20 different taxes and fees related to the environment in the areas of energy, transport, environmental pollution, and natural resources [61]. They aim to include ecological costs in the price of a service or product or direct producers and consumers towards activities characterised by greater environmental respect [62]. It is worth mentioning here that the new reporting obligations that are in force for 2024 (these regulations were not mandatory at the time of the study) are based on the European Union directive on corporate sustainability reporting (Corporate Sustainability Reporting Directive, CSRD) [63].
Pressure (PRE)	Factors with limited enterprise influence include high energy, water, material costs, or public procurement requirements.

Table 2. *Cont.*

Group of Factors	Description
Incentives (INC)	External factors supporting environmentally beneficial innovations, including government grants, subsidies, and increased demand for climate-adaptive products. Here, state policy tools constitute a factor in the supply side of innovative enterprise activity, such as government grants, subsidies, or other financial incentives to introduce eco-innovations. In this case, this form of support for innovation capacity mainly depends on decisions at the enterprise level. This category also includes a demand side factor, i.e., growing customer demand for products that help mitigate climate change or adapt to it (e.g., low-emission products). In this case, too, the decision to create an offer for this group of customers mainly depends on the enterprise's decision.
Reputation (REP)	Voluntary actions related to reputation building, such as adopting good environmental practices.

Source: own elaboration.

The list of measurement indicators (Table 3) was derived from theoretical considerations and the PNT-02 questionnaire.

Table 3. Specification of model variables.

Latent Variable	Observable Variable	
	Symbol	**Description**
Environmental Benefits (ECO)	ECO_1	Benefits obtained within the enterprise include the following: A. Reduced material or water use per unit of output; B. Reduced energy use or CO_2 'footprint'; C. Reduced soil, noise, water or air pollution; D. Replaced a share of materials with less polluting or hazardous substitutes; E. Replaced a share of fossil energy with renewable energy sources; F. Recycled waste, water, or materials for own use or sale.
	ECO_2	Benefits obtained during the consumption or use of a good or service by the end user include the following: A. Reduced energy use or CO_2 'footprint'; B. Reduced air, water, soil or noise pollution; C. Facilitated recycling of products after use; D. Extended product life through longer-lasting, more durable products.
Requirements (REQ)	REQ_1	An assessment of the importance of existing environmental regulations.
	REQ_2	An assessment of the importance of existing environmental taxes, charges or fees.
	REQ_3	An assessment of the importance of environmental regulations or taxes expected in the future.
Pressure (PRE)	PRE_1	An assessment of the importance of the high cost of energy, water, or materials.
	PRE_2	An assessment of the importance of the need to meet requirements for public procurement contracts.
Reputation (REP)	REP_1	An assessment of the importance of improving the enterprise's reputation.
	REP_2	An assessment of the importance of voluntary actions or initiatives for environmental good practice within the sector.
Incentives (INC)	INC_1	An assessment of the importance of government grants, subsidies, or other financial incentives for environmental innovations.
	INC_2	An assessment of the importance of current or expected market demand for environmental innovations.
Size Class (control variable)	SIZE	Size of enterprise: small (10–49 employees; S); medium (50–249 employees; M); large (250 or more employees; L).

Source: own elaboration.

Each latent variable (e.g., Pressure, Reputation) was measured using assigned observable variables, rated on a 4-point scale (1—not important, 4—very important). The

enterprise size class was represented by values [4,8], reflecting enterprise size leaps. The observable variables (assigned to the latent variable ECO environmental benefits) were classified using the following values: 0—no innovation beneficial to the environment was introduced; 1—an innovation with a negligible contribution to environmental protection was introduced; 2—an innovation with a significant contribution to environmental protection was introduced.

4. Results

4.1. Eco-Innovation in Polish Enterprises

During the examined period (2018–2020), out of the surveyed 8544 enterprises employing nine or more people, 31.8% indicated that they carried out innovative activities with positive environmental effects.

The highest percentage of enterprises implementing environmentally beneficial innovations at the stage of production or product use was recorded among the largest enterprises (over 249 employees), with 50.2% introducing eco-innovative solutions. Among medium-sized enterprises (50 to 249 employees), the percentage was approximately 31.4%, while, for small enterprises, it was 24.9%.

Most of the surveyed enterprises declared that, during the examined period, they implemented eco-innovations both at the production stage and at the product use or service utilisation stage (Figure 1). Regardless of the enterprise size, this percentage exceeded 60%. About a quarter of enterprises declared implementing eco-innovations only at the production stage, while a few reported implementing solutions whose effects were visible only during product use or service utilisation.

