



Krysiak, Z. (2025). Stock Prices Volatility as an Input to the Economic Assessment of the Nuclear Power Plant in the Real Option Method. *Copernican Journal of Finance & Accounting*, 14(2), 45–57. <http://dx.doi.org/10.12775/CJFA.2025.008>

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## STOCK PRICES VOLATILITY AS AN INPUT TO THE ECONOMIC ASSESSMENT OF THE NUCLEAR POWER PLANT IN THE REAL OPTION METHOD

**Keywords:** exchange traded funds, nuclear assets, Monte Carlo simulation, real options, volatility, regression analysis, nuclear power plant, small modular reactors, high-temperature gas-cooled reactors.

**J E L Classification:** E44, F21, G11, G15, G23, G32.

**Abstract:** The aim of the study was to determine the impact of the share in the activities of the companies for the nuclear sector on the volatility of their stock prices. Activities of the companies in the nuclear sector are measured by the value of produced nuclear assets (NUA) built in the nuclear power plants (NPP). If the impact of produced NUA on stock's volatility were to be found, then it may be used as a good measure of asset volatility when assessing the efficiency of nuclear power plant projects using the real options method supported by Monte Carlo simulation. The presented study covered 23 types of assets, including 10 ETF funds and 13 companies listed on various stock exchanges in the world, which operate in the nuclear sector. ETF funds usually have from several to a dozen or so different company assets in their portfolios, which means that the study actually covered approx. 150 entities involved in the provision of products and services for nuclear power plants and simultaneous production of heat and electricity based on nuclear energy. Regression analysis showed a strong correlation between volatility of stock prices and share in NUA production for ETF funds at the

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Date of submission: May 21, 2025; date of acceptance: August 25, 2025.

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level of with p-Value below 0.01. For the companies traded on the stock exchange, this relationship was very strong at the level of , with p-Value also below 0.01. The studied sample is considered to be representative, since it reflects a significant part of the nuclear sector. From 10% to 100% of the production and services of the studied entities are directed at the nuclear sector. Patterns of the volatility distributions were prepared to be used as an input variable for modeling the distribution of the option values and the value of a nuclear power plant, and also the level of risk. The final conclusion was that the growing share of companies' activities in the nuclear sector increases the standard deviation of return rates, which means that increasing risk will lead to attractive rates of return for the shareholders and stakeholders.

## ■■■ INTRODUCTION

Since 2022, there has been a strong development of the nuclear energy sector, which is caused by the growing demand for cheap and stable sources of electricity and heat. In connection with this, numerous companies and Exchange Traded Funds (ETF) that are active in the nuclear industry have been introduced to stock exchange trading. There is an increase in activities in the development of research, design, and construction of small nuclear reactors (SMRs). In connection with this, the question arises as to how such trends translate into the scale of production of products and services for the construction and operational activity of nuclear power plants and how this affects the standard deviation of the rates of return on shares of companies in the nuclear sector. For the study, the entities were selected whose shares or ETFs are listed on global stock exchanges. Research on the profitability of direct or indirect investments in various assets of the nuclear sector has great practical significance for enterprises and economics.

The presented scientific study examines the impact of the share of companies' production delivered to the nuclear sector on the volatility of their stock returns. This share is measured as a percentage of sales to the nuclear sector in relation to the total sales of a company operating in the energy sector. Therefore, the volatility of stock returns can be an estimator of an asset's variability used for building a nuclear power plant. In this context, we want to prove the dependence of the company's stock variability on the share of activity in the nuclear sector. Based on this, it can be concluded that this translates appropriately into the variability of assets that are supplied by these companies for the construction of nuclear power plants. Next, the distributions of stock price variability will also be obtained, which will be used as the estimators of volatil-

ity to create the distributions of the project's values in the real options model supported by Monte Carlo simulation. The use of the real options method supported by Monte Carlo simulation creates a multidimensional space of information necessary for a complementary assessment of the efficiency and risk of nuclear power plant construction projects.

The aim of this study is to present the variability of stock returns and their distributions for companies operating in the nuclear sector, as well as to use them to evaluate nuclear power plant construction projects based on the real option model. The main aim of the study will be to present the impact of companies' participation in nuclear sector activities on the standard deviation of their rates of return, which is to serve to build patterns of asset variability as components of nuclear power plants.

In the process of achieving the aim, the following hypothesis was put forward: the increasing participation of companies' production for the nuclear sector affects the increase in the volatility of their stock prices.

