SILESIAN UNIVERSITY OF TECHNOLOGY PUBLISHING HOUSE

SCIENTIFIC PAPERS OF SILESIAN UNIVERSITY OF TECHNOLOGY 2023
ORGANIZATION AND MANAGEMENT SERIES NO. 170

IMPACT OF EU ALLOWANCES COST ON THE FINANCIAL RESULTS OF POLISH POWER COMPANIES

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Purpose: The aim of the article is to estimate the impact of the EU Allowances price increase on the financial results and return on investment in the portfolio of shares of four listed power companies, i.e., Enea S.A., Energa S.A., PGE Polska Grupa Energetyczna S.A., and TAURON Polska Energia S.A.
Design/methodology/approach: Financial analysis of energy groups. Statistical analysis, a linear regression model with 6 independent variables and the dependent variable, i.e., the return on investment in the portfolio of shares of the analyzed companies. The studies cover the years 2016-2021.
Findings: The results of the financial analysis show that the analyzed energy groups did not always could include increased operating costs in the price of energy sold in 2016-2021?
The linear regression analysis did not indicate that the decrease in the profitability of investments in the shares of the surveyed companies can be explained by the increase in the prices of EU Allowances.
Research limitation/implications: The inability to determine the unequivocal impact of the EU Allowances price increase on the financial results and share prices of the considered companies can be explained by the number of operating segments in the energy groups, the outbreak of the COVID pandemic and negative GDP in 2020, and the "upward rebound" of the economy after the pandemic and high GDP in 2021**.**
Practical implications: The analysis is useful for shareholders of electricity companies and politicians who create regulations concerning the Polish energy policy. The results of the study are useful to all stakeholders of electricity companies.
Social influence: The high costs of EU Allowances affect electricity prices for the Polish society and prove very high CO_2 emissions when producing electricity in Poland.
Originality/value: The conducted financial analysis and regression analysis are one of the first attempts to indicate the impact of the increase in the cost of CO_2 emission allowances on the financial results and share prices of Polish energy companies. The article contributes to reducing the research gap existing in Polish literature in this area.

Keywords: power companies, EU Emissions Trading System, EU Allowances (EUA), regression analysis.

Category of the paper: research paper.

1. Introduction

Reducing greenhouse gas emissions has become a particularly important goal of the European Union. The main tool stimulating individual member states and companies operating in the EU energy, industrial, and aviation market to reduce greenhouse gas emissions, including CO_2, is the EU Emissions Trading System (EU ETS) established in 2005 (Directive 2003/87/EC, 2003). Currently, the EU ETS system covers all EU member states and three countries belonging to the European Free Trade Association (EFTA): Iceland, Liechtenstein, and Norway. Participation in the EU ETS is mandatory for companies in certain sectors, including the power sector, but in some sectors, such as heat generators, only plants of a certain size are considered. Every year, participants in the EU ETS system have to account for their actual emissions by redeeming an appropriate number of EU Allowances. Article 3(a) of Directive 2003/87/EC (the EU ETS Directive) defines the emission allowance as being *an allowance to emit one tonne of carbon dioxide equivalent during a specified period, which shall be valid only for the purposes of meeting the requirements of this Directive and shall be transferable in accordance with the provisions of this Directive*. If a company reduces emissions, it can keep some of its allowances to cover future needs or sell them to another company that does not have enough allowances.

The functioning of the EU Emissions Trading System (EU ETS) can be divided into four phases. The phase I covered the years 2005-2007, the II phase - years 2008-2012, the phase III - years 2013-2020, and in 2021 the fourth phase began, which will last until the end of 2030. Each subsequent phase is associated with an increasingly restrictive approach to pollutant emissions, including CO_2. This applies to the maximum amount of CO_2 that can be emitted in the European Union, the so-called "cap" and increasing the number of industries and gases covered by the EU ETS. For example, in the phase I (2005-2007), the EU Emission Trading Scheme (EU ETS) covered only CO_2 emissions of electricity producers and producers of energy-intensive industries, and all EU Allowances were allocated free of charge. The penalty for not redeeming EU Allowances was € 40 t/CO_2. In the phase II, the EU ETS also covered nitrous oxide emission, and the penalty for not redeeming EU Allowances increased to €100 t/CO_2. About 90% of EU Allowances were allocated free of charge. The plan for this period assumed a lower limit of EUA, i.e., about 6.5% less than in 2005 (European Commission, 30.09.2022). Since 2012, the aviation sector has also been included in the EU ETS.

In 2013, i.e., at the beginning of phase III, the so-called the "cap", i.e., the maximum amount of greenhouse gases that entities belonging to the EU ETS could emit in the European Union, amounted to 2,084,301,856 tonnes per year, and an obligation was introduced (Directive 2009/29/EC, 2009) to reduce this level by 1.74% per year (linear), i.e., by 38,264,246 tonnes (European Commission 31.10.2022).

For aviation, the maximum level of EU Aviation Allowances (EUAA) was set at 210,349,264 tonnes per year throughout the phase III (European Commission, 2015). From 2021 to 2030 (the phase IV), the maximum limit of EU Allowances, the so-called "cap", in the EU ETS is reduced by 2.2% (Directive (EU) 2018/410, 2018) per year (linearly). In December 2020, European Union leaders agreed to increase the reduction of greenhouse gas emissions from 40% to 55% by 2030 compared to 1990 levels. (FORSAL.PL, 2021). According to experts, achieving this result will be possible with a further reduction of the maximum level of EU Allowances from the current 2.2% to 3.8% annually, i.e., by 83 million tonnes, which will have a significant impact on future prices of EU Allowances (KOBiZE, 2019).

From 2013 (the phase III), electricity producers are not entitled to free EU Allowances, except in cases related to the so-called derogations. Pursuant to Article 10c of Directive 2003/87/EC, installations in certain Member States, including Poland, generating electricity that meet the modernization criteria may be temporarily allocated free EU Allowances (the number of free EU Allowances for a given country then decreases).

In 2021 in the European Union, 37% of electricity production came from fossil fuels, while in 2005 it was 52.8%, which is as much as 29.5% less (Figure 1). A similar downward trend was observed in the production of electricity from nuclear power plants, the share of which decreased from 31.7% in 2005 to 25.5% in 2021 (a decrease of 19.6%).

The reduction in electricity production from nuclear fuel and fossil fuels has been replaced by production from renewable energy sources (RES). Its share in electricity production in 2021 was 37.2%, while in 2005 it was 15.4% (an increase of 141.6%). The Polish energy mix in 2005 was based on fossil fuels at 97.5% and 83.3% in 2021 (a decrease of 14.5%). The share of electricity from renewable energy sources (RES), amounting to 2.5% in 2005, increased to 16.6% in 2021 (an increase of 568%). The Polish electricity production mix resulted from the production mix of Polish electricity companies. This means that the share of fossil fuels in the production of electricity in the largest Polish electricity companies was about 90%.

The analysis concerns 4 Polish power companies, the majority or dominant shareholder of which is the State Treasury, and whose total share in electricity production in Poland in 2021 was 65% (Figure 2). At the end of 2021, the State Treasury was the majority shareholder in 2 out of 4 examined companies, i.e., PGE Polska Grupa Energetyczna S.A. - 57.39% of shares and Enea S.A. - 51.50% of shares and a significant shareholder in TAURON Polska Energia S.A. - held directly 30.06% of the shares and indirectly, through KGHM Polska Miedź S.A., 10.0% of the shares (Bankier.pl, 31.07.2022).

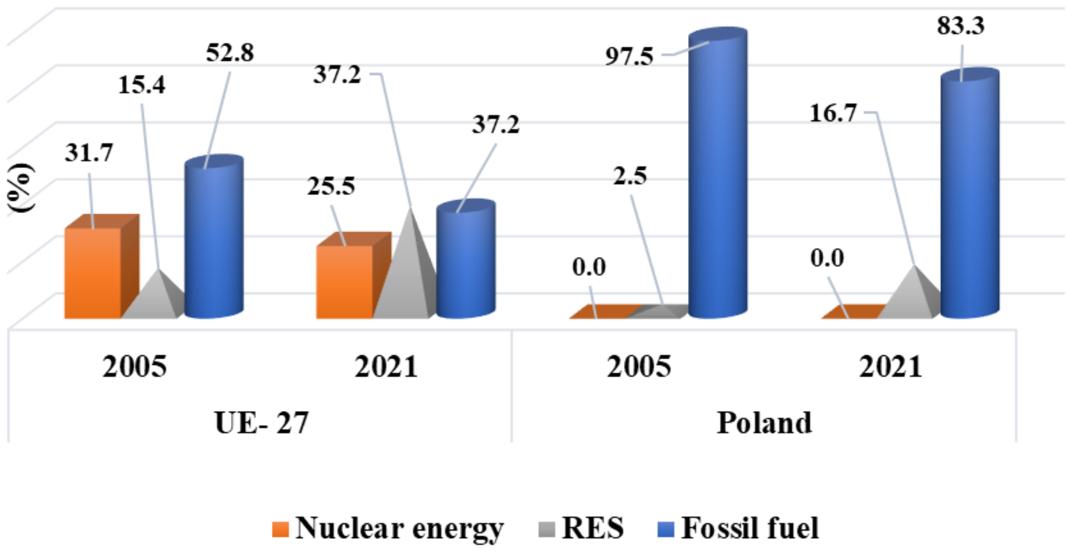

Figure 1. Electricity production by energy source in 2005 and 2021, (%).

