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ENVIRONMENTAL PERFORMANCE OF ENERGY COMPANIES UNDER CORONAVIRUS CRISIS AND EU CLIMATE POLICY

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Purpose: The aim of this paper is to assess changes in the reduction of gas emissions and improvement of energy efficiency of energy companies during the period of introducing rigorous changes in the EU climate policy and intensifying digitalization processes in the times of the COVID-19 crisis.
Design/methodology/approach: Based on the new EU climate and energy goals, diagnostic variables have been selected to estimate synthetic development measures related to the environmental and financial dimensions of business activities. The Kruskal-Wallis test is used to identify differences between firms' environmental and financial performance depending on the level of advancement of digitalization process in the COVID-19 period.
Findings: The energy companies in most of EU countries reduced their greenhouse gas emissions intensity between 2017 and 2021, which may indicate a stimulating role of the reformed EU ETS. Enterprises from the "new EU" and "old EU" countries differed in the energy intensity, the emission to allowances index and energy tax ratio. The degree of advancement of digitalization processes in individual EU countries differentiates studied companies in terms of environmental and financial performance.
Research limitations/implications: A limitation of empirical research was incomplete access to disaggregated data describing various aspects of environmental behavior of enterprises or the advancement of digitalization processes in enterprises.
Practical implications: The results help managers understand the impact of changes in environmental regulations and advances in digitalization processes on company performance, which can support their decisions about the scope of the low-carbon transformation.
Originality/value: This research results indicate the multidimensional linkage between digitalization processes, changes in EU climate policy and firms' environmental performance, which opens up interesting possibilities for further research related to the development of new tools supporting the environmental management process. This study pointed out the heterogeneous behaviours of EU energy companies in terms of energy efficiency and sensitivity to the impact of environmental policy instruments.
Keywords: environmental performance, management of energy companies, climate policy, digitalization, Covid-19 outbreak.
Category of the paper: research paper.

1. Introduction

In adopting the goal of achieving climate neutrality by 2050, the European Union has intensified work on: transitioning from a linear to a closed-loop economy, ensuring Europe's autonomy with regard to critical raw materials, reforming the structure of the EU electricity market and creating a competitive carbon-neutral industry. These actions were undoubtedly accelerated by the energy crisis triggered by Russia's invasion over Ukraine. The European Green Deal strategy and the Fit for 55 project package use a full set of environmental instruments: command-and-control, market-based and technology support options, which should shape companies' decisions to reduce emissions and energy intensity, as well as to replace fossil fuel energy with clean energy through, for example, electrification of industrial processes (Boldrini et al., 2024; Wolniak, Skotnicka-Zasadzień, 2023). The literature on the subject draws attention to the significant responsibility of industry in achieving the EU climate policy goals, especially those relating to energy efficiency. Factors accelerating the transformation of the energy sector include investments in renewable energy sources, the use of alternative fuels, technological breakthroughs stimulating innovation in the energy sector, and the growing role of information and communication technologies (Gajdzik et al., 2024b).

The issue of the impact of environmental regulation on firm performance, although it has been the subject of much research, has not been unambiguously resolved (Wang, Xu, Liang, 2021). Effective regulation to reduce the carbon intensity of industrial processes should encourage companies to adopt short-term energy efficiency measures, as well as to invest in R&D projects leading to sustainable energy savings and decarbonisation in the future (Martin et al., 2012). Consequently, changes in environmental regulation towards lower emission standards are most felt by firms characterised by energy-intensive industrial processes and limited ability to fully pass on the costs of pollution reduction to consumers (Dechezleprêtre, Sato, 2017). This is confirmed by empirical studies conducted on firms in selected EU regions (Benatti et al., 2023). Important issues related to the management of energy-intensive companies concern investing in new technologies for generation, storage and transmission that enable significant reductions in pollutant emissions, improvement of energy efficiency and increased use of renewable energy sources. In particular, increasing energy efficiency by reducing network losses, replacing old generating units with new, high-efficiency generating units, and using high-efficiency cogeneration is crucial to achieving the new goals of the EU's climate policy (Czerwińska, Radwański, Pacana, 2025). When assessing the impact of environmental regulation on firms‘ activities, the shape and direction of the relationship between environmental performance and firms' financial performance is also identified, while the environmental dimension of firms' activities is most often analysed either through the emission intensity of production processes or their energy efficiency (Trumpp, Guenther, 2017; Fan et al., 2017; Włodarczyk, Szczepańska-Woszczyna, Urbański, 2024). The effectiveness of price-based EU climate and energy policy instruments, including the EU Emissions Trading System and the environmental tax system, was also examined. Studies conducted for firms covered by the EU ETS in the third clearing phase identified a positive significant relationship between firms' environmental and financial performance, meaning that firms with lower emissions intensity were characterised by higher profitability. It has also been stressed that the implementation of low-carbon technologies by companies leads to a reduction in the need to purchase additional allowances due to emission reductions (Flori, Borghesi, Marin, 2024). Environmental taxes, on the other hand, can be an effective tool to reduce CO_2 emissions if their amount is aligned with climate policy objectives (Aydin, Esen, 2018).

The literature on the subject indicates that digital transformation has a positive impact on firms' environmental performance, mainly through the sharing of green technological innovations, and firms using advanced digital technologies collaborate with each other to implement green technological solutions (Xie, Zhang, Zhao, 2023). Furthermore, the document ‘A Clean Planet for all’ has already highlighted the crucial importance discoveries in the fields of digitisation, information, communication, artificial intelligence to stimulate the ecological transformation of the economy and society (COM/2018/773 final). Digital transformation has a positive impact on ESG performance, which may be linked to increased investments in information transparency or the development of dynamic capabilities of companies, enabling them to effectively respond to unpredictable events (Rydzewski, 2025). This is particularly important in times of stringent changes in EU climate policy and the crisis caused by the COVID-19 pandemic, when the integration of information and communication technologies can improve not only companies’ operational decisions but also long-term strategic planning regarding investments in green technologies or the optimisation of the use of natural resources. The COVID-19 pandemic has significantly affected the financial situation of EU companies, which have accelerated digitalization processes by investing in new technologies enabling the automation of business activities, e-commerce, and remote work (Luty, Zioło, Zuzek, 2025). It is emphasized that environmentally responsible companies were more resilient and profitable during COVID-19 thanks to their competitive advantage, competent managers and the support of environmentally oriented stakeholders, who were able to overcome the obstacles caused by the pandemic and find resources for investments in sustainable development. This effect was stronger in developed economies than in emerging economies (Lu, Khan, 2023). According to the European Investment Bank (2024), large companies representing renewable energy (67%) and energy-intensive (60%) industries, having a strategic monitoring system and using advanced digital technologies, were more willing to engage in climate investments, despite the economic slowdown related to the COVID-19 crisis and uncertainty about future climate regulations.