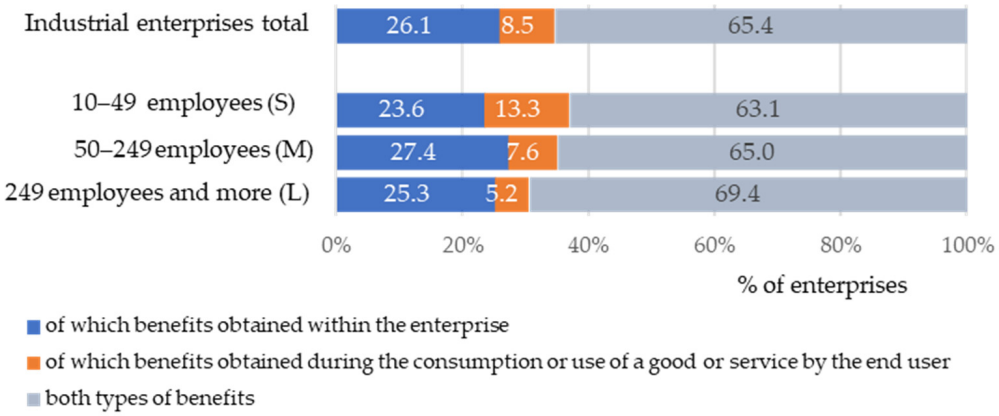


Figure 1. Structure of industrial enterprises conducting eco-innovative activity by type of eco-activity (2018–2020). Source: own elaboration.

The effects of eco-innovation activities included various environmentally beneficial changes. Most enterprises, regardless of size, generally assessed the implemented changes as minor (Table 4). Enterprises most frequently (over 52% combined) indicated internal changes related to recycling (ECO_{1F}), reducing soil, water, and air pollution or noise levels (ECO_{1C}), and lowering material consumption or water usage (ECO_{1A}) as significant or somewhat significant effects of eco-innovation. The highest percentage of enterprises declaring internal changes was among those employing over 249 people, while the lowest was among small enterprises (10 to 49 employees). For example, nearly 58% of large enterprises implemented significant or minor changes in recycling (ECO_{1F}), compared to 53.2% of medium enterprises and just under 52% of small enterprises. The greatest differences were observed in effects related to reducing energy consumption or CO_2 emissions (ECO_{1B});

here, 61.7% of large enterprises achieved these results, compared to 50.1% of medium enterprises and only 43.9% of small enterprises.

Table 4. Share of industrial enterprises implementing innovations with environmental benefits (2018–2020).

Specification	Total		Employed Persons					
			over 249 (L)		50–249 (M)		10–49 (S)	
	Significance Level							
	Low	High	Low	High	Low	High	Low	High
Innovation with benefits obtained within the enterprise								
ECO_{1A}	36.0	16.0	38.9	21.7	36.8	14.9	32.1	13.6
ECO_{1B}	33.0	17.9	37.4	24.2	33.5	16.6	28.2	15.7
ECO_{1C}	36.0	16.3	39.8	21.0	34.8	15.1	35.6	15.1
ECO_{1D}	36.1	14.0	40.0	17.4	36.0	12.4	33.2	14.9
ECO_{1E}	21.9	11.4	22.8	13.0	22.2	10.8	20.5	11.5
ECO_{1F}	35.3	18.5	34.2	23.7	35.0	18.2	36.8	14.9
Innovation with benefits obtained during the consumption or use of a good or service by the end user								
ECO_{2A}	34.9	18.0	36.3	20.3	33.9	16.9	36.0	18.5
ECO_{2B}	31.1	15.3	29.3	17.9	31.0	13.4	32.6	17.1
ECO_{2C}	27.0	12.6	27.7	13.7	26.2	12.4	28.2	12.3
ECO_{2D}	29.2	15.4	30.4	15.7	29.3	14.5	27.9	17.0

Source: own elaboration.

The most commonly introduced effect of eco-innovation at the product or service usage stage was reduced energy consumption or CO_2 emissions (ECO_{2A}), reported by 56.6% of the largest enterprises, 54.5% of small enterprises, and only 50.8% of medium enterprises.

The least frequently reported change, regardless of enterprise size, was product or service modifications aimed at facilitating product reuse (recycling) after its life cycle (ECO_{2C}) (large: 41.4%; medium: 38.6%; small: 40.5%).

In the discussion of the results, several important conclusions can be drawn regarding the differences between firms of varying sizes and their eco-innovation outcomes. First, a noticeable trend emerges wherein larger enterprises are more likely to implement environmentally beneficial changes, which can be attributed to their greater financial and technological resources, as well as a better capacity to invest in sustainable development. The data show that firms employing more than 249 people report a higher percentage of implemented changes, particularly in areas such as recycling, reducing material consumption, water usage, and lowering CO_2 emissions and energy consumption. In contrast, small enterprises (with 10–49 employees) report noticeably lower percentages of similar changes, suggesting a limited capacity for engaging in eco-innovation due to smaller financial resources, a lack of specialised expertise, or difficulties in accessing the appropriate technologies, which could indicate a need for further support through public policies that facilitate the adoption of more advanced environmental solutions.

4.2. Motivations for Engaging in Eco-Innovation: The Case of Polish Industrial Enterprises

Enterprises attribute varying levels of importance to factors influencing their decision to engage in innovative activities. The most common response was the assessment of a factor as "important", while "very important" was less frequently indicated (Figure 2).

The "important" rating was most commonly chosen for all factors except two: financial incentives (INC_1) and the pressure factor related to public procurement procedures (PRE_2). The latter was rated as "unimportant" by 40% of enterprises, while financial incentives were

slightly more frequently rated as "somewhat important" (33%), with a similar percentage rating them as "unimportant" (30%) and "important" (28%).