Source: (Moore, 2022).

Until April 2020, the State Treasury was also the majority shareholder in Energa S.A. - 51.50% of shares and 64.09% of votes. In April 2020, PKN Orlen S.A. because of a tender offer for the purchase of Energa S.A. shares acquired 80% of the shares of this company, including all Treasury shares in Energa S.A. Thus, the State Treasury, which was the dominant shareholder in PKN Orlen S.A. (18.79% of shares and the same number of votes) indirectly holds over 80% of shares in Energa S.A. (Bankier.pl, 2022).

The aim of the article is to estimate the impact of the EU Allowances price increase on the financial results and return on investment in the portfolio of shares of four listed power companies, i.e., Enea S.A., Energa S.A., PGE Polska Grupa Energetyczna S.A., and TAURON Polska Energia S.A.

It can be assumed that such large increases in the prices of EU Allowances had a negative impact on the financial results and share prices of Polish power companies. This assumption results from the fact that the share of fossil fuels in the production of electricity in the surveyed companies is over 90% and they emit about 100 million tonnes of CO_2 annually (their average CO_2 emissions in 2016-2021 amounted to 100.4 million tonnes of CO_2 (Figure 3).

The analysis covers the years 2016-2021. At the end of 2015, the price of EU Allowances was EUR 8.22/t CO_2, and at the end of December 2021, it was already EUR 80.65/t CO_2, more than 881% (Table 5).

In the studied period, i.e., from the end of 2015 to the end of 2021, the quotations of the companies share prices on the Warsaw Stock Exchange decreased respectively for: PGE Polska Grupa Energetyczna S.A. by 36.1%, Energa S.A. by 39.5%, Enea S.A. by 24.3%, TAURON Polska Energia S.A. by 7.2%. The share portfolio of these 4 companies fell by 31.7%.

In order to achieve the aim of this article, two research hypotheses were put forward:

H1 - the continuous increase in the prices of EU Allowances in 2016-2021 had a significant, negative impact on the aggregated financial results of the surveyed four power companies.

H2 - the continuous increase in the prices of EU Allowances in 2016-2021 had a significant, negative impact on the return on investment in the portfolio of shares of the surveyed four energy companies.

To test the validity of hypothesis H1, a financial analysis of the four energy groups and their operating segments was performed. Then, in order to examine the validity of hypothesis H2, a statistical analysis was carried out using a linear regression model to assess the impact of changes in the EU Allowances prices and other independent variables on the return on investment in the portfolio of shares of four energy groups. The selection of variables other than the price of EU Allowances that could affect the return on investment in the portfolio of shares of the surveyed companies was the result of the studies of the available literature on this subject, described later in the article.

2. The costs of EU Allowances and their impact on the aggregated financial results of the surveyed companies

The average net electricity production of the surveyed companies in the years 2016-2021 amounted to 102 TWh, which, with the average national production in these years of 163 TWh, accounted for 62.4%. The share of these companies in the production of electricity from fossil fuels (average annual 95 TWh) in domestic production (average annual 146 TWh) was 65.0%. In turn, their share in the production of electricity from RES (average annual 7 TWh) in domestic production (average annual 17 TWh) was 40.8% (Figure 2).

The high share of electricity from fossil fuels in total production resulted in the emission of a large amount of CO_2. In 2016-2021, the surveyed companies emitted an average of 100.4 million tonnes of CO_2, which meant the need to purchase such a a quantity of EU Allowances.

However, since these companies received part of the EU Allowances for free (because of the derogation and as the heat generators), the actual amount of EU Allowances that they had to buy on the market was lower than the amount of CO_2 emitted by approx. 14.5% (Figure 3).

Thus, the companies had to buy an average of 85.9 million tonnes of EU Allowances on the market in 2016-2021. In 2020-21, the allocation of free EU Allowances was negligible, and companies had to buy EU Allowances in amounts corresponding to their CO_2 emissions.

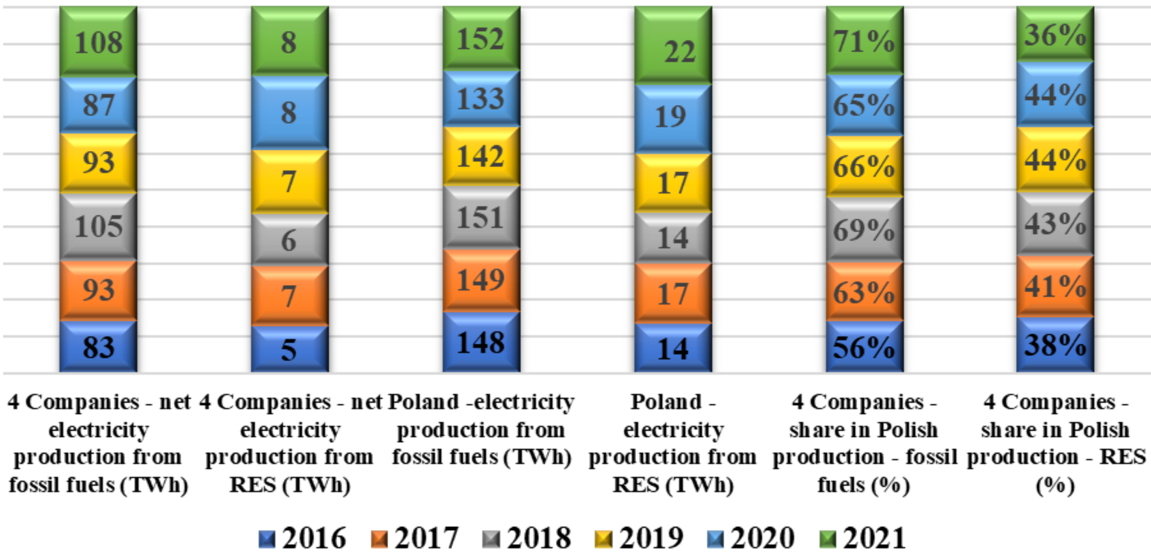

Figure 2. Electricity production in 2016-2021.

Source: (Financial statements, 2016-2022; Moore, 2022, own calculations).

The reduction in the number of free EU Allowances and the increase in their prices meant that the surveyed companies paid more for the purchase of EU Allowances from year to year. In 2016, they paid PLN 1.69 billion for EU Allowances, and in 2021 it was already PLN 13.51 billion (Figure 3). The increase in prices of EU Allowances in 2016-2021 resulted in an increase in the costs of generating MW of electricity from fossil fuels. The exact costs of EU Allowances for a given year are not known until the end of April of the following year, i.e., the date of redemption of EU Allowances. In this analysis, the costs of EU Allowances for a given year are the costs of redeemed EU Allowances reported by these companies in the following year.

The cost of EU Allowances at the unit cost of 1 MWh of electricity from fossil fuels amounted to: PLN 20.5/MWh in 2016; PLN 28.8/MWh in 2017; PLN 29.8/MWh in 2018; PLN 60.6/MWh in 2019; PLN 116.1/MWh in 2020 and PLN 125.0/MWh in 2021. Thus, the cost of electricity production per MW, due to higher prices of EU Allowances, increased in 2021 by PLN 104.5 compared to 2016 (an increase of 510%).