Taking into account the presented complex aspects of the low-emission transformation of the European industry, the aim of this article is to assess the changes in the reduction of gas emissions and the improvement of energy efficiency of energy companies during the period of introducing rigorous changes in the EU climate policy and intensifying digitalization processes in the times of the COVID-19 crisis. To achieve this goal, a new tool has been constructed in the form of a synthetic development measure that will assess the performance of EU energy companies in a multidimensional approach. The sets of diagnostic variables for the construction of the individual synthetic measures were chosen to relate to the effects of different types of EU climate policy instruments on companies. On this basis, research was conducted to assess changes in the environmental performance of energy companies in the context of reducing harmful emissions and improving energy efficiency during the period of implementation of rigorous changes in the EU climate policy and the shocks caused by the COVID-19 pandemic. Given the important role of the processes of digitisation of the economy and society in achieving EU climate policy goals, the degree of advancement of them in the different EU Member States have also been compared and it has been examined whether they differentiate companies in terms of environmental and financial performance.

2. Background: EU climate and energy policy related to energy companies

The EU's climate and energy policy has undergone significant changes, mainly in relation to decarbonisation targets, which may have a significant impact on the activities of heavily polluting companies. The initial set of binding rules on air pollutant emission reductions and energy efficiency are known as the EU 20/20/2020 targets. This climate and energy package set three key targets for 2020: reducing greenhouse gas emissions by at least 20%, increasing the share of renewable energy in EU energy consumption by 20%, achieving energy savings of at least 20% (Böhringer, Rutherford, Tol, 2009). In October 2014, the EU's 2030 Climate and Energy Policy Framework was adopted, which increased the targets for energy efficiency and RES use to 27% and the greenhouse gas emissions reduction target to 40%. In turn, the European vision of a climate-neutral economy with new, more rigorous 2030 targets of reducing primary and final energy consumption by at least 32.5% compared to 2007 projections and increasing the share of renewable energy to at least 32% of final energy consumption has been presented in ‘A Clean Planet for all’ (COM/2018/773 final). Another key EU initiative to counter climate change is the sustainable growth strategy for the economy presented in December 2019, referred to as the European Green Deal (European Council: European Green Deal). Under this strategy, climate neutrality is planned to be achieved in the entire EU economy by 2050, with an intermediate target to reduce net greenhouse gas emissions by at least 55% by 2030 compared to 1990 levels. Thus, the new EU Green Growth Strategy reaffirmed the commitments of the Paris Agreement of 2015, the European vision of a climate-neutral economy, and increased the binding 2030 emissions reduction target approved in 2014 by 15 pp. In order to formalise the EU's commitments on achieving deep decarbonisation of the economy, both greenhouse gas emission reduction targets were registered in The European Climate Law, which came into force in July 2021 (Regulation 2021/1119).

As a next step, the ‘Fit for 55’ legislative package was presented in 2021 with the aim of planning, implementing and monitoring actions in various sectors of the EU economy that would provide a framework for meeting the climate targets set for 2030. Key projects from the ‘Fit for 55’ package include (European Council: Fit for 55):

- strengthening and extending the scope of the EU Emissions Trading System (EU ETS),
- the introduction carbon border adjustment mechanism (CBAM), which is intended to reduce the risk of carbon-intensive industries relocating outside the EU,
- an increase in the EU's 2030 greenhouse gas emission reduction target for the sectors of the economy not covered by the EU ETS from 29% to 40% compared to 2005, as well as an update of the national targets in all EU Member States,
- increasing the target for the share of renewable energy sources in total energy consumption from 32% to at least 40% by 2030, and identifying individual plans and seeking measures to stimulate the use of renewable energy in sectors such as transport or industry,
- improving energy efficiency by reducing final energy consumption by 38% and primary energy consumption by 40.5% compared to 2030 projections made under the 2007 baseline scenario. The revised EU Energy Efficiency Directive aims to reduce energy consumption by at least 11.7% by 2030 compared to 2030 projections made under the 2020 baseline scenario.

The Fit for 55 package also modifies some of the rules of the EU ETS functioning, which is the EU's core tool in the fight against greenhouse gas emissions in the energy-intensive industrial sectors, electricity and heating. The most important change relates to the tightening of the CO_2 reduction target, namely that in 2030 emissions from all installations covered by the EU ETS should be by 62% lower than in 2005, raising the current reduction rate of 43% by 19 pp. To achieve this, it is planned to reduce the supply of carbon allowances in the market by withdrawing 117 million allowances over 2 years and reducing the total number of allowances each year by 4.3% (2024-2027) and 4.4% (2028-2030) (Directive (EU) 2023/959).

In May 2022, the EU presented the REPowerEU plan proposes to increase the RES target to 45% and the energy efficiency target to 13%, which together are expected to contribute to decoupling the EU economy from fossil fuel imports from Russia (COM/2022/230 final). Finally, the revised Renewable Energy Directive EU/2023/2413 has set a new EU renewables target for 2030 of at least 42.5%, with an ambition to increase it to 45%.

It is also worth emphasising that the European Green Deal stimulates not only the green, but also the digital transformation of EU Member States, as the reform packages it proposes require advanced technological knowledge and digital skills from the actors involved. The described changes in the green and digital transformation of European industry show that companies operate in an increasingly turbulent and unpredictable environment. Therefore, it is extremely important to provide tools that will help identify the impact of changes in EU climate policy and digitalization processes intensified by the COVID19 pandemic on the environmental and financial performance of enterprises.