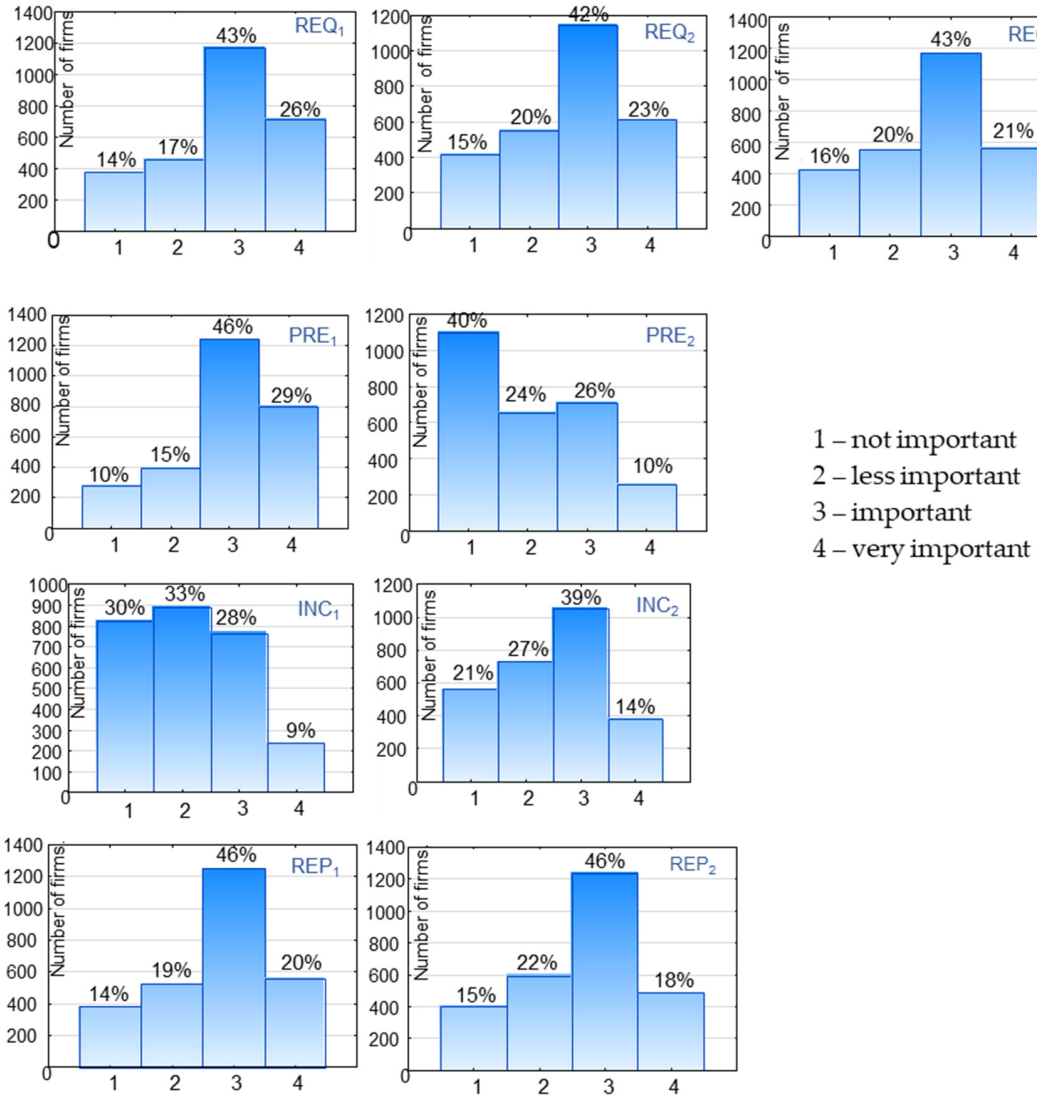


Figure 2. The distribution of industrial enterprise assessments of the importance of motives in deciding to implement innovations that provide environmental benefits (2018–2020). Source: own elaboration.

Figure 3 presents the share of enterprises by size, indicating a factor as important or very important in their decision to implement eco-innovations. Factors were ordered from most to least important. Analysing the values, the ranking of importance for individual factors is consistent across all enterprise sizes. However, the percentage of enterprises identifying each factor as significant varies by size, with larger enterprises more frequently identifying factors as important than medium and small enterprises. This percentage exceeded 20% for all enterprises but reached nearly 43% for large enterprises and was below 18% for small enterprises. Similarly rated factors included regulatory requirements (REQ_1) and factors related to company reputation (REP_1).

These findings suggest that, while enterprises acknowledge the relevance of various motivating factors, their overall perception of intensity remains moderate, with most factors rated as merely "important" rather than "very important". This may reflect a cautious or pragmatic approach among firms, especially in the context of uncertainty regarding the long-term benefits or implementation costs of eco-innovation. The relatively low perceived importance of financial incentives and public procurement-related pressures is particularly

noteworthy. It may indicate either limited access to or awareness of such mechanisms, or scepticism regarding their actual impact. Interestingly, the stronger recognition of these factors among large enterprises supports the notion that firm size correlates with institutional capacity and resource availability—both of which enhance responsiveness to external drivers. These patterns underscore the need for differentiated policy instruments that better resonate with the capabilities and priorities of small, medium, and large enterprises.