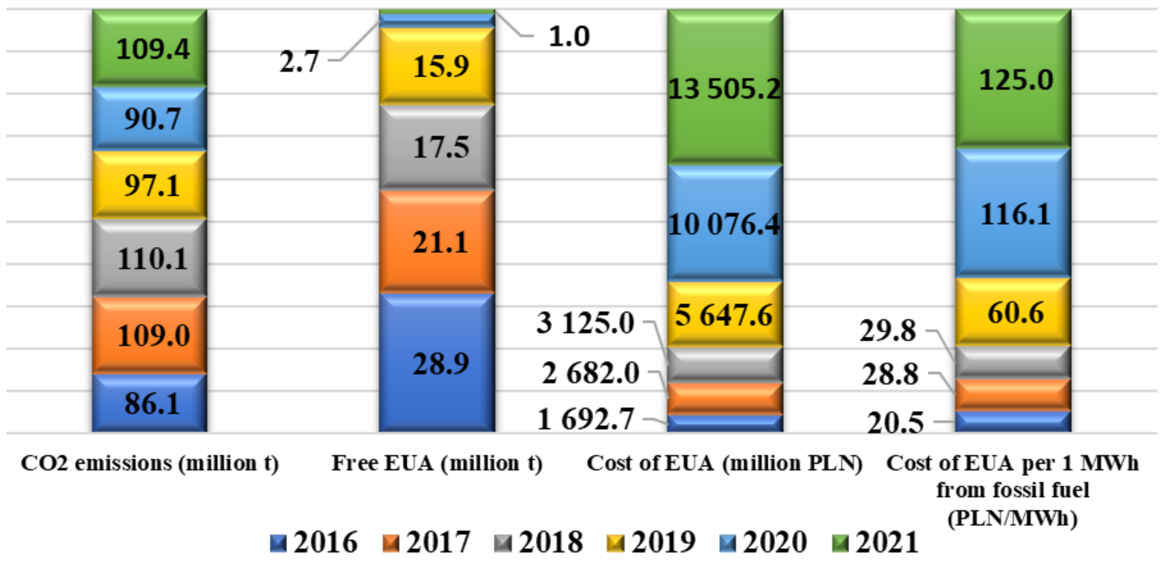

Figure 3. The 4 analyzed companies – CO_2 emission and its cost in 2016-2021.

Source: (Financial statements, 2016-2022; own calculations).

The considered power companies are among the largest Polish companies in terms of revenues. The total sales revenues of these four energy groups increased from PLN 67.2 billion in 2016 to PLN 113.6 billion in 2021 (an increase of 69%). Unfortunately, such a dynamic increase in sales revenues did not "contribute" to the improvement of their financial results. In 2019 and 2020, the companies recorded net losses of PLN 4.4 billion and PLN 4.7 billion. While, in 2016-2018, the companies' net profit amounted to: PLN 3.9 billion in 2016; PLN 6.0 billion in 2017; PLN 3.2 billion in 2018. In the last of the examined years, in 2021, the companies recorded a huge improvement in their financial results, and their total net profit amounted to PLN 7.1 billion (Figure 4).

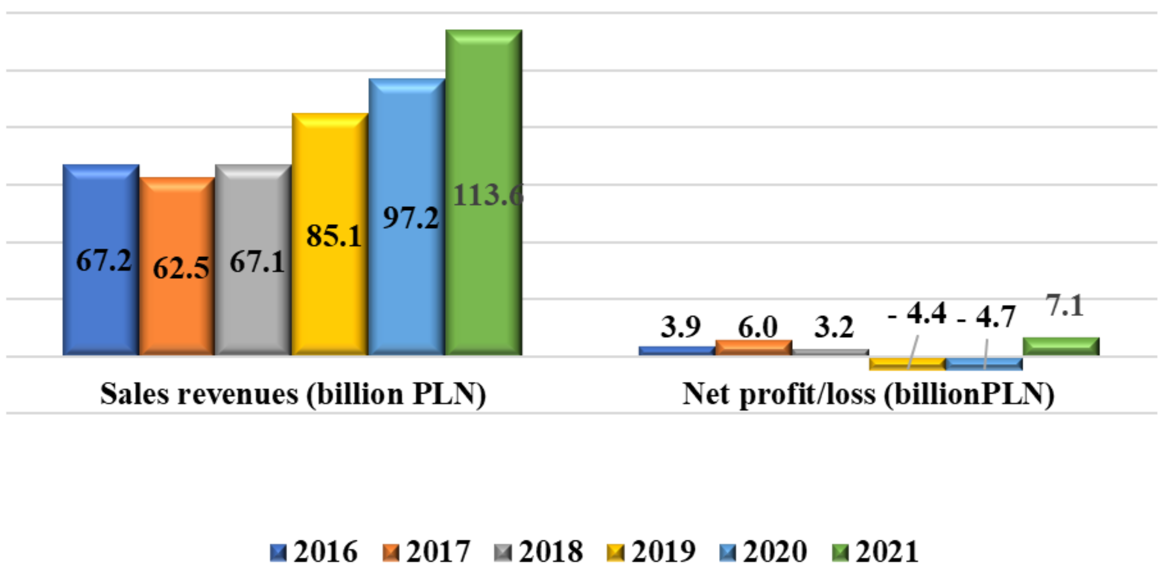

Figure 4. The 4 Analyzed companies - sales revenues and net profit/loss in 2016-2021.

Source: (Financial statements, 2016-2022).

The share of individual companies in the net profit in the examined years is shown in Figure 5. The largest share in the net profit of the 4 surveyed companies, amounting to 62% (average for 6 years), was held by PGE Polska Grupa Energetyczna S.A. The following places were taken by: Enea Group (26%), Energa Group (11%) and TAURON (1%). The greatest impact on the value of net profit reported by individual companies had the amount of sales revenues and the share of individual operating segments in revenues and EBIT in a given energy group (Tables 1 and 2).

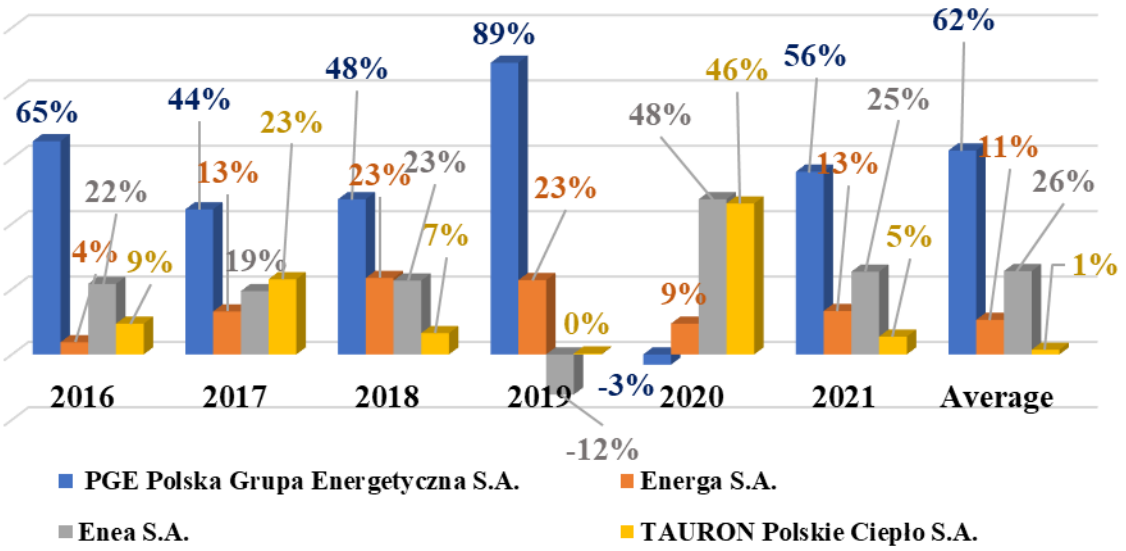

Figure 5. The share of individual companies in the net profit of all 4 companies in 2016-2021.
Source: (Financial statements, 2016-2022; own calculations).

The surveyed companies are energy groups consisting of several operating segments. Each of them consists of the following operating segments: Distribution, Conventional Power Generation, Sales or Trade, and Other activities. The Enea and Tauron Groups also have an operating segment Mining. From 2018, the PGE Group has a segment Heat Generation, separated from the operating segment Conventional Generation. The TAURON and PGE Groups also have an operating segment Renewables Power Generation. The Energa Group and the Enea Group do not have a separate Renewables Power Generation operating segment, and all electricity produced is reported in the Power generation operating segments.

The need to isolate an operating segment and report selected financial data of such a segment by listed companies results from the Accounting Act (Accounting Act, 1994, Article 55). Pursuant to the Act, listed companies obliged to prepare consolidated financial statements must apply the International Accounting Standards. In accordance with the International Financial Reporting Standard 8 Operating Segments, selected entities, mainly listed companies, must separate and disclose information about their operating segments.

Selected financial data for individual operating segments of the surveyed power groups in 2016-2021 are presented in Tables 1 and 2. Table 1 presents the sales revenues of individual operating segments of the surveyed energy groups and their shares in the total revenues of these groups. The share of Conventional Generation and Heat Generation operating segments in total revenues (excluding other revenues and consolidation adjustments) ranged from 31% in 2016 to 50% in 2021.