3. Methods

The aforementioned solutions proposed in the ‘Fit for 55’ project package will affect companies representing energy-intensive and carbon-intensive industries with greater intensity (Benatti et al., 2023). The gradual abandonment of the use of fossil fuels in the energy-intensive sectors of the EU economy in favour of their electrification and the use of hydrogen technologies will make energy companies an extremely important part of the new integrated EU energy system (Boldrini et al., 2024). For this reason, companies in NACE Rev. 2 Section D from each EU country whose activities consist of the generation and supply of electricity, gas, steam and air conditioning have been selected for the study.

The first set of diagnostic variables proposed in the study refers to the legislation included in the ‘Fit for 55’ package necessary to meet the new 2030 reduction targets. Horváthová (2012) approximated the environmental performance of companies by means of a specially constructed index based on normalised emission volumes of various pollutants. Accordingly, the following diagnostic variables have been used to describe the effects of reducing emissions of dust and gaseous pollutants contributing to the greenhouse effect, the acid precipitation effect or toxic effects on the human body by energy companies:

- greenhouse gases emission intensity (kilograms per euro),
- acidifying gases emission intensity (grams per euro),
- particulate matter 2.5 and 10 μm emission intensity (grams per euro),
- non-methane volatile organic compounds emission intensity (grams per euro),
- emission to allowances index estimated as the ratio of the EU-ETS verified emissions in the fuel combustion activity category to emissions accounted for using freely allocated allowances.

Most of above-mentioned diagnostic variables are estimated in the form of intensity indicators illustrating the aggregated annual volume of gases or dust emitted by enterprises from section D in relation to generated value added at factor cost. Furthermore, in view of the EU ETS reform project to reduce the pool of emission allowances on the market and the gradual phasing out of free allocation, an emission to allowances index has been included in the first set of diagnostic variables (Segura et al., 2018). All diagnostic variables are destimulants.

As part of the EU's ‘Fit for 55’ package, regulations have been prepared for increasing the use of renewable energy in industry, heating and cooling systems, which will cover the studied group of Section D companies. In addition, the new EU energy efficiency improvement targets refer to the implementation of cost-effective primary and final energy saving measures, which is relevant to the studied enterprises in the context of more efficient provision of heat or cooling, as well as the reduction of energy losses during transformation and transmission. The proposed second set of diagnostic variables therefore relates to the environmental performance of the studied EU companies in terms of meeting EU energy policy objectives:

– share of renewable energy sources in heating and cooling (%),
– share of renewable energy in total electricity production (%),
– net energy intensity (megajoule per euro),
– emission-relevant energy intensity (megajoule per euro).

The first two diagnostic variables, referring to changes in EU renewable energy regulations, are stimulants. Other variables describe net domestic energy use and emission-relevant use of energy product converted to the unit of value added at factor cost for a group of enterprises from section D. These energy intensity indicators, related to changes in EU regulations on energy, are destimulants. It is worth emphasizing that net energy intensity, which corresponds to the sum of the own consumption of a given industrial sector and losses during energy processing and distribution, refers to the overall energy efficiency of the analysed enterprises, while emission energy intensity refers mainly to the activities of companies directly related to fuel combustion.

The third set of diagnostic variables proposed to describe the financial performance of the EU energy companies indicates the profitability of their activities, the propensity of companies to undertake investment in tangible goods, and the scale of the environmental cost burden on companies:

– investment rate calculated as gross investment in tangible goods divided by value added at factor cost (%),
– gross operating rate estimated as the surplus generated by operating activities after the labour factor input has been recompensed referred to market sales of goods or services supplied to third parties (%),
– energy taxes ratio calculated as the total amount of taxes on energy products used for both stationary purposes and transport purposes, in particular carbon taxes levied on the carbon content of fossil fuels, converted per unit of value added at factor cost (%),
– other environmental taxes indicator estimated as the total amount of transport taxes, pollution taxes and resource taxes, including i.e. taxes on raw materials extraction, air and water emissions or waste management, converted per unit of value added at factor cost (%).

The first two diagnostic variables describing the financial performance of companies are stimulants. The remaining variables, depicting the costs incurred by companies related to the harmful impact of their activities on the environment, are destimulants. It is worth emphasising that the new proposal to revise the Energy Taxation Directive focuses on aligning the taxation of energy products with the EU energy and climate policy objectives promoting clean production technologies and discouraging the use of fossil fuels (European Council: Fit for 55). Therefore, it will be important regulation for analysed companies, which justifies the inclusion of these diagnostic variables in the construction of a synthetic measure.

Individual diagnostic variables relating to the environmental and financial dimensions of Section D enterprises' activities were estimated using data from Eurostat and the European Environment Agency. Due to the availability of data for Section D enterprises, Cyprus, Luxembourg and Malta were excluded from the study. Empirical research was conducted for the period 2017-2021 due to the intensification of work on tightening the EU climate policy goals and the impact of shocks generated by the COVID-19 pandemic on the activities of energy companies in this period, as well as taking into account the criterion of data availability. In the initial stage of the analysis related to the selection of diagnostic variables, the criteria of adequate variability and weak correlation were verified. The selected three sets of diagnostic variables will be used in the Hellwig's development pattern method. In Hellwig's method, which is dedicated to the analysis of complex phenomena described by a multidimensional set of diagnostic factors, a set of n objects O_i ($i = 1, 2, \ldots, n$) characterised by m features are ordered. Each object, identified with a group of companies from a given EU country, is treated as a point in an m-dimensional Euclidean space whose individual coordinate axes correspond to the diagnostic variables X_j ($j = 1, 2, \ldots, m$) (Mesjasz-Lech, Włodarczyk, 2020). The starting point in the development pattern method is the standardisation of the value of each diagnostic variable measured at least on an interval scale:

$$z_{ij} = \frac{x_{ij} - \bar{x}_j}{s_j} \tag{1}$$

where:

x_{ij} – values of the j-th diagnostic variable X_j describing the i-th object O_i,

$\bar{x}_j$ – arithmetic mean of the j-th diagnostic variable,

s_j – standard deviation of the j-th diagnostic variable,

z_{ij} – standardized values of this variable corresponding to the i-th object.