The following research questions will support the verification of the hypothesis:

- Are companies from the energy sector increasing their activity in the nuclear industry?
- How strongly does the involvement of a particular company in the nuclear sector affect the volatility of its stock prices?
- Is the increase in the number of ETF quotations from the energy sector engaged in nuclear production maybe a measure of the strong development of the nuclear sector?

The following research methods were used to verify the hypothesis: literature studies, secondary data analysis, statistical analysis of time series, linear regression, and comparative method.

## LITERATURE REVIEW

In the assessment of the efficiency of nuclear power plants (NPPs), the quality of input data is crucial. A key input data for such an assessment is the variability of cash flow components. The variability and its distribution allows obtaining NPV value distributions based on the Monte Carlo simulation (MCS), as well as obtaining option value distributions based on the real options approach. The assessment of NPV distributions also leads to inferences about the risk of

negative NPV, i.e., the risk of financial losses. In order to assess the efficiency of NPPs, as well as to compare NPPs of different technologies, the classic Discounted Cash Flow (DCF) method was used and, on this basis, such indicators as Net Present Value (NPV), Present Value (PV), Internal Rate of Return (IRR), Discounted Payback Period (DPP) and Levelized Cost (LC) were measured (Andrianov, Kuptsov, Osipova & Andrianova, 2020). It has been found that NPV for reactors ranging from 300 MW to 1200 MW can achieve positive NPV after 13 years for a 1200 MW reactor, after 17 years for a 600 MW reactor and after 22 years for a 300 MW reactor (Andrianov et al., 2020). Agar and Locatelli discuss the INCAS (INtegrated model for Competitiveness Assessment of SMRs) investment model for NPPs based on DCF and IRR, NPV indicators (Agar & Locatelli, 2020).

The INCAS (INtegrated model for Competitiveness Assessment of SMRs) model is a simulation code developed by Politecnico di Milano, in collaboration with the IAEA (International Atomic Energy Agency), to assess the economic viability of deploying Small Modular Reactors (SMRs) versus Large Reactors (LRs) (INCAS, 2025). It focuses on evaluating the economic and financial performance of staggered SMR deployment, considering factors such as construction and deployment. INCAS aims to help decision-makers evaluate the competitiveness of SMRs by comparing their economic and financial performance with traditional large reactors. INCAS considers various aspects of SMR deployment, including staggered construction and the economic implications of multiple SMR modules. The model includes a module specifically designed to assess the impact of external factors on the overall viability of SMRs, helping to evaluate the choice of reactor size as a multidimensional problem. The INCAS model has been used in various contexts, including assessing the potential for nuclear power expansion in countries such as Bulgaria.

The INCAS model uses the following cost structure for the entire NPP cycle: Capital-Costs = 64%, Operating and Maintenance Costs = 14%, Fuel-Costs = 20%, and Decommissioning-Costs = 2%, which were proposed by Carelli, Mycoff, Garrone, Locatelli, Mancini, Ricotti, Trianni and Trucco (2008). Boarin and Ricotti present a comparative analysis of the costs and LCOE of small reactors versus large ones (Boarin & Ricotti, 2014). Locatelli et al. present the use of real options in assessing the flexibility of SMRs based on different input

scenarios, but do not use MCS (Locatelli, Mancini, Ruiz & Solana, 2012). Comparing the efficiency of different energy production technologies using MCS with NPV measurement and using the real options method allows the selection of the most efficient NPP technology from the perspective of risk level and NPV value (Locatelli, Pecoraro, Meroni & Mancini, 2017; Locatelli, Pecoraro, Meroni, Mancini, 2020). The issues of measuring NPP efficiency from the perspective of the learning curve and scale economies in the process of implementing new SMR technologies are also addressed by comparing SMRs to large reactors (LR) (Lyons & Roulstone, 2018; Trianni, Locatelli & Trucco, 2009).

The literature also discusses the issues of economics of nuclear reactors (Rothwell, 2016; Weibezahn, 2024), efficiency and economics of using HTR-type SMRs in conventional power plants (Bartnik, 2024; Bartnik, 2025), estimation of LCOE (Levelized Cost of Energy), and NPV of investment projects using Monte Carlo simulations (Steigerwald, Weibezahn, Slowik & Von Hirschhausen, 2023). Methods for assessing the efficiency of investment projects and estimating the costs of building nuclear power plants based on SMRs are also presented (Steigerwald et al., 2023; Krysiak, 2025).