Table 1.
Revenues of the 4 surveyed power companies, broken down into operating segments - 2016-2021

Operating segments	REVENUES (PLN m)					
	2016	2017	2018	2019	2020	2021
Conventional Generation and Heat Generation	20 544	23 330	30 886	38 359	44 310	57 037
Renewables Generation (RES)	717	724	839	1 039	1 707	2 333
Sales	42 835	40 522	42 949	46 966	63 765	81 068
Distribution	19 455	20 692	18 792	16 437	20 805	21 301
Mining	3 097	3 322	3 023	2 503	2 874	3 830
Other activities and consolidation adjustments	-19 473	-26 126	-29 391	-20 240	-36 356	-52 337
Total	**67 175**	**62 464**	**67 098**	**85 065**	**97 105**	**113 231**
Operating segments	**REVENUES (%)**					
	2016	**2017**	**2018**	**2019**	**2020**	**2021**
Conventional Generation and Heat Generation	31%	37%	46%	45%	46%	50%
Renewables Generation (RES)	1%	1%	1%	1%	2%	2%
Sales	64%	65%	64%	55%	66%	72%
Distribution	29%	33%	28%	19%	21%	19%
Mining	5%	5%	5%	3%	3%	3%
Other activities and consolidation adjustments	-29%	-42%	-44%	-24%	-37%	-46%
Total	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

Source: (Financial statements, 2019-2021; own calculations).

In 2019-2020, Conventional Generation and Heat Generation operating segments had negative EBIT values of PLN 6.3 and PLN 6.0 billion respectively. In 2016-2018, the total EBIT was positive and amounted to: PLN 1.7 billion in 2016; PLN 2.4 billion in 2017 and PLN 1.7 billion in 2018. However, the average price of EU Allowances (the sum of the prices at the end of each month divided by 12) was: EUR 5.32/t CO_2 in 2016; EUR 6.35/t CO_2 in 2017; EUR 18.11/t CO_2 in 2018; EUR 25.85/t CO_2 in 2019, EUR 25.67/t CO_2 in 2020, and EUR 55.37/t CO_2 in 2021 (Table 5). Therefore, the average prices of EU Allowances in 2021 were 904% higher than in 2016.

This may indicate that the increase in prices of EU Allowances had an impact on these values. The increase in the prices of other production factors did not have a significant impact on the costs of Conventional Generation and Heat Generation operating segments. For example, coal prices in the discussed period increased by only 12%. Gas prices at the end of 2021 were higher by 543% compared to December 2015 (Table 5), but the production of electricity from gas in the surveyed enterprises was very low or equal to zero. It follows that the increase in gas prices had no impact on the costs of electricity production in the surveyed companies. In turn, the financial results of Conventional Generation and Heat Generation operating segments in 20021 was positive and amounted to PLN 3.127 billion. The improvement in profits was possible due to higher electricity prices on the stock exchange (it is assumed that the increase in electricity prices on the stock exchange resulted in an increase in the prices of electricity sold by the surveyed companies).

Table 2.
EBIT of the 4 analyzed power companies, broken down into operating segments - 2016-2021

Operating segments	EBIT (PLN m)					
	2016	2017	2018	2019	2020	2021
Conventional Generation and Heat Generation	1 676	2 418	1 700	-6 023	-6 320	3 127
Renewables Generation (RES)	-770	-36	205	657	551	910
Sales	1 103	1 831	331	781	1 307	394
Distribution	4 083	3 921	4 186	3 846	4 573	5 223
Mining	36	140	-948	-974	-760	-62
Other activities and consolidation adjustments	-154	-105	100	-348	-786	-128
Total	5 973	8 169	5 575	-2 060	-1 435	9 465

Source: (Financial statements, 2016-2021; own calculations).

At the end of 2016, electricity prices were 8.5% higher than in December 2015 (Table 5). At the end of 2017, the price of electricity was only 5% higher compared to the end of 2015. A year later, in December 2018, the price of electricity was 60% higher than in December 2015 while in December 2019, the price of electricity was 29% higher than in December 2015, i.e., 19% lower than in December 2018. At the end of 2020, electricity prices on the stock exchange were 78% higher than in December 2015. In December 2021, the price of electricity was 476.6% higher than in December 2015, i.e. 224.4% higher than in 2020.

Such a level of electricity prices on the stock exchange proves that it is not possible to "pass" higher electricity production costs onto customers in 2019-2020.

One of the reasons for the inability to increase the prices of electricity sold in 2020 was the outbreak of the COVID pandemic, which had a significant impact on the global economy in 2020. In Poland, Gross Domestic Product (GDP) in 2020 was negative and amounted to 2.7% In 2019 Polish GDP increased by 4.7% (GUS, 21.12.2022). Electricity production in Poland in 2020 decreased by 3.3% compared to 2019 (Figure 2). In 2021, the surveyed companies reported a total EBIT of PLN 3.127 billion from Conventional Generation and Heat Generation operating segments. The improvement in the result was significantly influenced by the increase in electricity prices, which increased by 260% compared to December 2019 and by 224.4% compared to December 2020. In 2021, Polish GDP increased by 6.8% (GUS, 2022), and electricity production increased by 12.4% compared to the previous year (Figure 3). The total EBIT value of the 4 surveyed groups in 2021 amounted to PLN 9.5 billion (in 2020, the total EBIT was PLN -6.3 billion, and in 2019 - PLN -6.0 billion).

Apart from 2021, Conventional Generation and Heat Generation operating segments had a low or negative return on assets (Table 3). This situation also applies to Mining operating segments. It can be stated that those companies that produced large amounts of electricity from fossil fuels and had Mining operating segments reported worse financial results.

Table 3.
EBIT/ASSETS of the 4 analyzed power companies, broken down into operating segments - 2016-2021

Operating segments	EBIT/ASSETS (%)					
	2016	2017	2018	2019	2020	2021
Conventional Generation and Heat Generation	6%	8%	5%	-18%	-27%	15%
Renewables Generation (RES)	-535%	-44%	199%	435%	17%	34%
Sales	17%	34%	5%	11%	18%	5%
Distribution	10%	10%	10%	9%	10%	11%
Mining	1%	3%	-21%	-23%	-18%	-2%
Other activities and consolidation adjustments	16%	-6%	6%	-21%	369%	-7%
Total	7%	10%	6%	-2%	-2%	11%

Source: (Financial statements, 2016-2021; own calculations).

The data in Table 4 shows that in 2019-2021, the change in sales revenues of the operating segments was higher than the change the in cost of EU Allowances. This could mean that the increase in costs of EU Allowances has been "passed on" to customers.

The increase in the cost of EU Allowances compared to the increase in sales revenues amounted to 36% in 2017; 6% in 2018; 34% in 2019; 74% in 2020 and 27% in 2021. It reduced the margins on the electricity sold and the need to make multi-billion write-offs of non-financial assets in these operating segments in 2019-2020.

Table 4.
Selected operation and financial data for the Portfolio of 4 surveyed power companies in 2019-2021 – "The Conventional generation and heat generation" operating segments

Data		2016	2017	2018	2019	2020	2021
EBIT	PLN m	1676	2418	1700	-6023	-6320	3127
Write-offs related to the impairment of non-financial assets	PLN m	-2172	936	62	6982	5678	884
EBIT after correction for write-offs	PLN m	-496	3354	1762	959	-642	4011
Cost of EU Allowances	PLN m	1693	2682	3125	5648	10076	13505
Revenue	PLN m	20544	23330	30886	38359	44310	57037
Change in revenues	PLN m	0	2786	7556	7473	5951	12727
Change in EU Allowances costs	PLN m	0	989	443	2523	4429	3429
Change in EUA costs/Change in revenues	%	0%	36%	6%	34%	74%	27%
Cost of EU Allowances as % of revenues	PLN m	8.2%	11.5%	10.1%	14.7%	22.7%	23.7%
Profitability of sales (EBIT after corrections/revenues)	%	-2.4%	14.4%	5.7%	2.5%	-1.4%	7.0%

Source: (Financial statements, 2016-2021; own calculations).

The change in the financial situation of the surveyed companies occurred only in 2021, which is indicated by the high electricity prices on the stock exchange (Table 5). The mere analysis of the electricity prices sold by the companies in question is of little use because the price of electricity sold includes electricity produced by a given energy group and electricity purchased from other entities.

Hypothesis H1 assumed that the continuous increase in the prices of EU Allowances in 2016-2021 had a significant, negative impact on the financial results of the surveyed four energy companies. The financial analysis of the combined financial results of the four energy groups and their operating segments shows that the increase in the prices of EU Allowances had a negative impact on the financial results of Conventional Generation and Heat Generation operating segments in 2019-2020 (Table 4). It can therefore be concluded that this impact was also negative on the consolidated financial results of these energy groups in 2019-2020.