The performed transformation of the diagnostic variables brought the orders of their magnitudes to a state of comparability (Walesiak, 2011). Next, a benchmark object (O_w) and an anti-benchmark (O_a) are determined, the geometric representation of which are points $Z_w = (z_{w1}, z_{w2}, \ldots, z_{wm})$ and $Z_a = (z_{a1}, z_{a2}, \ldots, z_{am})$, respectively, with coordinates:

$$z_{wj} = \begin{cases} \max\limits_i z_{ij}, if\ X_j\ is\ stimulant \\ \min\limits_i z_{ij}, if\ X_j\ is\ destimulant \end{cases} \tag{2}$$

$$z_{aj} = \begin{cases} \min\limits_i z_{ij}, if\ X_j\ is\ stimulant \\ \max\limits_i z_{ij}, if\ X_j\ is\ destimulant \end{cases} \tag{3}$$

In the next step, the similarity of objects O_i with respect to the benchmark object O_w is assessed by estimating the Euclidean distances according to the formula:

$$d_{iw} = d(z_{ij}, z_{wj}) = \sqrt{\sum_{j=1}^{m} (z_{ij} - z_{wj})^2} \text{ (i = 1, 2, …, n).} \tag{4}$$

The synthetic measure of development (d_i) for the i-th object is determined according to relations:

$$d_i = 1 - \frac{d_{iw}}{d_{wa}} \text{ (i = 1, 2, …, n)} \tag{5}$$

where:

$$d_{wa} = d(z_{wj}, z_{aj}) = \sqrt{\sum_{j=1}^{m} (z_{wj} - z_{aj})^2}. \tag{6}$$

The synthetic measure of development takes values in the range [0,1], with the closer its values are to unity, the more similar the i-th object is to the benchmark object. In other words, higher values of the synthetic measure of development d_i correspond to objects that are more developed due to the complex phenomenon under analysis (Ostasiewicz, 1998).

The Friedman test was used to assess differences between synthetic measures of development describing the environmental and financial performance of the studied group of companies in particular years (Domański, Pruska, 2000). The following test statistic was used to verify the null hypothesis of no differences between the measurements of the synthetic measure of development against the alternative hypothesis of the existence of at least one pair of measurements of the synthetic indicator differing from one another:

$$\chi^2 = \frac{12}{k \cdot (k+1) \cdot n} \sum_{i=1}^{k} \left(\sum_{j=1}^{n} r_{ij} \right)^2 - 3 \cdot (k+1) \cdot n \tag{7}$$

where:
k – number of measurements,
n – number of objects,
r_{ij} – rank for the j-th object in the i-th measurement.

In a situation where the null hypothesis of the Friedman test is rejected, a Wilcoxon test comparing each pair of measurements should be carried out to identify the years in which the studied group of objects differed in terms of the value of the synthetic measure (Domański, Pruska, 2000; Mesjasz-Lech, Włodarczyk, 2020). The test statistic is described by the following formula:

$$Z = \frac{T - \frac{n \cdot (n+1)}{4}}{\sqrt{\frac{n \cdot (n+1) \cdot (2n+1)}{24} - \frac{\sum t^3 - \sum t}{48}}} \tag{8}$$

where $T = min(\sum R_{-}, \sum R_{+})$ - minimum of the sum of negative and positive ranks.

In addition, the objects studied can be divided into homogeneous groups in terms of the value of the selected composite indicator according to the following scheme (Nowak, 1990; Luty, Zioło, Zuzek, 2025):

$$\begin{cases} d_i \geq \bar{d}_i + s_{di}, \text{group I with high level of the phenomenon,} \\ \bar{d}_i + s_{di} > d_i \geq \bar{d}_i, \text{group II with medium} - \text{high level of the phenomenon,} \\ \bar{d}_i > d_i \geq \bar{d}_i - s_{id}, \text{group III with medium} - \text{low level of the phenomenon,} \\ d_i < \bar{d}_i - s_{id}, \text{group IV with low level of the phenomenon.} \end{cases} \tag{9}$$

where $\bar{d}_i$ is the mean value and $s_{id}$is the standard deviation of the selected indicator.

The obtained groups of objects can be compared in terms of the occurrence of differences in the values of the synthetic measure of development describing the environmental or financial performance of enterprises using the non-parametric Kruskal-Wallis test. To verify the null hypothesis of no differences between groups of objects the following formula can be used (Evans, 2014):

$$\chi^2 = \frac{12}{n \cdot (n+1)} \sum_{j=1}^{k} \frac{\left(\sum_{i=1}^{n_j} r_{ij}\right)^2}{n_j} - 3 \cdot (n-1) \tag{10}$$

where:
k – number of groups,
n – number of objects,
n_j – number of objects in the j-th group,
r_{ij} – rank for the i-th object in the j-th group.

If the null hypothesis is rejected in favour of the alternative hypothesis, it can be inferred that at least one pair of analysed groups of objects is significantly different in terms of the value of the development measure.

4. Results and Discussion

Based on the constructed sets of diagnostic variables, the values of the three synthetic development measures have been determined according to formulas (1)-(6). The values of the synthetic measure of development in the dimension of the reduction of gaseous and particulate emissions intensity by Section D companies, presented in Table 1, show a weak decreasing trend in the mean and median levels between 2017 and 2021. In 2021, the companies were most differentiated in terms of the intensity of pollutant emissions and the manner of allocation of CO_2 emission allowances against the actual volume of emissions. The lowest values of the synthetic measure evolved positively over the study period, gradually increasing from a level of 0.1695 in 2017 to a level of 0.3451 in 2020. A similar trend can be observed for the maximum values of this indicator, which increased from a level of 0.9672 in 2017 to a level of 0.9741 in 2021. The greatest impact was due to the significant reduction in GHG emissions intensity of the companies studied in all EU countries, with the largest decreases in GHG emissions intensity observed for Portugal, Spain, Estonia or Germany. The analysed groups of companies were most differentiated by the emission to allowances index, which could increase the variability of the synthetic index in 2021. In the third trading period 2013-2020, electricity generating installations were able to apply for free allocation of emission allowances under the derogation scheme when they had incurred investments in reducing GHG emissions.