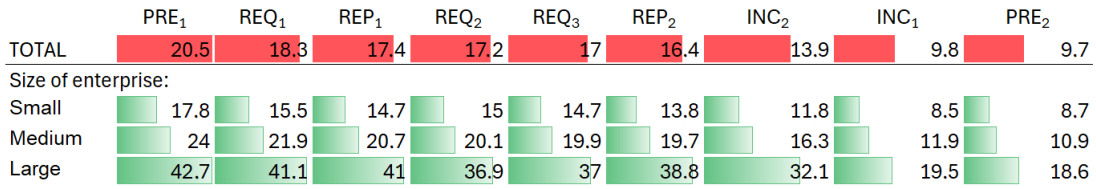


Figure 3. The importance of factors in deciding to implement innovations that provide environmental benefits in industrial enterprises (2018–2020) (sum of replies of "important" and "very important"). Source: own elaboration.

The least frequently identified important or very important factors for engaging in eco-innovation were financial incentives such as grants and the pressure related to meeting public procurement requirements, both of which were indicated by fewer than 10% of enterprises overall. However, the percentage was slightly higher for large enterprises, reaching nearly 20%.

It should also be noted that the interpretation of these results is subject to limitations arising from the construction of the PNT-02 questionnaire. The use of ordinal measurement scales, while common in survey-based research, may limit the ability to capture more nuanced differences in respondents' perceptions. For example, the categories "important" and "very important" (e.g., Figure 2), as well as "significant" (indicated as "low" for clarity in Table 4) and "less significant" (indicated as "high" in Table 4), may not fully reflect subtle distinctions. These methodological considerations should be taken into account when generalising the findings and may guide future improvements in survey design.

4.3. Structural Models of Eco-Innovation Activities in Polish Industrial Enterprises by Size Class

Figure 4 presents a structural model of eco-innovation activity based on 2714 units, illustrating relationships between variables (Requirements, Pressure, Incentives, Reputation) and the dependent variable ECO, controlled for Class Size.

Table 5 provides the parameters for three structural models estimated for different enterprise size categories (small, medium, large) and the entire set of enterprises.

Table 5. Structural model of eco-innovative activity of industrial enterprises by size class (path coefficients) (no control variable, i.e., size of enterprise).

	Total		**Small**		**Medium**		**Large**	
Pressure → ECO	0.092	(0.000)	0.120	(0.011)	0.091	(0.002)	0.078	(0.069)
Requirements → ECO	0.071	(0.001)	0.050	(0.167)	0.059	(0.027)	0.124	(0.010)
Reputation → ECO	0.162	(0.000)	0.182	(0.001)	0.142	(0.000)	0.156	(0.003)
Incentives → ECO	0.179	(0.000)	0.119	(0.023)	0.221	(0.000)	0.163	(0.002)

Source: own elaboration.

The models underwent a two-stage statistical verification. Initially, the measurement models were assessed (Table 6). The analyses demonstrated satisfactory theoretical validity and reliability. According to Ursachi et al., a Cronbach's alpha value between 0.6 and 0.7 indicates an acceptable reliability level, while a value of 0.8 or higher indicates a very good reliability level [64]. Most variables had a Cronbach's alpha and composite reliability

exceeding the 0.7 threshold [65,66]. For the Pressure (PRE) construct, the Cronbach's alpha and composite reliability values were below 0.6. However, the construct was retained due to its theoretical significance, and other indicators (AVE, composite reliability) showed acceptable values.

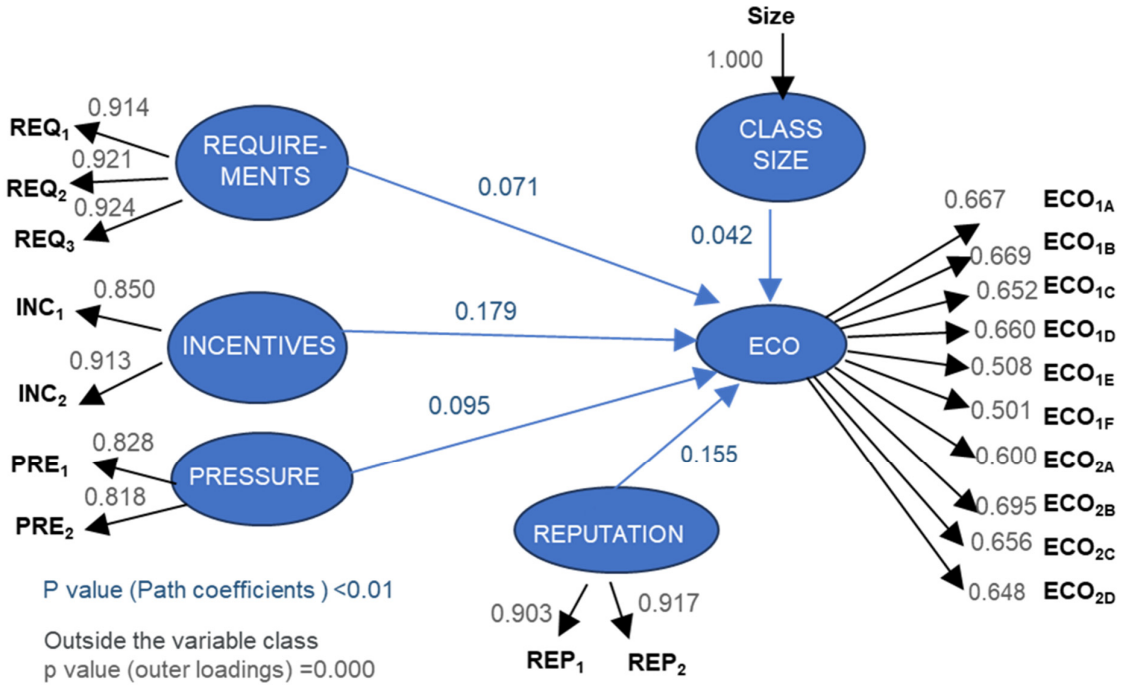


Figure 4. Structural model of eco-innovative activity of industrial enterprises. Source: own elaboration.