In 2021 a greater increase in the prices of EU Allowances and other factors of production was "transferred" into higher electricity prices (Table 5). In 2021, Polish GDP increased by as much as 6.8% and electricity production by 12.4% (Figure 3) compared to the previous year. In conclusion, hypothesis H1 is true for 2019-2020 and not true for 2016-2018 and for 2021. In conclusion, hypothesis H1 cannot be rejected for 2019-2020 and can be rejected for 2016-2018 and 2021. The higher costs of EU Allowances in 2021 were paid by the whole of Polish society.

3. The costs of EU Allowances and their impact on the share portfolio price of surveyed companies

3.1. Literature review

A review of the literature shows that some authors analyzed the impact of the prices of several factors on the prices of EU Allowances while other authors studied the impact of EU Allowances and the prices of other factors on the stock prices of European energy companies.

In general, we can say that the factors that determine prices of EU Allowances, considered in the literature, are microeconomic and macroeconomic (characteristics of the energy sector, GDP, emissions growth, emission targets), energy factors (the price of energy sources, and energy substitutability possibilities) and climate factors (temperature and climatic conditions) (Bataller et al., 2006). According to some authors, energy prices are the key factors shaping the prices of EU Allowances in the short term due to the ability of electricity producers to switch the energy source from coal to gas and vice versa, which generates different demands for EU Allowances. Other factors influencing the prices of EU Allowances are regulations and extreme temperatures (Chevallier, 2010). Some authors define factors influencing the prices of EU Allowances and analyse the relationship between prices of EU Allowances, electricity prices, and electricity costs for industry (Reinaud, 2007).

The impact of free allocation of EU Allowances (the phase I, 2005-2007) on the electricity prices and the profitability of power generation companies was dealt with by Jos Sijm, Karsten Neuhoff, and Yihsu Chen (Sijm et al., 2006). Electricity prices are determined by the cost of fossil fuels, mainly coal and gas, costs of EU Allowances, the impact of climate policy, and climatic factors such as temperature and rainfall (Kiriat, Ahmanda, 2011). According to some authors, an increase in the number of extremely hot days may adversely affect the EU Allowances prices because on hot days more cooling is needed, which increases the demand for energy, and thus prices of EU Allowances (Rickels et al., 2010). In turn, the cost of EU Allowances depends on the efficiency of power units and the CO_2 emission rate per MWh of electricity produced from individual energy sources (Schumacher et al, 2012). Benz and Trück (Benz E., Trück, 2009) analyzed the short-term EU Allowances spot price of the new EU-wide CO_2 emissions trading system (EU-ETS).

Other authors have not examined the factors influencing the prices of EU Allowances but have studied the effect of EU Allowances cost on the returns on shares of electricity producers.

The relationship between the prices of EU Allowances and the stock exchange quotations of energy companies has been the subject of research by many authors in terms of their impact on the various stages of the development of the EU Emissions Trading System (EU ETS).

U. Oberndorfer (2009) studied, among others, the impact of changes in EU Allowances prices on changes in the share price portfolio of 12 European energy companies from 6 EU countries in the period from August 4, 2005, to June 19, 2007, i.e., in the period covering the entire phase I (2005-2007). He assumed that the share prices of the companies under consideration, apart from prices of EU Allowances, were influenced the crude oil prices, gas prices, and electricity prices. His calculations showed that the increase in the prices of EU Allowances had a positive or negative impact on the share prices of the company, depending on which country it came from.

On the other hand, Veith, Werner, and Zimmermann (2009) examined the impact of EU Allowances return and other independent variables (including daily gas and oil return, market portfolio return, and exchange rate return) on daily return on the shares of 22 European electricity companies in the period from April 25, 2005, to August 31, 2007 (128 companies in the second step). The calculations showed that the share prices of the surveyed companies were positively correlated with the prices of EU Allowances. These results may indicate that these companies could easily pass on the increase in prices of EU Allowances to the electricity prices (Veith et al., 2009).

Tian Y., Akimov A., Roca E., and Wong V. (2016) examined the impact of changes of EU Allowances prices, gas prices, oil prices, electricity prices, and the Dow Jones Euro Utilities Index on changes of share prices of the portfolio of 12 European stocks included in this index in the period from November 21, 2005, to December 5, 2012. The adopted period covers the phases I and II. The stock energy volatility was largely driven in the same direction by EU Allowances market volatility (Tian et al., 2016).

The relationship between the change in EU Allowances returns and the change in shares returns of electricity companies from 6 EU Member States in the phase III (2013-2020) was analysed by Garcia, Garcia-Alvarez, and Moreno (Garcia et al., 2020). Estimated coefficients for the period from January 1, 2013, to July 22, 2018, indicated that the EU Allowances prices had a satisfactory positive impact on the share prices of the surveyed power companies.

In addition to the impact of EU Allowances price changes on the share prices of power companies, many authors have examined their impact on other sectors of the economy, such as steel, and cement (Branger et al., 2001; Moreno, Pereira da Silva, 2016) and aviation industries (Velzen et al., 2019). The strength of this impact depends on the EU Allowances prices (Rabe et al., 2019). The expected high prices of EU Allowances will determine the profitability of replacing coal-fired units with new high-efficiency units, the scale of the RES share increase, as well as the competitiveness of renewable energy in general (Rabe et al., 2020).

Research by the above-mentioned authors shows that the rate of return on shares of a power company is influenced by returns on coal, electricity, EU Allowances, and gas. Other important factors that affect stock returns are market index returns and currency exchange returns.

3.2. Empirical analysis

The research hypothesis H2 assumes that there is a statistical correlation between returns on investment in the portfolio of shares of the surveyed companies (dependent variable) and returns on investments in coal, electricity, WIG index, gas, and investments in currencies (EURO). In other words, the research hypothesis H2 assumes that the prices of gas, coal, and electricity, the exchange rate, and the value of the WIG index explain the changes in the share prices of the surveyed companies. To confirm or reject the research hypothesis H2, a regression analysis was performed. Finally, the following data were entered as independent variables: EUA return, coal return (PSCMI 1), electricity return (DAM), gas return (TTF), and exchange rate return. The dependent variable is the return on the portfolio of shares of the 4 examined companies.

Thus, 72 monthly data (from January 2016 to December 2021) were used to estimate the parameters of the regression model, calculated on the basis of the data in Table 5.

The share prices of the surveyed companies listed on the Warsaw Stock Exchange, EU Allowances prices and ICE Dutch TTF Natural Gas Futures prices listed by ICE (Intercontinental Exchange, Inc., NYSE: ICE), exchange rates published by the National Bank of Poland (NBP) and values of the Warsaw Stock Exchange Index (WIG) are daily data from the last trading day of each month. Prices of electricity (DAM) and coal (PSCMI 1 index) on the Polish Power Exchange (TGE) are average prices from individual months.

It is assumed that the price of the stock portfolio is the average price of the shares of the 4 surveyed companies. The logarithmic rate of return was used to calculate the rate of return on investment in individual variables: $\ln (r_t / r_{t-1})$. The regression analysis was performed in the Gretl program based on the data in Table 5. The dependent variable, denoted by Y, is the return on the portfolio of shares of the surveyed companies, and the independent variables are: X1 - EUA return, X2 - Coal return (PSCMI 1), X3 - Electricity return (DAM), X4 - Gas return (TTF), X5 - Exchange rate return and X6 - WIG index return. After introducing all 6 independent variables and one dependent variable into the regression model, it turned out that not all of the proposed independent variables are statistically significant (p-value less than 0.05) and should be included in the regression model. After excluding 5 statistically insignificant independent variables (Table 6), it turned out that only one independent variable remained in the regression model, i.e. X6 - the return from the WIG index.

Table 5.