Table 1.
Synthetic development indicators related to environmental performance of enterprises

Country	Emission target					Energy efficiency target				
	2017	2018	2019	2020	2021	2017	2018	2019	2020	2021
Austria	0.9571	0.9594	0.9433	0.9500	0.9564	0.7657	0.7658	0.7360	0.7492	0.7194
Belgium	0.8696	0.8663	0.8526	0.8357	0.8576	0.4082	0.3959	0.3348	0.3852	0.3988
Bulgaria	0.6210	0.7074	0.6032	0.3888	0.2887	0.2902	0.2959	0.2363	0.1787	0.1204
Croatia	0.8499	0.8317	0.8049	0.7570	0.6698	0.7210	0.7106	0.6819	0.6809	0.6774
Czechia	0.6389	0.6251	0.6292	0.5368	0.4805	0.3391	0.2915	0.2085	0.2164	0.2630
Denmark	0.9466	0.9401	0.9486	0.9205	0.9016	0.7975	0.8017	0.8104	0.7524	0.7748
Estonia	0.1695	0.2860	0.4287	0.3569	0.3778	0.1328	0.1454	0.2124	0.2680	0.2930
Finland	0.8763	0.8740	0.8828	0.8546	0.8399	0.6345	0.6191	0.6016	0.5839	0.6035
France	0.9672	0.9715	0.9677	0.9720	0.9741	0.4610	0.4368	0.3988	0.4204	0.4428
Germany	0.8022	0.8032	0.7944	0.7862	0.7448	0.5140	0.5178	0.4934	0.5163	0.5227
Greece	0.3968	0.2445	0.1510	0.3451	0.3814	0.5072	0.3741	0.2732	0.4392	0.4921
Hungary	0.8134	0.8026	0.7975	0.7288	0.7468	0.3473	0.3116	0.2435	0.2442	0.3017
Ireland	0.8164	0.8281	0.8130	0.8352	0.8246	0.4652	0.4506	0.4101	0.4465	0.4247
Italy	0.7782	0.7956	0.8036	0.7708	0.7541	0.5620	0.5353	0.4999	0.5133	0.5086
Latvia	0.5792	0.4855	0.4263	0.3749	0.3366	0.8237	0.6973	0.6305	0.6442	0.7011
Lithuania	0.5436	0.5509	0.6536	0.7315	0.6369	0.5687	0.5273	0.5021	0.4909	0.5005
Netherlands	0.8580	0.8619	0.8398	0.8358	0.8544	0.3568	0.3406	0.2987	0.3492	0.3959
Poland	0.6879	0.6853	0.6759	0.5036	0.4595	0.3440	0.3048	0.3012	0.3112	0.3077
Portugal	0.7273	0.7490	0.7766	0.7771	0.7734	0.7053	0.7045	0.6953	0.6843	0.7017
Romania	0.6224	0.6604	0.5977	0.5835	0.5069	0.4584	0.4616	0.3973	0.4347	0.4220
Slovakia	0.9125	0.9035	0.8854	0.8891	0.7963	0.4113	0.3803	0.3982	0.4071	0.3593
Slovenia	0.8074	0.7889	0.7372	0.6819	0.6448	0.5194	0.4896	0.4110	0.4105	0.4445
Spain	0.7360	0.7604	0.7754	0.8061	0.7917	0.5350	0.5133	0.4883	0.5208	0.5370
Sweden	0.9319	0.9266	0.9420	0.9181	0.8592	0.8726	0.8405	0.8596	0.8622	0.8402
Average	0.7462	0.7462	0.7388	0.7142	0.6857	0.5225	0.4963	0.4635	0.4796	0.4897
Median	0.8048	0.7991	0.7959	0.7740	0.7505	0.5106	0.4756	0.4106	0.4428	0.4683
Coefficient of variation	25.6%	25.9%	26.3%	27.7%	30%	35.8%	37.1%	41.7%	37.7%	36.6%

Source: own calculation.

In most of the EU-14 countries, the values of this index in 2017-2021 were at similar levels, which indicated the need to purchase the missing allowances in the auction system, but the scale of this need was significantly lower than for energy companies in some of the 'new union' countries. This impact of the EU ETS on enterprises, combined with the observed decrease in greenhouse gas emission intensity in 2017-2021, may indicate a significant role of the reformed EU ETS in stimulating the reduction of greenhouse gas emissions. Previous research shows that emissions reduction policies that use ETSs or carbon taxes can effectively promote emissions reductions and energy efficiency gains for firms, and sometimes stimulate the development of renewable energy (Segura et al., 2018; Zhang, Liu, Zhou, 2022). The countries where companies maintained high positions in the environmental performance rankings for emissions reductions between 2017 and 2021 include: France (1), Austria (2), Denmark (3) and Sweden (4). In contrast, the lowest values of the synthetic measure of development over the period were observed for companies from Bulgaria, Estonia, Latvia and Greece.