Table 6. Measurement model assessment: reliability and convergent validity (model for enterprises total).

	Cronbach's Alpha	Composite Reliability (rho_a)	Composite Reliability (rho_c)	Average Variance Extracted (AVE)
Pressure	0.523	0.523	0.807	0.677
Requirements	0.909	0.910	0.943	0.847
Reputation	0.793	0.793	0.906	0.829
Incentives	0.719	0.719	0.877	0.781
ECO	0.828	0.834	0.866	0.396

Source: own elaboration.

The convergent validity, measured using AVE (Average Variance Extracted), remained above the 0.5 threshold, verifying measurement reliability [67,68]. AVE was below the threshold only for the ECO construct. However, according to Fornell and Larcker [69], if AVE is below 0.5 but composite reliability exceeds 0.6, the convergent validity can still be considered adequate. Therefore, the ECO construct was left in the model, considering that it is a construct of significant theoretical importance for the tested model, and other indicators (Cronbach's alpha, composite reliability) show acceptable values.

In a formative measurement model, collinearity issues occur when two or more indicators are highly correlated, which can inflate the standard error. The variance inflation factor (VIF) was used to check for indicator collinearity. Researchers commonly use a VIF threshold of below 3 [70] or below 5 [67]. During the analysis of the study results, it was observed that the variance inflation factor values fell within the desired range, remaining below the threshold of five.

The next step is to evaluate the statistical significance and relevance of the outer weights in the model. These weights indicate the relative importance of each formative indicator in shaping the higher-order construct. It is important to ensure that the loading of formative indicators is higher than 0.5. According to Bollen and Diamantopoulos [71], formative indicator variables capture the entire essence of the construct and are not interchangeable, unlike reflective constructs. Therefore, formative measurement indicators should not be automatically removed.

In the general model (with Size as the control variable) shown in Figure 4, all indicators reflected the constructs with similar strength.

The structural model estimates indicated that Pressure, Requirements, Reputation, and Incentives had a positive, statistically significant effect on the ECO variable in the case of the total number of enterprises (Table 5). These factors (Pressure, Requirements, Reputation, Incentives) work synergistically, creating a comprehensive motivational system for eco-innovation.

Cost-related pressures and formal public procurement requirements (Pressure) influenced eco-innovation decisions, driving resource optimisation for environmental benefits. Meanwhile, environmental regulations (Requirements) created a framework requiring enterprises to adopt greener technologies and processes. However, Reputation and Incentives emerged as stronger drivers of eco-innovation across all enterprise sizes. Reputation protection is crucial, as consumer trust loss can impact financial performance significantly, making image preservation a priority. Economic incentives, such as grants and subsidies, further motivate enterprises to invest in eco-friendly solutions.

Regarding size-specific results, the p-value exceeded 0.05 in two cases, indicating a non-significant relationship (Table 5). For large enterprises, Pressure had a relatively weak and statistically insignificant effect on the ECO variable, as high costs of materials, energy, and water often lie beyond their control. This result may be influenced by including two differently assessed phenomena in the Pressure factors: costs and requirements for public procurement contracts. Costs are perceived as an important factor of eco-innovation by the largest percentage of enterprises, while requirements for public procurement are the least often indicated as important for eco-innovation activities. This mixed assessment of the importance of pressure factors may ambiguously translate into the introduction of noticeably beneficial environmental solutions.

Requirements had a relatively weak and non-significant effect on the ECO variable for small enterprises, possibly due to limited financial, technological, and human resources, which constrain their ability to meet formal eco-innovation requirements.

Despite these exceptions, the Pressure and Requirements factors generally significantly impacted eco-innovation adoption, confirming the research hypotheses.

5. Discussion and Limitations

The analysis of the modelling results indicates the necessity of a balanced approach to combining pressure and requirements. Regulatory pressure stimulates innovation by driving the development of technologies and processes that comply with environmental standards. Requirements from environmental regulations and current or expected tax policies significantly influence the implementation of eco-innovations in industrial enterprises (this confirms hypothesis H1, except in the case of small enterprises, where the significance of pressure factors did not clearly correlate with the importance of the introduced environmentally beneficial innovations). Legal requirements seem to be the most influential factor in achieving positive environmental innovation outcomes in large enterprises, which, according to the model, most strongly link regulatory changes with the positive effects of

implemented eco-innovations. This highlights the importance of consistent and predictable regulations as a tool to support eco-friendly initiatives.