An important element of the quality of the assessment of NPP efficiency and risk based on real options using MCS is the method of selecting the volatility of NPP assets and its value distribution, which is a deficit in scientific studies. Therefore, this study focuses on estimating the volatility for NPP based on the volatility of stock prices and ETFs of nuclear companies' assets listed on stock exchanges. A particular research gap is the analysis of the impact of the level of involvement of companies in the nuclear sector on the volatility of stock prices, which is the subject of the presented study. The likely reason for the deficit of scientific studies in this area is the fact that companies and ETFs from the nuclear industry have recently started their listing on stock exchanges, as this took place in the years 2022–2024, while companies that were previously listed as operating in the energy sector have now started to develop or intensify their activities in the nuclear industry, which is the result of the very good prospects for the development and implementation of new SMR technologies in the energy sector, including in particular HTGR technology. This study and its results and conclusions can be a scientific contribution to the assessment of NPP efficiency and the attractiveness of investing in the nuclear sector.

### **DETERMINANTS OF THE DEVELOPMENT OF THE NUCLEAR INDUSTRY**

Nuclear assets (NUA) have been becoming increasingly attractive for several years, as evidenced by the introduction of many companies and investment funds based on nuclear sector assets to stock exchange trading in the last few years. At the end of 2023, the installed capacity of nuclear power plants in the world was 396 GW, and an additional 299 GW is planned to be installed in the near future (RANGEETF, 2025). The fact that the planned doubling of capacity in nuclear energy is also justified by the growing interest of investors by investing capital in companies and ETF funds listed on stock exchanges.

In recent years, there has been significant technological advancement in the design and construction of SMRs, and in particular high-temperature High-Temperature Gas-cooled Reactors (HTGR). Poland, with the POLA reactor concept developed in 2018–2023, belongs to the leading group of five countries, alongside Japan, Russia, the USA, and South Africa, that have developed such an HTGR reactor. Two such reactors in China and one in Japan have already started operating. The POLA reactor may be the basis for commercial reactors used in Polish industrial plants (National Center for Nuclear Research, 2024).

Currently, there are about 450 different types of nuclear power plants in the world, and forecasts indicate that in the long term, until 2050, there will be a great demand and supply boom for new nuclear power plants. In the next 25 years, about 1000–2000 new nuclear power plants based mainly on SMRs may be built in the world, about 100–200 in Europe, and about 10–20 small modular reactors in Poland (Ministry of Energy, 2017). It can be assumed that HTGR technologies will have a significant share in the construction of nuclear power plants. Considering the growing number of entities involved in the production of various components and components for SMRs, as well as the growing demand for stable energy sources in the world, the future of SMR applications looks very positive.

### **THE RESEARCH METHODOLOGY**

The verification of the hypothesis was based on data from 23 types of assets, of which 13 are companies and 10 are ETF funds, which are listed on many stock exchanges in the world. The assets of the entities studied are often listed simul-

taneously on several stock exchanges. ETF funds usually have up to a dozen or so assets of different companies in their portfolios, which means that the study actually covered approximately 150 entities involved in the supply of products and services for power plants producing electricity and heat based on nuclear energy. It can be stated that the number of approximately 150 key entities from the nuclear sector in the world and the listing of their shares on a dozen or so major stock exchanges in the world reflect the representativeness of the research sample.

For the entities undergone in the research study, the standard deviation of the returns on stock prices was referred to the shares of their scale of business involvement in the nuclear market. On this basis, the dependence of the variability of the rates of return on shares of the companies and ETF funds was examined. Data on NUA's share in the entire activity of a company or ETF funds come from the MorningStarBest market service (Best Stocks and Funds to Invest in Nuclear Energy, 2024). Linear regression analysis was used to examine the above mentioned relationship. The time scope of the study includes data for the period from the beginning of 2021 to the end of 2025. Based on the time series of stock exchange quotations from the period 2021–2025, a 60-day moving average was estimated, as well as volatility distributions from this period, which can be used as input data for the real options model using MCS in the process of assessing the efficiency of NPP investments.

The period under study embraces the time interval starting from 2022, in which a large number of concepts, designs, constructions, and introductions to operational activity of commercial SMRs in energy production are observed, and at this time the beginnings of strong activity of companies in the nuclear sector are observed and the introduction of these companies to stock exchange trading, which indicates interest from investors.

## RESEARCH RESULTS AND THEIR ANALYSIS

Table 1 presents the share of NUA in the total activity of the particular companies and the volatility of rates of return in the period from the beginning of 2021 to the end of 2025. These data were used for the regression analysis of the dependence of companies share price volatility on the share of NUA in their entire activity.