When analysing the values of the synthetic measure of development in the dimension of energy efficiency improvement listed in Table 1, one can see a gradual decrease in the median level from 0.5106 in 2017 to 0.4106 in 2019. This initial decreasing trend turns into an increasing trend from 2019 onwards, however, the median in 2021 of 0.4683 is lower than the median of 2017 or 2018, which may indicate that the studied companies are moving away from the benchmark object. In 2019, companies in each EU country had the highest variability in the synthetic measure describing the degree of renewable energy use and their progress in reducing the energy intensity of their operations. It should be noted that companies from most EU countries reduced their energy intensity in 2021 compared to 2017, with Germany, Estonia, Portugal and Spain having the highest achievements in this respect. In most of the 'new union' countries, the energy intensity ratios of the companies studied were significantly higher than the ratios set for companies in the EU-14. In terms of emission-relevant energy intensity, companies from Bulgaria, Estonia, Poland and Romania were the worst performers, while companies from Belgium, Estonia, Germany, Portugal and Spain managed to reduce this energy intensity ratio by more than 40% in 2021 compared to 2017. Energy-intensive companies often comply with mandatory energy efficiency regulations to avoid penalties rather than seize the opportunity to improve production technology. Meanwhile, a study on Chinese enterprises with high energy intensity of production processes found a positive relationship between enterprises' energy efficiency and their financial performance, which provides an incentive to take energy saving and emission reduction measures (Fan et al., 2017). In the category of the degree to which RES is used to generate electricity, companies from Austria, Denmark, Sweden were the best performers, while companies from the Czech Republic, Hungary and Poland were the worst performers. Other researchers have also noted that Western European countries have higher renewable energy consumption rates compared to Central and Eastern European countries over a similar period. However, taking into account the rate of renewable energy growth and the decrease in the energy intensity of industry in the new EU countries, it is assumed that this disproportion between the old and new EU countries will disappear (Gajdzik et al., 2024a). Countries where companies maintained high positions in the rankings made on the basis of the synthetic development measure include: Sweden (1), Denmark (2) and Austria (3). In contrast, the lowest values for the indicator describing energy efficiency were observed for companies from Bulgaria, the Czech Republic, Estonia, Hungary and Poland.

Based on the values of the synthetic development measure presented in Figure 1, it can be seen that companies from the different EU countries differed the most in terms of financial performance in 2021, for which the coefficient of variation was 31.1%. It is noteworthy that in most EU countries, in 2021 compared to 2017 and 2020, the profitability of the studied enterprises measured by the gross operating rate deteriorated, while the indicator measuring gross investment in tangible goods improved.

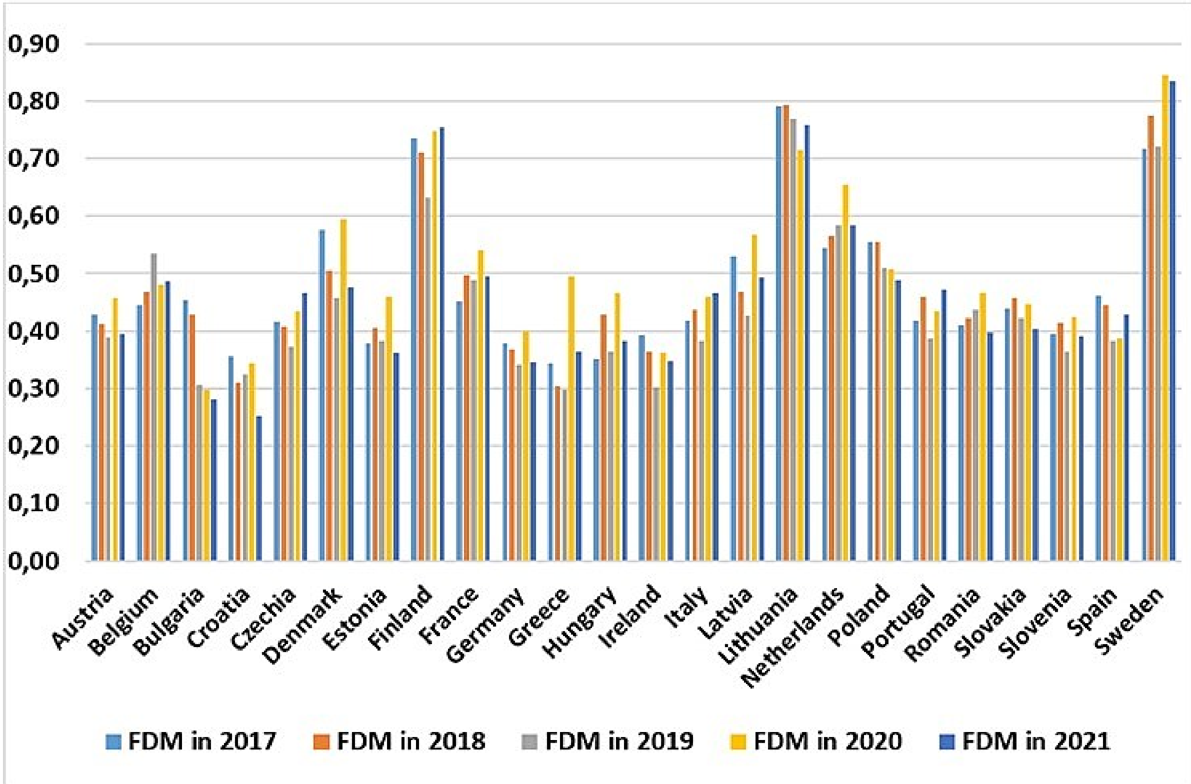

Figure 1. Synthetic development measure for the financial performance of enterprises (FDM).
Source: own elaboration.

Other studies have shown that many EU businesses have faced falling turnover, rising operating costs, cash flow problems and job cuts, which have worsened their financial situation during the COVID-19 pandemic. However, the impact of the pandemic crisis on businesses in the EU was varied (Luty, Zioło, Zuzek, 2025). Although an increase in the energy taxes ratio for companies in most EU countries can be observed in 2021 compared to 2017, for more than half of the countries the highest values of this indicator were recorded in 2019. The upward trend in the energy tax level announced in Fit for 55 may affect the deterioration of the financial situation of companies that were characterized by a high energy taxes ratio. This group in 2021 included companies from Bulgaria, Estonia, Greece, Romania and Slovenia. Analysing the relationship between environmental taxes and carbon emissions in EU countries, a significant negative impact of an aggregate environmental tax, as well as energy, pollution and resource taxes on carbon emissions only after a certain threshold value has been identified (Aydin, Esen, 2018). An interesting aspect related to the environmental tax system has also been pointed out, namely that the deterioration of a country's air quality can be identified by an increase in the share of energy taxes in the total tax pool (Postula et al., 2024). Between 2017 and 2021, companies from Lithuania, Sweden and Finland were in the top three positions in the rankings positioning Section D companies in terms of the best financial performance described by the synthetic development measure, changing positions in the rankings relative to each other from year to year. The worst financial performance characterised companies from Bulgaria, Croatia, Estonia, Germany and Ireland.