Pressure from high costs, such as materials and water, and formal requirements related to participating in public tenders significantly contribute to the implementation of eco-innovations in industrial enterprises (this confirms hypothesis H4, except for large enterprises, wherein no statistically significant correlation between the importance of pressure factors and the introduction of beneficial environmental solutions was found). Cost factors and formal requirements influence the positive assessment of implemented environmental solutions in small enterprises slightly more. However, it should be noted that a relatively low percentage of small enterprises rated pressure factors as important or very important. This perception is influenced by several factors, including resource constraints, and limited awareness. Small and medium enterprises (SMEs) typically operate with limited financial and human resources, which can hinder their ability to engage with complex regulatory environments or invest in energy efficiency measures. Given their limited resources, SMEs often concentrate on core business activities that directly impact their survival and profitability. SMEs with lower energy intensity may perceive fewer benefits from investing in energy efficiency and thereby deprioritize such initiatives. It is worth stressing one more limitation: SMEs often have limited access to information regarding public procurement opportunities and energy efficiency programmes. This information gap can result in a lack of awareness about the benefits and requirements of such initiatives, further contributing to the perception that these factors are of lesser importance.

Public procurement plays a growing role in Poland's environmental policy landscape. As part of the implementation of EU directives on Green Public Procurement (GPP), Polish authorities have increasingly integrated environmental criteria into tendering processes, thereby encouraging suppliers and contractors to adopt more sustainable practices. These formal requirements exert institutional pressure on enterprises that seek to participate in public tenders, incentivizing the adoption of eco-innovative solutions. It should be noted that this shift not only promotes environmental responsibility among market participants but also creates a competitive advantage for businesses that invest in green technologies and practices. However, considering enterprise size, SMEs may feel disadvantaged due to competition with larger firms that possess more resources and experience. This competitive imbalance can discourage SMEs from participating in procurement processes, reinforcing the belief that such avenues are less significant for their business growth.

The regulatory context (Pressure, Requirements) provides a necessary framework for implementing eco-innovations (ECO). However, corporate Reputation and Incentives emerge as stronger drivers of eco-innovation. Incentives resulting from future demand or available financial resources play a significant role in implementing eco-innovations in industrial enterprises, with this influence appearing across all sizes of enterprises (this confirms hypothesis H3). The connection between the assessment of the incentive factor and the positive effects of eco-innovation is most visible in the case of medium and large enterprises, for which it is a factor whose importance translates to the greatest extent into the significance of implemented eco-innovations. This result suggests that financial support mechanisms can significantly accelerate eco-innovation adoption. Enterprises may recognise that meeting requirements (e.g., sustainability criteria) increases their chances of securing external funding, which can further motivate environmental actions. Examples include grants and government subsidies awarded to companies implementing environmentally friendly technologies in response to regulations, such as CO_2 emission reduction policies. Requirements related to anticipated or upcoming regulations may drive enterprises to take faster innovative actions to comply with future standards. In response

to these future changes, businesses may actively seek available financial incentives for implementing environmental innovations.

There is substantial evidence supporting the effectiveness of public subsidies in promoting eco-innovation. Montmartin and Herrera [72] emphasise the importance of government support for innovation, noting that subsidies not only provide essential funding sources but also alleviate financial shortages and reduce the overall costs associated with innovation. Similar findings were reported by Greco et al. [73], who showed that public subsidies can significantly enhance innovation efficiency by relaxing financial constraints, mitigating technological risks, and encouraging partnerships that generate positive social and economic externalities. This reinforces the relevance of well-designed public funding instruments in promoting both the scale and quality of eco-innovative activities. While the positive impact of public subsidies on eco-innovation is well-documented, it is important to acknowledge potential risks associated with excessive reliance on public funding. Carboni [74] highlights that public intervention may, under certain conditions, have adverse effects on firms' innovation and R&D efforts. Specifically, companies that benefit from government support may reduce or even eliminate their own private investments in innovation, leading to a form of dependency on public funding. This crowding-out effect can undermine the long-term sustainability of innovation strategies, as firms may become less motivated to pursue high-risk or breakthrough innovations independently. Such dependency may also distort competitive dynamics, particularly if subsidies are not effectively targeted or monitored. Therefore, while public financial instruments are essential for promoting eco-innovation, their design must include safeguards to ensure they complement—rather than replace—private sector initiatives and investments.

Eco-innovations respond to the growing market expectations for environmentally friendly products and services. This type of innovation enables firms to strengthen their image and reputation by aligning with consumer values related to sustainability. Building a company's reputation is a long-term process involving various stakeholder groups. Reputation plays a crucial role in shaping business strategies, as a positive image can boost stakeholder trust and support the company's ability to attract investments and customers. In the context of eco-innovation, Reputation becomes particularly important, as eco-friendly activities enhance the company's image of being responsible and committed to sustainable development. Implementing environmental innovations allows companies to stand out from the competition, potentially increasing customer loyalty and investor interest. Furthermore, companies with strong reputations are more likely to engage in eco-friendly activities that exceed minimum regulatory requirements to strengthen their image. Reputation significantly influences the adoption of eco-innovations in industrial enterprises, with its impact appearing consistent across all sizes of industrial companies (this confirms hypothesis H2). Among the four groups of eco-innovation motives considered (REP, PRE, INC, REQ), Reputation has the greatest impact on the importance of implemented eco-innovations in the case of small enterprises. This result suggests the universal importance of this factor.