Selected Monthly data for regression analysis – December 2015-December 2021

Date	EUA price - EUR/EUA	Gas price (TTF) - EUR/MWh	X 5 Exchange rate - EUR/PLN	X 1- EUA price - PLN/pcs.	X- 2 Coal price (PSCMI 1) - PLN/tonne	X 3 - Electricity price (DAM) - PLN/MWh	X 4 - Gas price (TTF) - PLN/MWh	X - WIG Index	PGE share price PLN/pcs.	ENERGA share price - PLN/pcs.	ENEA share price - PLN/pcs.	TAURON share price - PLN/pcs.	AVERAGE PRICE - PLN/pcs.
30.12.2015	8.22	14.61	4.2615	35.03	225.98	142.90	62.26	46 467	12.79	12.64	11.30	2.88	9.90
29.01.2016	6.04	13.38	4.4405	26.82	201.17	169.50	59.41	44 290	13.80	13.52	11.72	2.71	10.44
29.02.2016	4.99	12.19	4.3589	21.75	192.97	140.00	53.13	45 430	12.94	12.69	11.06	2.53	9.81
31.03.2016	5.20	11.94	4.2684	22.20	194.34	146.40	50.96	49 017	13.98	13.11	11.92	3.01	10.51
29.04.2016	6.17	12.78	4.4078	27.20	195.00	157.40	56.33	47 642	13.18	12.44	11.80	2.96	10.10
30.05.2016	6.08	13.91	4.3820	26.64	195.40	155.60	60.95	45 844	12.61	9.85	10.02	2.58	8.77
30.06.2016	4.46	14.38	4.4265	19.74	193.54	209.40	63.65	44 749	11.82	9.50	9.90	2.84	8.52
29.07.2016	4.41	14.46	4.3684	19.26	196.13	151.60	63.17	46 172	12.80	9.74	10.96	3.08	9.15
30.08.2016	4.46	11.54	4.3555	19.43	188.78	140.50	50.26	47 935	11.54	8.10	9.86	2.78	8.07
30.09.2016	4.96	15.35	4.3120	21.39	197.09	155.20	66.19	47 085	10.15	7.50	8.51	2.60	7.19
31.10.2016	5.90	17.79	4.3267	25.53	189.71	169.30	76.97	49 159	10.27	8.04	10.04	2.65	7.75
30.11.2016	4.58	18.21	4.4240	20.26	189.49	159.70	80.56	48 619	9.28	7.95	9.30	2.65	7.30
30.12.2016	6.54	19.54	4.4405	29.04	190.49	155.00	86.77	51 754	10.45	9.10	9.50	2.85	7.98
31.01.2017	5.69	20.75	4.3308	24.64	198.38	162.40	89.86	51 754	10.45	9.10	9.50	2.85	7.98
28.02.2017	5.57	16.90	4.3166	24.04	198.60	155.70	72.95	55 232	10.92	10.21	10.13	2.95	8.55
31.03.2017	5.04	15.80	4.2198	21.27	200.20	146.50	66.67	58 300	11.87	10.92	10.67	3.00	9.12
28.04.2017	4.94	16.18	4.2170	20.83	199.26	141.10	68.23	57 911	11.40	10.63	11.31	3.39	9.18
31.05.2017	5.35	15.29	4.1737	22.33	208.64	148.80	63.82	61 645	11.53	9.96	11.92	3.29	9.18
30.06.2017	5.42	14.84	4.2265	22.91	208.45	153.10	62.72	60 092	10.92	9.84	11.30	3.22	8.82
31.07.2017	5.73	14.97	4.2545	24.38	208.39	155.20	63.69	61 018	12.11	10.47	13.36	3.58	9.88
31.08.2017	6.54	16.45	4.2618	27.87	200.76	162.80	70.11	62 596	13.10	12.73	15.15	3.81	11.20
29.09.2017	7.59	17.38	4.3091	32.71	206.17	171.40	74.89	64 974	14.27	13.64	15.25	3.92	11.77
31.10.2017	7.81	18.21	4.2498	33.19	208.75	174.50	77.39	64 290	13.30	13.40	14.80	3.75	11.31
30.11.2017	7.97	20.30	4.2055	33.52	211.41	170.30	85.37	64 867	13.05	12.65	13.93	3.52	10.79
29.12.2017	8.60	19.63	4.1709	35.87	212.66	150.40	81.87	62 440	11.93	12.09	11.89	3.10	9.75
30.01.2018	9.85	17.95	4.1461	40.84	226.76	161.00	74.42	66 048	11.89	12.00	10.99	3.03	9.48
28.02.2018	10.73	19.18	4.1779	44.83	228.22	187.00	80.13	61 703	10.14	10.42	10.12	2.55	8.31
29.03.2018	14.04	18.39	4.2093	59.10	230.75	206.00	77.41	58 377	9.91	9.63	9.22	2.43	7.80
30.04.2018	14.60	20.25	4.2204	61.62	238.22	180.00	85.46	59 932	10.47	10.31	10.43	2.35	8.39
31.05.2018	16.16	22.60	4.3195	69.80	237.20	221.00	97.62	57 283	9.84	9.43	10.26	2.24	7.94
29.06.2018	16.51	21.87	4.3616	72.01	239.42	228.00	95.39	55 954	9.34	8.94	9.14	2.29	7.43
31.07.2018	19.34	22.11	4.2779	82.73	238.10	227.00	94.58	59 964	9.83	8.95	9.58	2.25	7.65
31.08.2018	23.20	26.13	4.2953	99.65	248.44	258.00	112.24	60 201	9.00	8.40	8.54	2.00	6.99
28.09.2018	24.63	27.33	4.2714	105.20	245.38	272.00	116.74	58 975	9.52	7.82	8.00	1.77	6.78
31.10.2018	18.49	23.87	4.3313	80.09	243.44	254.00	103.39	55 313	10.51	7.80	8.04	1.78	7.03
30.11.2018	22.70	24.69	4.2904	97.39	250.78	253.00	105.93	58 203	11.67	9.09	10.70	2.25	8.43
31.12.2018	27.06	48.99	4.3000	116.36	241.76	229.00	210.66	57 691	10.00	8.91	9.90	2.19	7.75

Cont. table 5.

Date	EUA price - EUR/EUA	Gas price (TTF) - EUR/MWh	X 5 Exchange rate - EUR/PLN	X 1- EUA price - PLN/pcs.	X- 2 Coal price (PSCMI 1) - PLN/tonne	X 3 - Electricity price (DAM) - PLN/MWh	X 4 - Gas price (TTF) - PLN/MWh	X - WIG Index	PGE share price PLN/pcs.	ENERGA share price - PLN/pcs.	ENEA share price - PLN/pcs.	TAURON share price - PLN/pcs.	AVERAGE PRICE - PLN/pcs.
31.01.2019	23.90	19.85	4.2802	102.30	254.77	246.00	84.96	60 367	11.86	10.14	10.73	2.37	8.78
28.02.2019	23.13	17.89	4.3120	99.74	255.97	213.00	77.14	59 904	11.60	9.80	10.08	2.33	8.45
29.03.2019	22.82	14.43	4.3013	98.16	258.14	199.00	62.07	59 668	9.94	8.63	8.75	2.02	7.34
30.04.2019	27.43	14.53	4.2911	117.70	260.91	227.00	62.35	60 146	9.52	7.50	7.65	1.73	6.60
31.05.2019	25.45	11.21	4.2916	109.22	256.52	243.00	48.11	57 910	9.23	7.74	8.41	1.59	6.74
28.06.2019	27.50	9.62	4.2520	116.93	263.75	256.00	40.90	60 187	9.59	7.80	9.34	1.71	7.11
31.07.2019	29.38	11.00	4.2911	126.07	260.00	243.00	47.20	59 671	8.89	7.33	8.25	1.58	6.51
30.08.2019	27.37	10.72	4.3844	120.00	258.89	266.00	47.00	56 740	7.71	6.62	8.68	1.50	6.12
30.09.2019	25.76	16.39	4.3736	112.66	263.36	243.00	71.68	57 320	7.99	6.40	8.60	1.55	6.13
31.10.2019	26.35	16.13	4.2617	112.30	266.03	226.00	68.74	57 783	8.19	6.15	8.45	1.65	6.11
29.11.2019	25.94	15.65	4.3236	112.15	266.35	218.00	67.66	57 502	8.72	6.89	8.95	1.78	6.58
31.12.2019	25.18	12.29	4.2585	107.23	265.23	185.00	52.34	57 833	7.96	7.08	7.92	1.64	6.15
31.01.2020	24.31	9.78	4.3010	104.56	268.32	190.00	42.06	56 681	6.86	7.18	7.17	1.49	5.67
28.02.2020	24.02	8.87	4.3355	104.14	261.84	176.00	38.46	49 277	4.47	7.02	5.60	1.10	4.55
31.03.2020	18.42	6.90	4.5523	83.85	262.49	165.00	31.41	41 625	3.81	6.90	4.73	1.12	4.14
30.04.2020	20.39	6.22	4.5424	92.62	263.94	151.00	28.25	46 117	4.12	7.78	5.54	1.13	4.64
29.05.2020	22.18	4.38	4.4503	98.71	267.21	173.00	19.49	48 128	4.84	7.90	5.86	1.24	4.96
30.06.2020	27.68	6.16	4.4660	123.62	267.39	217.00	27.51	49 569	6.87	8.14	7.16	2.36	6.13
31.07.2020	27.22	6.02	4.4072	119.96	263.10	222.00	26.53	50 468	6.62	7.80	7.13	2.60	6.04
31.08.2020	29.53	11.24	4.3969	129.84	263.94	231.00	49.42	51 629	6.04	8.10	6.65	2.53	5.83
30.09.2020	27.50	12.35	4.5268	124.49	260.69	242.00	55.91	49 412	6.42	8.30	5.70	2.20	5.65
30.10.2020	24.19	14.22	4.6188	111.73	262.06	240.00	65.68	44 098	4.51	8.31	4.52	1.74	4.77
30.11.2020	29.60	15.14	4.4779	132.55	256.99	244.00	67.80	52 639	5.76	7.44	5.44	2.13	5.19
31.12.2020	32.94	19.12	4.6148	152.01	254.80	254.00	88.23	57 026	6.50	7.88	6.54	2.72	5.91
29.01.2021	33.18	20.91	4.5385	150.59	255.97	253.00	94.90	56 979	6.54	7.82	6.86	2.81	6.01
26.02.2021	37.60	15.69	4.5175	169.86	253.82	265.00	70.88	56 970	6.65	7.78	6.52	2.56	5.88
31.03.2021	42.89	18.99	4.6603	199.88	252.24	273.00	88.50	58 082	6.85	7.79	6.48	2.75	5.97
30.04.2021	49.31	23.29	4.5654	225.12	247.43	274.00	106.33	60 811	10.22	8.03	8.43	3.35	7.51
31.05.2021	52.24	25.12	4.4805	234.06	242.94	297.00	112.55	66 285	9.94	8.22	8.76	3.40	7.58
30.06.2021	56.78	34.62	4.5208	256.69	249.69	344.00	156.51	66 067	9.30	7.90	8.40	3.39	7.25
30.07.2021	53.69	40.76	4.5731	245.53	246.03	375.00	186.40	67 638	8.80	7.83	8.61	3.21	7.11
31.08.2021	61.07	49.68	4.5374	277.10	248.52	374.00	225.42	70 930	10.00	7.85	9.85	3.63	7.83
30.09.2021	62.16	97.78	4.6329	287.98	245.17	463.00	453.00	70 341	9.02	8.16	9.38	3.36	7.48
29.10.2021	59.08	64.86	4.6208	273.00	246.37	480.00	299.71	73 586	9.92	8.12	10.08	3.29	7.85
30.11.2021	75.73	93.15	4.6834	354.67	237.41	545.00	436.26	67 815	8.69	7.86	9.50	2.97	7.25
31.12.2021	80.65	87.03	4.5994	370.94	253.47	824.00	400.29	69 296	8.17	7.65	8.55	2.67	6.76