The differences observed above in the synthetic measures of development for each year are confirmed by the results of the Friedman test (7) presented in Table 2.

Table 2.
Friedman test for synthetic development measures

Scope of development indicators	Friedman statistics	p-value
Emission target	16.9000	0.0020***
Energy efficiency target	36.9667	0.0000***
Financial performance	21.6667	0.0002***

Note: ***, **, * indicate significant statistics at the level respectively 1%, 5%, 10%.

Source: own calculation.

For the period 2017-2021, the largest differences were identified in the measurements of the development indicator describing the environmental performance related to energy efficiency of Section D enterprises and the indicator describing their financial performance. The Wilcoxon test (8) was used to identify years with significant differences between the estimated values of the development measure for EU countries.

Table 3.
Wilcoxon test for synthetic development measures

Scope of development indicators	Compared years	Wilcoxon statistics		p-value	Compared years	Wilcoxon statistics		p-value
		T	Z			T	Z	
Emission target	2017-2018	145	0.1429	0.8864	2019 - 2020	77	2.0857	**0.0370**
	2017-2019	110	1.1429	0.2531	2017 - 2021	64	2.4571	**0.0140**
	2018-2019	102	1.3714	0.1702	2018 - 2021	60	2.5714	**0.0101**
	2017-2020	78	2.0571	**0.0397**	2019 - 2021	50	2.8571	**0.0043**
	2018-2020	82	1.9429	0.0520	2020 - 2021	57	2.6571	**0.0079**
Energy efficiency target	2017-2018	28	3.4857	**0.0005**	2019 - 2020	79	2.0286	**0.0425**
	2017-2019	21	3.6857	**0.0008**	2017 - 2021	39	3.1714	**0.0015**
	2018-2019	33	3.3429	**0.0002**	2018 - 2021	102	1.3714	0.1702
	2017-2020	24	3.6000	**0.0003**	2019 - 2021	71	2.2571	**0.0240**
	2018-2020	77	2.0857	**0.0370**	2020 - 2021	95	1.5714	0.1161

Cont. table 3.

Financial performance	2017-2018	144	0.1714	0.8639	2019 - 2020	23	3.6286	**0.0003**
	2017-2019	56	2.6857	**0.0072**	2017 - 2021	129	0.6000	0.5485
	2018-2019	33	3.3429	**0.0008**	2018 - 2021	113	1.0571	0.2904
	2017-2020	84	1.8857	0.0593	2019 - 2021	81	1.9714	**0.0487**
	2018-2020	83	1.9143	0.0556	2020 - 2021	49	2.8857	**0.0039**

Note: the bold p-value means that the development indicator values for EU countries are significantly different in the two compared years.

Source: own calculation.

The analysis of the results presented in Table 3 can confirm the preliminary observations that the values of the synthetic measure relating to the emission reduction target in 2020 and 2021 differed significantly from the earlier years, and in the case of the indicator describing the energy efficiency improvement target, the measurements in 2019 and 2020 differed from the other years. It can also be observed that the studied companies differed more in terms of environmental effects in the energy efficiency dimension than in the emission reduction dimension. It has also been confirmed that the values of the measure describing the financial performance of the companies in 2019 were significantly different from the measurements of this measure in the other years, and that significant differences between the financial performance of the studied companies occurred between 2020 and 2021.

In the final stage of the analysis, it was examined whether the degree of digitisation of the economy and society in individual EU countries has an impact on the environmental and financial performance of the studied companies. EU countries were grouped according to the Digital Economy and Society Index (DESI), which takes into account such important issues as: connectivity, digital public services, human capital and digital skills, integration of digital technologies by enterprises. Taking into account the results of the Wilcoxon test and the rules described in equation (9), EU countries were grouped according to their DESI values in 2019 and 2021. Based on the 2019 DESI index values, the studied EU countries were divided into four groups characterised by similar advancement of digitalisation processes:

- Group I with high DESI index values ($d_i \geq 12.04$): Denmark, Finland, the Netherlands, Sweden;
- Group II with medium-high DESI index values ($9.90 \leq d_i < 12.04$): Austria, Belgium, Estonia, Ireland, Latvia, Lithuania, Portugal, Slovenia, Spain;
- Group III with moderately low DESI index values ($7.76 \leq d_i < 9.90$): Croatia, Czechia, France, Germany, Hungary, Italy, Slovakia;
- Group IV with low DESI index values ($d_i < 7.76$): Bulgaria, Greece, Poland, Romania.

It was then tested whether the resulting groups of countries differed in terms of the environmental and financial performance of Section D companies using the non-parametric Kruskal-Wallis test (10).

Table 4
Kruskal-Wallis test for grouping countries based on DESI criterion in 2019

Scope of development indicators	Kruskal-Wallis statistics	p-value	Average value of the development measure			
			I	II	III	IV
Emission target	10.8651	0.0125**	0.9059	0.7116	0.8008	0.5092
Energy efficiency target	6.4339	0.0923*	0.6393	0.4884	0.4187	0.3016
Financial performance	7.4969	0.0576*	0.5983	0.4362	0.3852	0.3882

Source: own calculation.

The results of the Kruskal-Wallis test presented in Table 4 indicate the existence of statistically significant differences between the identified groups of EU countries in terms of environmental and financial performance of Section D companies in 2019. The largest differences can be observed between the group of countries with the most advanced processes of digitisation of the economy and society (I) and the group of countries with a low level of digitisation (IV). Group I companies are characterised by the best environmental performance in terms of reducing gaseous and particulate emissions (average value of the synthetic development index is 0.9059) and increasing energy efficiency (average value of the development index 0.6393), as well as better financial performance than the other company groups (average value of the development index 0.5983). Group IV companies are characterised by the worst environmental performance, both in terms of emissions intensity (0.5092) and energy intensity of operations and use of renewable energy (0.3016). Group IV companies were also characterised by much worse financial performance than groups I and II (0.3882). Similar differences can be observed between Group I and II, as companies from countries with medium-high DESI index values were characterised by poorer environmental and financial performance compared to companies from countries with high DESI index values. The relatively high average value of the synthetic index describing the dimension of pollution reduction in group 3 is surprising, but this may be due to the inclusion of France, characterised by a high value of the synthetic development index for the dimension of pollution emissions.