In light of the existing literature, research suggests that market demand plays a crucial role in motivating firms to adopt eco-innovative practices, particularly in competitive environments where green differentiation can offer a strategic advantage [75]. Firms often perceive eco-innovation not only as a response to regulatory pressure but also as an opportunity to enhance customer loyalty and brand value through the development of sustainable offerings. Reputation-building is especially important in sectors where stakeholders are highly sensitive to environmental issues. Research by Bammens and Hünermund [76] indicates that family ownership is positively associated with the adoption of eco-innovations within firms. One of the key explanations for this relationship is the

heightened importance that family-owned businesses often place on maintaining and enhancing their corporate reputation. Unlike non-family firms, which may prioritise short-term financial returns, family enterprises tend to adopt a longer-term perspective, viewing sustainability and environmental responsibility as integral to their legacy and public image. This reputational concern can act as a strong internal driver for the implementation of eco-innovative practices. The ability to meet market demand for green products also contributes to long-term competitiveness and may provide access to new, sustainability-oriented market segments. However, it should be noted that the eco-innovations may also include initiatives that merely create a false impression of environmental improvement. Companies often introduce minor changes or rebranding that only superficially represent eco-friendly practices, a tactic commonly referred to as "greenwashing". Greenwashing misleads consumers and undermines the credibility of genuine environmental innovations. This issue is widely discussed in the scientific literature [40,77].

The analysis highlights the connections between Pressure, Requirements, Reputation, and Incentives and the perceived benefits of introduced eco-innovations. Understanding these relationships is crucial for businesses that increasingly recognise the strategic importance of eco-innovations. The study results suggest that companies pay attention to environmental regulations and see opportunities for gaining competitive advantages through eco-innovative activities. Similar conclusions were drawn by Delmas and Burbano [77], who noted that the increased consumption of eco-friendly products and services has encouraged many organisations to adopt and communicate environmental practices, which creates a positive public image.

However, there are limitations to this analysis. Firstly, the study is based on unit data collected by Statistics Poland from the PNT-02 questionnaire ("Report on Innovations in Industry"), meaning the authors had no control over how questions were formulated or the choice of measurement scales.

Secondly, the study did not consider the specifics of individual industrial sectors. Future research should also explore how different industrial sectors respond to Pressure, Requirements, Reputation, and Incentives in the context of eco-innovation implementation. Each sector has unique regulatory requirements, competitive dynamics, and technological or financial resource availability. For example, the chemical industry might be more sensitive to regulatory pressure related to emissions, while the food industry might focus on sustainability-based reputation building. A comparative sector analysis could reveal which factors are critical in each industry and how their significance varies depending on the business context.

Thirdly, the results may be partially distorted by companies practising greenwashing, where businesses claim to engage in eco-friendly actions without genuine innovation.

Fourthly, the analysis covers the years 2018–2020, overlapping with the challenging early phase of the COVID-19 pandemic, which may have impacted corporate priorities, shifting their focus away from eco-innovations and towards survival. Supply chain disruptions, revenue declines, and financing issues could have negatively affected enterprises' ability to implement eco-innovations. Many companies focused on survival, limiting strategic activities. Consumer preferences and demand structures also shifted during the pandemic, influencing business decisions regarding eco-innovation. Future studies should analyse data collected during a more stable period to better understand the long-term mechanisms of Pressure, Requirements, Reputation, and Incentives influencing eco-innovation adoption. Comparing results from the pandemic period with data from more stable times would help assess to what extent innovative actions were reactions to extraordinary circumstances versus long-term trends. When planning future research, it is worth focusing on panel (longitudinal) data, which allow for the observation of the behaviour of the same

firms over a long period. This makes it possible to identify changes in behaviour resulting from COVID-19—or the lack thereof.

Fifthly, the study did not account for the long-term effects of eco-innovation activities, which could provide a more comprehensive picture of the outcomes.

6. Conclusions

The energy transformation involves a comprehensive shift in how energy is produced, consumed, and managed. Through innovations in technology, changes in consumption patterns, and the evolution of energy management systems, this transformation is paving the way for a more sustainable, efficient, and resilient energy future. The dynamic nature of these changes requires ongoing research. A complex interaction of factors drives eco-innovation.

Disparities among European Union countries in the implementation of eco-innovation highlight a persistent and complex challenge related to the design and provision of effective support mechanisms for environmentally oriented innovation. These disparities are particularly pronounced when comparing Western Europe with Central and Eastern European countries.

Within this context, a critical research gap becomes evident—namely, the absence of comprehensive empirical studies that examine the full spectrum of factors shaping eco-innovation adoption at the firm level. This shortcoming is particularly relevant in the case of transition economies, where eco-innovation pathways may deviate from patterns observed in more advanced economies. Our research addresses this gap by offering new insights into the determinants that influence firms' engagement in eco-innovative activities. Additionally, our analyses complement general studies on innovation in Poland, which are based on data from the PNT-02 questionnaire or surveys derived from the PNT-02 and PNT-02u forms [27,59,78–83].

