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Stock Portfolio Optimization of Several Companies Engaged in Renewable Energy for Investment Decision-Making Using the Markowitz Model

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Abstract

This study focuses on optimizing the renewable energy company's stock portfolio using the Markowitz model, which aims to balance risk and return for proper investment decision making. With the increasing demand for clean energy, portfolio optimization in the renewable energy sector is important for investors. This research takes into account historical stock performance and applies the Mean-Variance Optimization framework to minimize risk while maximizing return. This portfolio consists of selected renewable energy companies, and the analysis runs from September 2021 to August 2024. This study aims to analyze the allocation of investment portfolios in renewable energy company stocks in Indonesia. Based on the analysis results, the investment portfolio is allocated to five main stocks, namely BUMI.JK with an investment value of IDR 17,075,844 (17.08%), INDY.JK of IDR 5,825,852 (5.83%), KEEN.JK of IDR 33,766,798 (33.77%), RAJA.JK of IDR 43,084,876 (43.08%), and WIKA.JK of IDR 246,630 (0.25%). These results indicate that most of the funds are invested in RAJA.JK and KEEN.JK stocks, which contribute more than 75% of the total investment portfolio.

Keywords: Renewable energy, stock portfolio, markowitz model, risk-return, portfolio optimization

1. Introduction

Investment is an activity that aims to allocate funds or assets to various instruments in order to gain profits in the future (Longo et al., 2023). In recent decades, investment in the renewable energy sector has become increasingly attractive to investors (Majid, 2020). Increasing awareness of climate change and changes in government policies (Olabi and Abdelkareem, 2022) in various countries to reduce carbon emissions have driven the growth of the renewable energy sector, such as solar, wind, hydro, and bioenergy (Owusu et al., 2016; Osman et al., 2023). Therefore, it is important for investors to optimize their portfolios in this sector to maximize profits and minimize risks (Ivanova and Dospatliev, 2017).

One of the most common approaches used in portfolio optimization is the Markowitz Model (Zhang et al., 2018; Miskolczi, 2016), also known as *Mean-Variance Optimization* (Mba et al., 2022). This model was introduced by Harry Markowitz in 1952 and is the basis of modern portfolio theory (Verdiyanto, 2020; Radović et al., 2018). The Markowitz model is used to achieve portfolio diversification (Lee et al., 2016), which is combining various assets into a portfolio to reduce risk without sacrificing expected returns (Zhang, 2022). In the context of renewable energy investment, the Markowitz model can be used to identify the optimal combination of renewable energy company stocks based on the level of risk and expected return (Odeh et al., 2018; Fauzi et al., 2019).

Amid the increasing demand for clean energy (Aktar, 2021), companies operating in the renewable energy sector face stock price fluctuations that are often caused by regulatory changes (Alotaibi et al., 2020), technological innovations, and fossil fuel prices. Investors often only focus on returns without considering the associated risks (Pandey, 2012). Markowitz's approach in developing portfolios is that investors must evaluate their portfolio based on their expected return and the risk (Putri, 2018), so that investment decisions become more rational and measurable (Binu, 2024).

The development of renewable energy is also supported by changes in government policies in many countries (Majid, 2020) Policies that benefit renewable energy shareholders in Indonesia include government support for the development of new and renewable energy, as well as incentives for investment in the clean energy sector. Incentives for investment in the clean energy sector and regulations that encourage the use of renewable energy in the national energy mix can increase demand and share value (Pambudi et al., 2023).

The government is seeking to increase investment in the clean energy sector and create a clear framework to support renewable energy development, which could contribute to increasing demand and share value in the sector (Supriyanto, 2024). The implementation of the Markowitz model in renewable energy portfolio optimization allows investors to understand the optimal diversification between different renewable energy subsectors (Bai et al., 2019; Neto et al., 2017). Although the Markowitz model offers a systematic approach to managing risk and return (Tóth, 2016), there are several challenges in applying it to renewable energy portfolios. One of them is the higher surface compared to traditional sectors such as fossil fuels or the financial sector (Olabi et al., 2023).

This study focuses on optimizing the stock portfolio of renewable energy companies for investment decision making using the Markowitz model. This study aims to demonstrate how the Markowitz model can be effectively applied in this context. This study will not only explore the formation of an optimal portfolio that balances risk and return, but will also provide practical insights for investors in making more informed investment decisions in the renewable energy sector.