The EU countries studied were then grouped according to the DESI index value of 2021:

- Group I ($d_i \geq 14.27$): Denmark, Finland, Ireland, the Netherlands, Sweden;
- Group II ($11.76 \leq d_i < 14.27$): Austria, Estonia, Germany, Slovenia, Spain;
- Group III ($9.24 \leq d_i < 11.76$): Belgium, Croatia, Czechia, France, Hungary, Italy, Latvia, Lithuania, Portugal, Slovakia;
- Group IV ($d_i < 9.24$): Bulgaria, Greece, Poland, Romania.

The results of the Kruskal-Wallis test presented in Table 5 indicate the presence of statistically significant differences (p-value < 0.1) between the four groups of EU countries in terms of emissions reduction performance and corporate financial performance in 2021.

Table 5.
Kruskal-Wallis test for grouping countries based on DESI criterion in 2021

Scope of development indicators	Kruskal-Wallis statistics	p-value	Average value of the development measure			
			I	II	III	IV
Emission target	10.2150	0.0168**	0.8532	0.7026	0.6985	0.4053
Energy efficiency target	4.2160	0.2391	0.6117	0.5066	0.4830	0.3355
Financial performance	6.4320	0.0924*	0.5990	0.3852	0.4639	0.3796

Source: own calculation.

As in 2019, the largest differences in the environmental and financial performance of the studied companies can be observed between the groups of countries with the most and least advanced processes of digitisation of the economy and society (I and IV). Group II and Group III companies are relatively similar in terms of environmental performance in 2021. The surprising differences in the average values of the financial measure of development for Group II and Group III companies may be due to the different response of companies to the effects of the economic downturn caused by the pandemic. Analysing the environmental performance of companies in 2021, it can be seen that the processes of digitalisation of the economy and society have a positive impact on the performance of Section D companies in the dimensions of reducing emissions and improving energy efficiency. However, this preliminary observation requires further in-depth analysis. Brodny and Tutak (2022) constructed an enterprise digitalization index, based on which significant differences were identified between the "new EU" and "old EU" countries in terms of digitalization. It was also noted that research and development expenditure positively stimulates the process of enterprise digitalization, while the obtained results did not differ significantly when the DESI index was used to measure the involvement of EU countries in digitalization processes (Brodny, Tutak, 2022). In addition, it has been confirmed that digital transformation can significantly improve the environmental performance of enterprises, and the sharing of green technological innovations moderates the relationship between digital transformation and enterprise environmental performance (Xie, Zhang, Zhao, 2023). Empirical studies on EU countries, where the degree of integration of digital technologies was approximated by the Digital Economy and Society Index (DESI), indicated a positive impact of energy innovation, improved environmental performance and digital transformation on the sustainability of these countries. It was emphasized that the transformation of the energy sector towards the production of clean and safe energy or the development of smart grids would require investments in green energy technologies and information and communication technologies (Noja et al., 2024).

5. Conclusions

The article presents the most important changes in the EU's climate and energy policy, especially in terms of tightening greenhouse gas emission reduction targets, increasing the energy efficiency of industrial processes and the related increase in the use of renewable energy sources, which significantly affect the activities of heavily polluting enterprises. The conducted empirical research allows to assess and compare environmental performance of highly polluting enterprises from EU member states in the period of dynamic changes in climate policy. It has been noted that in the years 2017-2021, the analysed companies in all EU countries reduced their greenhouse gas emission intensity, with individual countries differing in the intensity of this phenomenon, which may indicate a significant role of the reformed EU ETS in stimulating GHG emission reductions. Attention has also been drawn to the differences between enterprises from the "new EU" and "old EU" countries in terms of the energy intensity of their operations and the relationship between the level of greenhouse gas emissions and the allowances allocated free of charge, which may generate higher costs related to participation in the EU ETS in the case of the first group of enterprises. For companies from most EU countries, the share of energy taxes in value added increased in 2021 compared to 2017. It is worth emphasizing that the modification of energy taxes announced in the European Green Deal strategy in order to adapt their levels to the new climate policy goals will adversely affect the financial results of companies with a high energy tax ratio. Moreover, it has been shown that the digitalization of the economy and society has a positive impact on the environmental and financial performance of enterprises from section D in 2021. In EU countries with a high level of digitalization processes, enterprises achieved the best financial results and also successfully managed to reduce pollutant emissions and improve energy efficiency. In countries with a low level of digitalization processes, enterprises achieved poor financial and environmental performance.

Given the identified positive relationship between digitalization processes and the environmental performance of EU energy companies, this may constitute a mitigating response to the risk of green transformation resulting from the enforcement of the new climate policy. The obtained analytical results provide important information on the heterogeneity of energy enterprises from individual EU countries in terms of environmental performance. This study points to the multidimensional relationship between digitalisation processes, changes in EU climate policy and the environmental performance of enterprises, which opens up interesting opportunities for further research related to the development of new tools supporting the environmental management process. Future research on the issue presented in this study will focus on building models describing the relationships between the financial and environmental performance of energy companies, taking into account their varied involvement in digitalization processes.

The presented research results may be useful to both politicians and managers making decisions regarding the scope and advancement of the digital and green transformation of the energy industry. Policymakers, especially in countries with a lower level of digitalization, can design solutions that stimulate the low-emission transformation of the energy sector in line with the guidelines presented in the Fit for 55 package regarding investments in new production technologies or the transition from high-emission energy carriers to clean energy. The research results can help managers understand the impact of changes in environmental regulations and the degree of engagement in digitalization processes on the performance of energy companies, which can support their decisions regarding the scale of investment in new green technologies and the development of employees' digital competences.

The presented results constitute a preliminary stage of research, which requires in-depth analyses based on disaggregated data on the performance of EU enterprises. The analysis conducted for the industrial sector may be biased by aggregation error, whereby the different effects of stringent climate policies observed at the enterprise level may cancel out at the industrial sector level. A significant limitation of the analyses conducted so far has been the limited access to non-financial data on the activities of enterprises.

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