**Table 1.** NUA's Share in the Total Activity of Companies and the Volatility of Their Stock Prices

No.	Name	Symbol of stock quotations	Share NUA in whole business	Average Std Dev MA(60) (2021–2025)
1	Duke Energy Corp	DUK	10.0%	18.0%
2	Southern Co	SO	5.0%	19%
3	Iberdrola SA	IBE	5.0%	19%
4	CLP Holdings Ltd	CLP	10.0%	18.9%
5	Endesa SA	ELE	10.0%	19.5%
6	PSEG Inc	PEG	50.0%	20%
7	Entergy Corp	ETR	24.9%	22.2%
8	Dominion Energy Inc	D	24.9%	22.3%
9	TC Energy Corp	TRP	50.0%	22%
10	Edison International	EIX	24.9%	23.4%
11	PG&E Corp	PCG	49.9%	27%
12	CGN Power Co Ltd	CGN	67.0%	29.3%
13	Constellation Energy Corp	CEG	100.0%	44.8%

Source: Std Dev data own elaboration and shares are from Best Stocks and Funds to Invest in Nuclear Energy (2024).

Table 2 presents the share of NUA in the total activity of ETF funds and the volatility of rates of return in the period from the beginning of 2021 to the end of 2025. These data were used to perform a regression analysis of the dependence of the volatility of ETF prices on the share of NUA in their total activity.



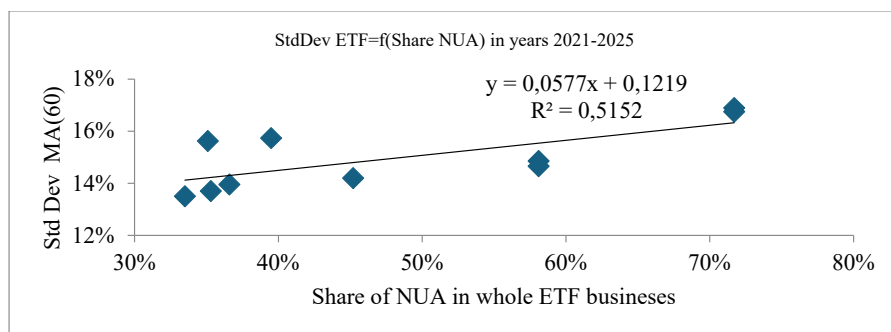
**Table 2.** NUA's Share in the Total Activity of ETF's and the Volatility of Their Stock Prices

L.p.	Name	Symbol of stock quotation	Std Dev MA(60) (2021–2025)	Share NUA in whole business
1	Xtrackers MSCI World Utilities ETF 1C	XDWU	14.9%	58.1%
2	SSPDR® S&P US Utilities Select Sect ETF	SXLU	16.8%	71.7%
3	SPDR® MSCI World Utilities ETF USD Acc	WUTI	14.7%	58.1%
4	SPDR® MSCI Europe Utilities ETF	STUX	13.9%	36.6%
5	iShares STOXX Europe 600 Utilities (DE)	EXH9	15.6%	35.1%
6	iShares S&P 500 Utilities Sect ETF USD Acc	IUUS	16.9%	71.7%
7	FTGF ClearBridge Global Infrastructure Income Fund	FTGF	13.5%	33.5%
8	Europe Utilities ESG Screened UCITS ETF 1C	XS6R	15.7%	39.5%
9	Ecofin Sustainable Listed Infrastructure UCITS Fund B		14.2%	45.2%
10	Amundi S&P Global Utilities ESG UCITS ETF DR	UTIW	13.7%	35.3%

Source: Std Dev data own elaboration and shares are from Best Stocks and Funds to Invest in Nuclear Energy (2024).

Figure 1 shows the relationship between the volatility of the rates of returns and the share of NUA in the activity of ETF funds. The coefficient of determination for this regression at the level of  $R^2 = 0.52$  indicates a medium-high relationship. This relationship is statistically significant because p-Value is below 0.01. The conclusions based on the cause-effect fundamental analysis are consistent with the relationship showed in the obtained regression.