Source: (National Bank of Poland, 22.09.2022; Polish Power Exchange, 29.09.2022; ICE, 28.11.2022; INVESTING.com, 22.12.2022).

Table 6.
*Independent variables excluded from the regression model **

Model	β	t	p
X1 - EUA return	-0.003[b]	-0.036	0.9715
X2 - Coal return (PSCMI 1)	-0.271[b]	-0.804	0.4245
X3 - Electricity return (DAM)	0.015[b]	0.199	0.8427
X4 - Gas return (TTF)	-0.031[b]	-0.786	0.4346
X5 - Exchange rate return	1.209[b]	1.858	0.0677

* Dependent variable: Y Portfolio return.

Source: (Own calculation using the Gretl program).

The results of the regression analysis with only one independent variable, X6 - WIG index return, and one dependent variable, Y Portfolio return, are presented in Table 7.

The measure of the fit of the regression line to the empirical data is the coefficient of determination - R^2. The calculated coefficient of determination R^2 is 0.388, which means that 38.8% of the change in the Y Portfolio return can be explained by the change of the independent variable, the X 6 WIG index return. The data in Table 5 show that the value of the significance of F parameter is lower than the adopted significance level $\alpha = 0.05$. It means that there are grounds for stating the existence of a linear relationship between the explained variable and the explanatory variable in the regression equation. The mean square (MS) is at an incredibly low level (0,005), which means that the average deviation of the actual values from the benchmarks is incredibly low. The standard error of estimate (0.153) is not high.

Table 7.
Regression analysis results

Portfolio of 4 companies				
	R Square	Adjusted R Square	Standard Error	Observations
Regression model	0.3968	0.3882	0.1537	72
Predictor (constant) - X6 - WIG index return				
Dependent variable - Y Portfolio return				
	Coefficients	Standard Error	t Stat	P-value
Intercept	-0.0111	0.0082	-1.345	0.1830
X 6 WIG index return	1.0434	0.1537	6.787	<.001
ANOVA				
	df	MS	F	Significance F
Regression	1	0.2230	46.0600	<.001
Residual	70	0.0048		

Source: (Own calculation using the Gretl program).

After receiving the regression analysis results it should be checked whether all assumptions of the regression model are fulfilled. The assumptions of the regression model are as follows:

- existence of a linear relationship between the dependent variable Y and the independent variable X,
- existence of normal distribution of error terms,
- the non-existence of autocorrelation among error terms,
- the absence of heteroscedasticity which means that exists the homoscedasticity of the model (the variance of the error terms in the model is constant, i.e., the random component is homoscedastic).

The test for the existence of a linear relationship between X and Y uses the following hypotheses (A.D. Aczel, J. Sounderpandian, 2019, p. 629):

H_0: $\beta_0 = 0$,

H_1: $\beta_1 \neq 0$.

In order to check the existence of a linear relationship between X and Y, the Student's t-test is performed. The estimated β coefficient determining the direction and strength of the impact of the variable X6 (WIG index return) on the variable Y (Portfolio return) is positive and amounts to 1.0434 (Table 7). This means that an increase in WIG index return (X6) by 1% increases the return on the equity portfolio by 1.0434%. The linearity of the β coefficients is evidenced by p values which are much lower than the adopted significance level. Moreover, the critical value for the t-statistic with 71 (72-1) degrees of freedom and $\alpha = 0.05$ for the Student’s t-distribution, 1.99 (read from the Student’s t-distribution tables), is lower than 6.787 (Table 7). This proves that we cannot accept the hypothesis H_0: $\beta_0 = 0$.

The normal distribution of error terms is one of the main assumptions of a regression model. The Doornik-Hansen test for multivariate normality was performed to verify the normal distribution of error components. A histogram was also used for this.

The Doornik-Hansen test uses the following hypotheses for the normal distribution of error terms:

H_0: normal distribution of error terms exists,

H_1: normal distribution of error terms does not exist.

The outcomes of the Doornik-Hansen test for the null hypothesis of the normal distribution: Chi-square (2) = 3.987 with a p-value of 0.136 and the histogram (Figure 6) show that the H_0 hypothesis cannot be rejected.

The normality of the distribution of error terms can also be checked by other tests using the Gretl program, such as Shapiro-Wilk test, Lilliefors test, and Jarque-Bra test. The results of these tests are as follows:

- Shapiro-Wilk test = 0.972, with a p-value of 0.114,
- Lilliefors test = 0.089, with a p-value of 0.160,
- Jarque-Bra test = 4.299, with a p-value of 0.117.

All the results of the above tests show that hypothesis H0 cannot be rejected.