The implementation of eco-innovation at the microeconomic level is not solely a function of regulatory compliance but often stems from strategic business decisions aimed at enhancing both environmental and economic performance. Firms increasingly view eco-innovation as a means to achieve cost reductions, market differentiation, and long-term competitiveness. However, the realisation of such benefits depends on the presence of enabling conditions, including access to funding, technological infrastructure, and knowledge networks.

Developing effective instruments to support eco-innovation in enterprises is thus a multi-dimensional and iterative process. It involves two critical stages: the accurate identification of country-specific determinants of eco-innovation and the subsequent tailoring of policy instruments to leverage these factors. Misalignment between identified drivers and implemented policies can significantly undermine the efficacy of public interventions.

The literature identifies several key elements that encourage companies to engage in eco-innovations. Referring to the theoretical framework analysed, it should be noted that the conditions for implementing eco-innovations are directly related to Pressure, Requirements, Incentives, and Reputation. Structural model estimates for industrial enterprises indicated that Pressure, Requirements, Reputation, and Incentives positively and statistically significantly impacted the ECO variable. This conclusion aligns with expectations and confirms the formulated research hypotheses.

It appears that Requirements from current and future regulations and Pressure from high operational costs and administrative formalities are important for initiating eco-innovation activities in industrial enterprises. Future environmental regulations may encourage businesses to accelerate innovation efforts to meet upcoming standards. Additionally, regulations may increase demand for low-emission products, further driving

business innovation. Meanwhile, Incentives (such as funding availability and expected demand growth) and Reputation (as a long-term corporate asset) are crucial factors supporting eco-innovation. The optimal use of a combination of Pressure, Requirements, and Incentives can maximise the effects of eco-friendly activities.

Concluding our analysis, it is also worth highlighting the eco-innovations enterprises implement to focus on reducing energy consumption. Among the introduced product innovations, companies most frequently pointed to innovations that resulted in a noticeably reduced energy use or carbon footprint. It can be assumed that this is a change expected by customers who seek to purchase goods that are not only environmentally friendly but also cost-effective to use. On the other hand, although enterprises more frequently indicate the high cost of energy, water, or materials as an important driver for introducing eco-innovations, they least often cite energy-related factors (ECO_{1B}: reduced energy use or CO_2 footprint, and ECO_{1E}: replacing a share of fossil energy with renewable energy sources) as significant effects of eco-innovation activity. This suggests the existence of barriers to improving this area within enterprise production processes.

Although it was possible to confirm a statistically significant, positive impact of individual groups of factors (motivators) of undertaking innovative activity on the beneficial effects of eco-innovation, it should be noted that their assessment differed slightly between enterprises of different sizes. In the case of large enterprises, three groups of factors influenced the positive effects of eco-innovation activity, namely Incentives (0.163), Reputation (0.156), and Requirements (0.124). In the case of medium-sized enterprises, all four groups of factors significantly translated into the effects of eco-innovation, with the factors Incentives (0.221) and Reputation (0.142) playing leading roles. For small enterprises, Reputation (0.182) turned out to be crucial, followed by Pressure (0.120) and Incentives (0.119) at a similar level.

Although the findings for Poland reflect specific national institutional and economic conditions, it may be cautiously assumed that similar patterns could be observed in other EU transition economies, particularly those with comparable levels of development and regulatory pressure related to environmental protection.

The presented research results refer to the period before COVID-19 and the war in Ukraine, both of which significantly impacted resource flows and access. Despite these limitations, it seems possible to formulate certain general conclusions that are of a timeless nature. First, policymakers should tailor eco-innovation support schemes to enterprise size, recognising that small firms are primarily reputation-driven, whereas larger firms are more responsive to regulatory requirements and financial incentives. Second, the findings highlight the importance of designing long-term and predictable regulatory frameworks that reduce uncertainty and stimulate proactive innovation responses, particularly in sectors burdened by high operational costs. Third, increased accessibility to public funding may help lower the entry barriers to eco-innovation. Lastly, efforts to promote eco-innovations should be accompanied by awareness-raising campaigns that emphasise not only regulatory compliance but also the reputational and economic benefits of sustainability-oriented transformation. These strategies could accelerate the diffusion of eco-innovation and contribute to achieving national and EU-level environmental and energy transition goals.

Since, in most European countries, public statistics conduct periodic surveys of the innovation activities of enterprises based on the standard international methodology described in the Oslo Manual published by the OECD and Eurostat [84], it is also worth conducting an international comparison of factors that motivate enterprises to engage in activities aimed at innovations that yield environmental benefits (eco-innovations) in further analyses. The results of such an analysis could indicate the determinants of differences in the level of the Eco-Innovation Index (EII) developed by the European Commission [85].

Such international comparisons could be effectively supported by employing specific metrics, particularly the subcomponents of the Eco-Innovation Index (EII), which include eco-innovation inputs, eco-innovation activities, eco-innovation outputs, environmental outcomes, and socio-economic outcomes. Analysing these dimensions may help identify policy areas with the greatest potential for improvement. Eco-innovation plays a pivotal role in supporting the energy transformation, as it contributes to technological advancements, shifts in consumption patterns, and the development of more efficient and sustainable energy systems—all of which are essential for achieving the EU's green transition targets. Considering the undertaken problem's importance, it is justified to monitor the activity of enterprises towards eco-innovations, especially for policymakers interested in increasing the level of eco-innovation in the country.

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