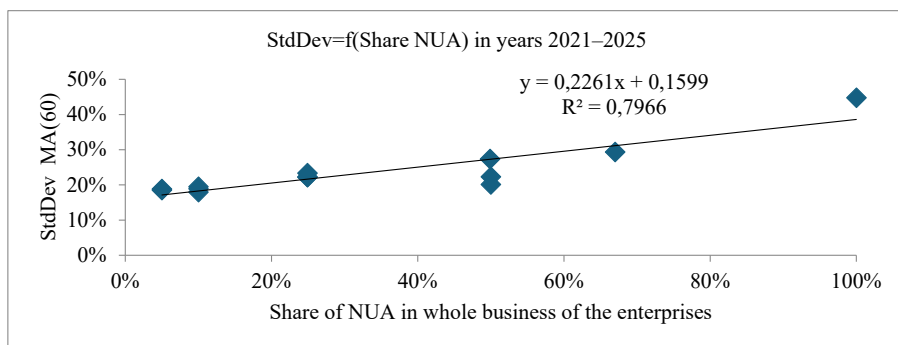
The demand for stable and cheap energy from nuclear power plants around the world is growing. While projects to build nuclear power plants are burdened with a higher risk than other types of investments in the energy sector, the greater involvement of companies in the nuclear sector is associated with the investors' expectations for higher rates of returns.

**Figure 1.** Dependence of the Volatility on NUA Share in ETF Activity

Source: own elaboration.

Figure 2 shows the dependence of the volatility of the stock's rates on NUA share in enterprises' activity. This dependence shows a very high coefficient of determination at the level of  $R^2 = 0.79$ , which indicates a strong dependence. The examined dependence is statistically significant because the p-Value was below 0.01. The fundamental analysis of these companies indicates a very strongly growing activity in the nuclear sector, which is particularly visible from 2022. Production and services in the nuclear sector are subject to greater risk than in other areas of the energy industry; therefore, the greater involvement of companies in this sector is associated with the expectation of higher rates of return by investors. The strong increase in the prices on the stock exchanges observed for these companies for several years indicates growing operating profits and good prospects for the nuclear sector.

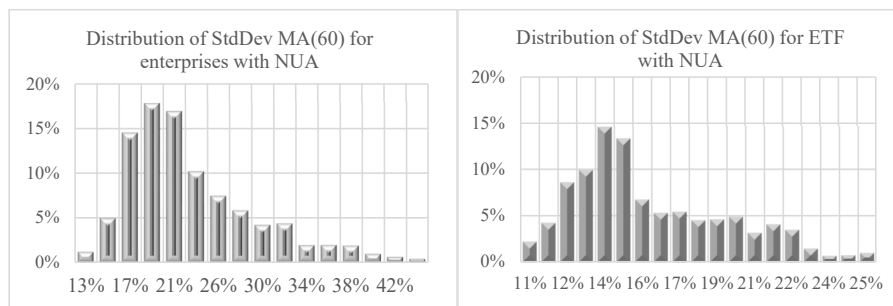
**Figure 2.** Dependence of the Volatility on NUA Share in Enterprises' Activity



Source: own elaboration.

Figure 3 shows the distributions of stock price returns on the stock exchange for the companies and ETFs operating in the nuclear sector. These distributions can be used as an input data reflecting the volatility of assets included in the implemented nuclear power plant projects.

**Figure 3.** Distribution of the Stock Prices Volatility in the Period 2021–2025



Source: own elaboration.

Assets produced by companies from the nuclear sector are components of nuclear power plants. So, the volatility of assets build in nuclear power plants, as a recipient of assets from the producer, are replicated by the volatility of the producer's assets, and the volatility of the producer's assets are just the volatilities of its stocks. Therefore, there is a close cause-and-effect relationship in

this situation, which provides a basis for using the volatility of NUA stock prices to evaluate nuclear power plants projects.

## ■■■ CONCLUSIONS

The hypothesis put forward in the study, that the increasing participation of companies' production for the nuclear sector affects the increase in the volatility of their stock prices, was verified positively. This implies that the templates of the volatility distributions obtained for its stocks may be used as volatility inputs in the evaluation of the nuclear power plant projects. The proven hypothesis forms the basis for the use of stock price volatility distributions in the assessment of the efficiency of nuclear power plant projects based on the real options model with the support of Monte Carlo simulation.

During the research study, the real templates for volatility distributions of each company were elaborated, which practically may be used to feed the real option model to assess the efficiency of the nuclear power plant projects supported by the Monte Carlo simulation. Such practical benefits are an added value of the research study, which allows us to estimate the distributions of the nuclear power plant projects such as NPV, LCOE, and other measures along with risk estimation as a probability of negative outcomes.

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