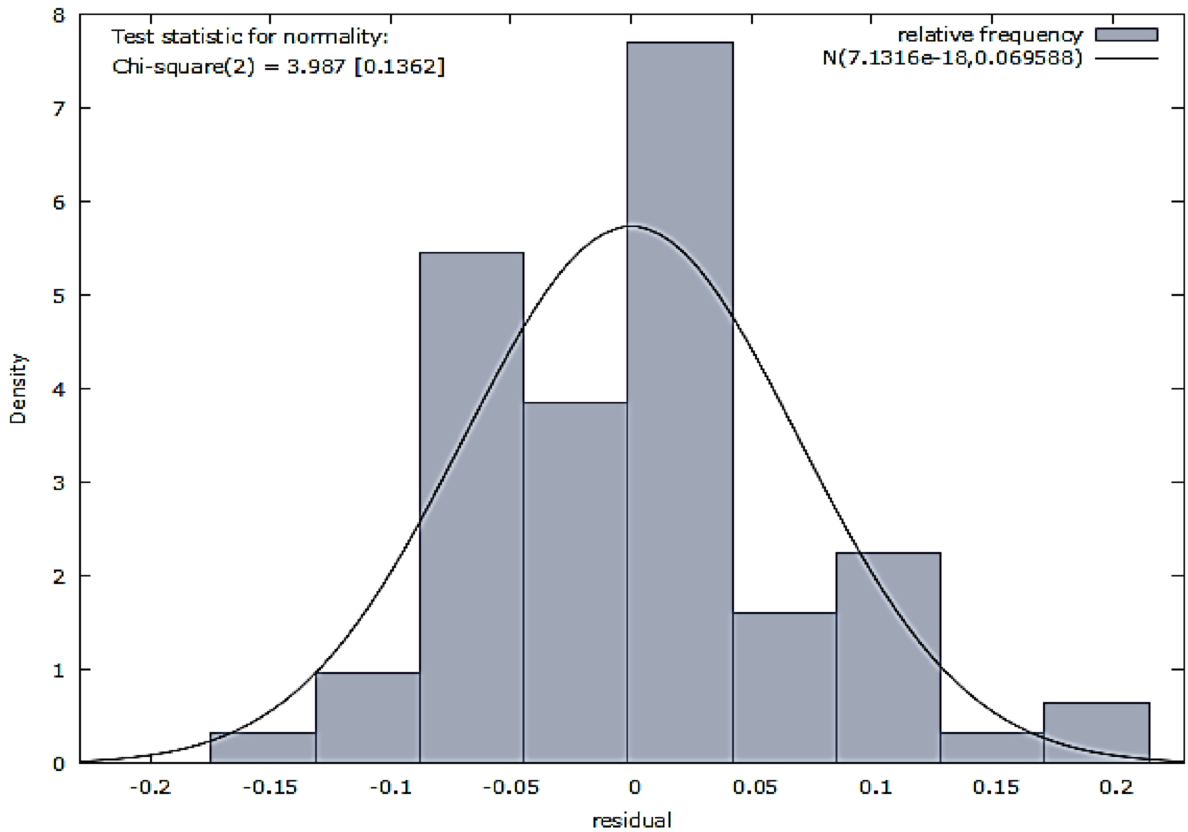

Figure 6. Histogram - test statistic for normality.

Source: (own calculations in the Gretl program based on data from Table 5).

The non-existence of autocorrelation among error terms is the next assumption of a regression model. If autocorrelation does exist, the outcomes of the model might be unreliable. Therefore, it's essential to check this assumption. Autocorrelation occurs when the error terms of a regression model are not independent of each other. In other words, if the value of error terms e_i depends on the value of error terms e_{i-1}. Autocorrelation leads to underestimation of the standard error of predictor variables. Autocorrelation or lagged autocorrelation can be measured for various lags, the most common being lag-1. However, there are also lag-2, lag-3, etc.

- Lag-1: Checks the correlation between e_i and e_{i-1}.
- Lag-2: Checks the correlation between e_i and e_{i-2}.
- Lag-3: Checks the correlation between e_i and e_{i-3}.
- etc.

In order to check the autocorrelation, the Durbin-Watson test and the Breusch-Godfrey test were performed. The Durbin-Watson test checks the first-order autocorrelation (i.e., lag-1). It uses the following hypotheses:

- H_0: First-order autocorrelation does not exist. There is no correlation among the error terms.
- H_1: First-order autocorrelation exists. The error terms are autocorrelated.

The Durbin-Watson test result shows the test statistic DW = 1.99 and is higher than the upper critical value of 1.6457. Therefore, it can be concluded that there is no statistical evidence that the data are positively correlated.

The next test, the Breusch-Godfrey test, checks autocorrelation between first-order, second-order, and third-order, etc. error terms. First and twelfth-order autocorrelation was checked.

The Breusch-Godfrey test uses the same hypotheses as the Durbin-Watson test, namely:

- H_0: First-order and twelve-order autocorrelation does not exist. There is no correlation among error terms.
- H_1: First-order and twelve-order autocorrelation exist. Error terms are autocorrelated.

The coefficient in the Breusch-Godfrey test for Lag-1 is minus 0.024, and the p-value – is 0.8537 while the coefficient for Lag-12 is 0.150, and the p-value – is 0.2999. It can be concluded that there is no autocorrelation among the error terms.

In order to check the correctness of the next assumption of the regression model, i.e., the lack of heteroscedasticity (the variance of error terms in the model is constant), the Breusch-Pagan test and the White test were performed.

The Breusch-Pagan test checks whether error terms' variance depends on the independent variable's value.

The Breusch-Pagan test hypotheses:

- H_0: error terms are distributed with equal variance (there is homoscedasticity).
- H_1: error terms are distributed with equal variance (there is no homoscedasticity, there is heteroscedasticity).

The result of the Breusch-Pagan test for heteroscedasticity shows a test statistic LM -0.6736 and a p-value of 0.411 (not significant, i.e., >0.05). Therefore, the hypothesis H_0 that the error terms are distributed with equal variance cannot be rejected, the error terms are homoscedastic.

The other test, the White test, checks whether error terms' variance depends on the independent variable's value.

The White test uses the same hypotheses as the Breusch-Pagan test:

The White test hypotheses:

- H_0: error terms are distributed with equal variance (there is homoscedasticity).
- H_1: error terms are distributed with non-equal variance (there is no homoscedasticity, there is heteroscedasticity).

The result of the White test for heteroscedasticity shows a test statistic LM =0.6619 and a p-value of 0.718 (not significant, i.e., >0.05). Therefore, hypothesis H_0 that error terms are homoscedastic cannot be rejected.

Research hypothesis H2 assumed that the continuous increase in the prices of EU Allowances in the years 2016-2021 had a significant, negative impact on the return on investment in the portfolio of shares of the surveyed four power companies. In order to analyze the validity of Hypothesis 2, a statistical analysis was performed using a linear regression model. Based on the studied literature, it was assumed that, apart from the prices of EU Allowances, the return on the portfolio of shares of the examined four power groups was affected by other variables, i.e., X1 - EUA return, X2 - Coal return (PSCMI 1), X3 - Electricity return (DAM), X4 - Gas return (TTF), X5 - Exchange rate return and X6 - WIG index return.

However, the regression analysis shows that only the value of the WIG index return had an impact on the value of the return on investment in the portfolio of shares of the four considered power groups. The change in the return on the WIG index in 38.82% (adjusted R^2) explains the changes in the return on the portfolio consisting of shares of the 4 power companies.

4. Summary

The prices of EU Emission Allowances are influenced by the European Emissions Trading System (EU ETS), whose primary task is to reduce greenhouse gas emissions.

This impact results from the reduction of the maximum amount of CO_2 that can be emitted in the European Union and from the decreasing number of free rights (allowances) transferred to individual enterprises in the European Union in particular accounting periods. In turn, prices of EU Allowances affect the economic results of power companies, and thus their value. Considering the EU's greenhouse gas emission reduction policy until 2050, a further increase in the prices of EU Allowances should be expected. The high level of the prices of EU Allowances is intended to encourage the liquidation of high-emission units for economic reasons.

The article analyzed the impact of the increased cost of EU Allowances on the financial situation of the surveyed companies. Additionally, using the regression analysis, the influence of independent variables was estimated, i.e.: X1 - EUA return, X2 - Coal return (PSCMI 1), X3 - Electricity return (DAM), X4 - Gas return (TTF), X5 - Exchange rate return, and X6 - WIG index return for the profitability of investment in the equity portfolio of the surveyed power groups.

The financial analysis of the combined financial results of the four energy groups and their operating segments shows that the increase in the prices of EU Allowances had a negative impact on the financial results of - Conventional Generation and Heat Generating operating segments in 2019-2020. These companies were unable to increase the prices of electricity sold to take into account the higher operating costs of these segments in 2019-2020, but it was already possible in 2016-2018 and 2021. In conclusion, hypothesis H1 stating that the continuous increase in the prices of EU Allowances in 2016-2021 had a significant, negative impact on the aggregated financial results of the surveyed four power companies cannot be rejected for 2019-2020 and can be rejected for 2016-2018 and 2021.

The second research hypothesis, H2, assumed that the continuous increase in the prices of EU allowances in 2016-2021 had a significant, negative impact on the return on investment in the portfolio of shares of the surveyed four energy companies was not confirmed using the linear regression model. It is not possible to determine the unambiguous impact of the EU Allowance price increase on the share prices of the analyzed companies due to the fact that the analyzed companies are vertically integrated energy groups consisting of many independent operating segments. In addition, the COVID pandemic broke out in 2020 and resulted in a negative GDP in 2020. In 2021, there was a sharp "upward recovery" of the Polish economy after the pandemic, which resulted in a significant increase in GDP in 2021.

To sum up, the lack of action on the part of the state and the surveyed companies, at least in the last dozen or so years, to change the Polish energy mix and the energy mix of the surveyed companies increases the costs of transforming the Polish energy sector towards low-emission energy sources. These costs, in connection with the increase in electricity prices, are and will be borne by the Polish society, shareholders of the surveyed companies and Polish enterprises, which will result in a deterioration of their international competitiveness due to higher electricity costs.

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