2. Methodology

2.1. Research Object

The research object consists of stocks listed on the stock exchange that focus on the renewable energy sector, including companies engaged in solar power, wind power, hydroelectricity, and bioenergy (Rahman, 2022; Strielkowski, 2021). Through historical performance analysis and return projections, this study will explore the relationship between risk and return of various stocks in the renewable energy sector (Saculsan and Kanamura, 2019).

2.2. Population and Sample

The population and sample in this study take closing price data from Yahoo Finance which focuses on the renewable energy sector and (Kyritsis and Serletis, 2019) has sufficient historical data to be analyzed between the period of September 1, 2021 to August 30, 2024. This sample will consist of 5 carefully selected companies that are considered representative, ensuring the analysis covers various subsectors within renewable energy.

Table 1: List of renewable energy stock issuers

No	Stock code	Nama Emiten
1	BUMI.JK	PT Bumi Resources Tbk
2	INDY.JK	PT Indika Energy Tbk
3	KEEN.JK	PT Kencana Energi Lestari Tbk
4	RAJA.JK	PT Rukun Raharja Tbk
5	WIKA.JK	PT Wijaya Karya (Persero) Tbk

2.3. Markowitz Model Calculation Theory

The Markowitz Model calculation theory, developed by Harry Markowitz in 1952 (Mangram, 2013; Baste et al., 2002), is the foundation of modern portfolio theory and focuses on managing risk and return in investments. This model introduced the concept of diversification as a strategy to reduce portfolio risk (Leković, 2021). Investors can achieve an optimal portfolio by combining different assets, where the risk associated with an individual investment is offset by the performance of other assets in the same portfolio (Rachmat and Nugroho, 2013). Calculation of the optimal portfolio in the Markowitz model can be done in several stages:

1. Calculating daily returns for each stock (Islam and Sultana, 2015):

$$R_{i,t} = \frac{P_{i,t} - P_{i,t-1}}{P_{i,t-1}}$$

where
$R_{i,t}$: daily return for stock i at time t
$P_{i,t}$: the closing price of stock i at time t
$P_{i,t-1}$: the closing price of stock i at time $t-1$

2. Calculating average return (MU) for each stock

$$\mu_i = \frac{1}{T}\sum_{t=1}^{T} R_{i,t}$$

where
μ_i : average stock return i
T : number of time periods (number of days)

3. Calculating standard deviation (Sigma) for each stock

$$\sigma_i = \sqrt{\frac{1}{T}\sum_{t=1}^{T}(R_{i,t} - \mu_i)^2}$$

where
σ_i : standard deviation of stock returns$i$

4. Calculating the covariance between two stocks

$$Cov(R_i, R_j) = \frac{1}{T}\sum_{t=1}^{T}(R_{i,t} - \mu_i)\ (R_{j,t} - \mu_j)$$

where
R_i, R_j : return from shares i and j
μ_i and μ_j : average stock return i and j

5. Calculating portfolio variance

$$\sigma_p^2 = \frac{1}{T}\sum_{i=1}^{N} w_i^2\sigma_i^2 + \sum_{i=1}^{N}\sum_{j\neq i} w_i w_j Cov(R_i R_j)$$

where
σ_p^2 : variance of the portfolio
w_i : weight of stock i in the portfolio
N : number of stocks in a portfolio

6. Calculating the Ratio (Sharpe Ratio)

$$Ratio = \frac{\mu_p - r_f}{\sigma_i}$$

where
μ_p : average portfolio return
r_f : risk-free rate of return (expected return)
σ_i : portfolio standard deviation

3. Results and Discussion

3.1. Closing stock price movements

In this study, to display the results of the closing stock price, visualization will be used using Python with Google Collabs tools (Dwivedi et al., 2022), the results are as in Figure 1 below:

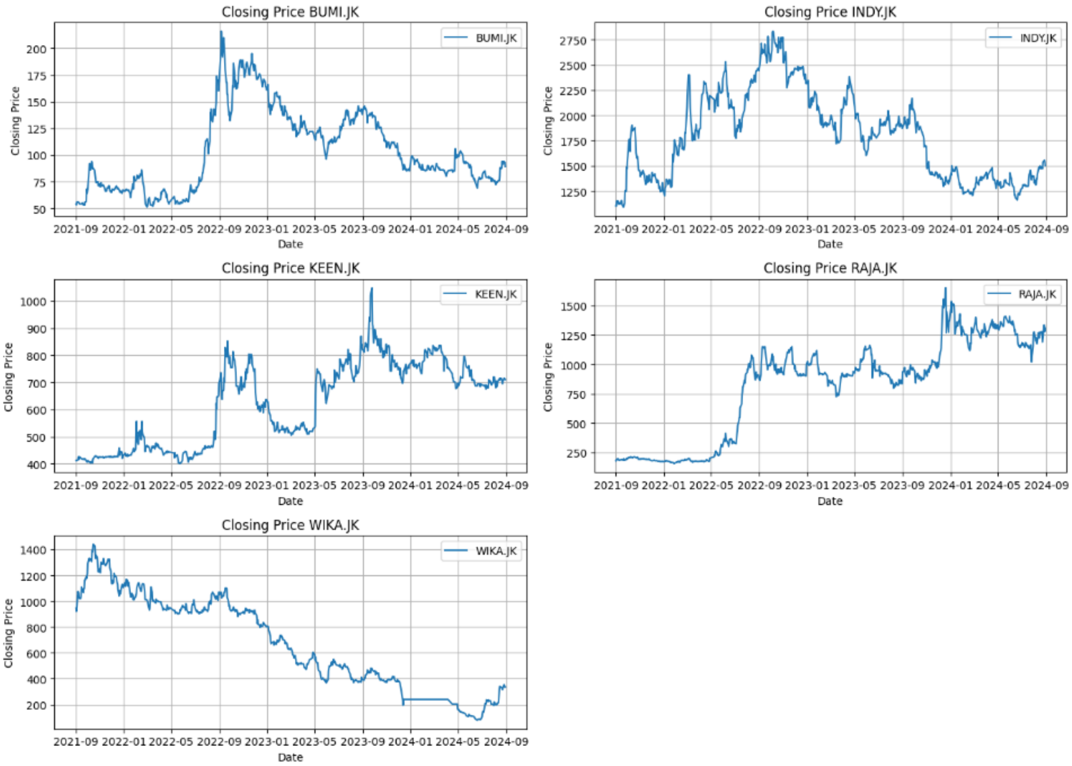
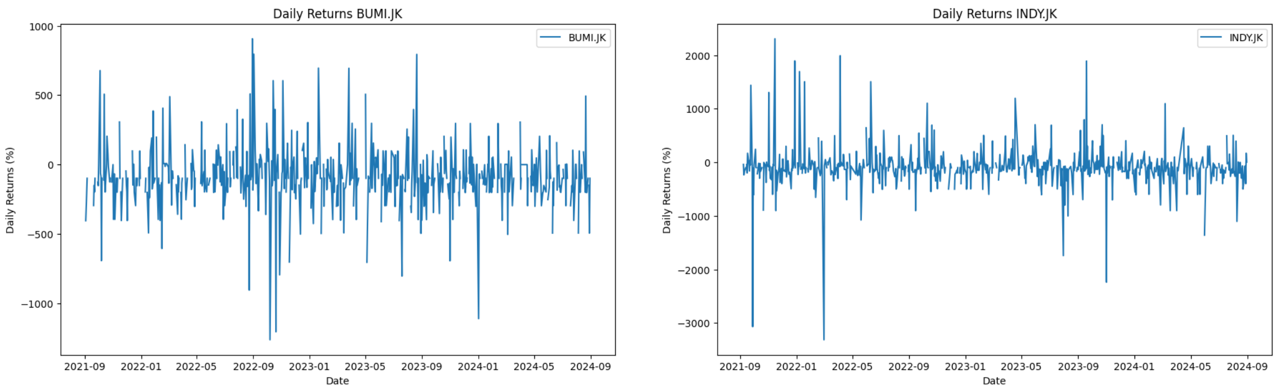


Figure 1: Closing price of five stocks

below 75, but experienced a dramatic surge in mid-2022, peaking around 200 and the price experienced a gradual decline and fluctuating between 75 and 125. INDY.JK showed a more consistent increase. From an initial level of around 1000, the price rose gradually to a peak of around 2750 in mid-2023. After that, there was a correction and the price fluctuated in the range of 1500 to 2000, The KEEN.JK chart shows extreme volatility. The price was initially low, then experienced several sharp spikes, with the highest peak reaching around 950 in early 2023. After that, the price fluctuated significantly between 600 and 800, indicating a high level of risk and potential return.

ADRO.JK showed the most stable and consistent increase. From an initial level of around 1000, the price continued to rise to a peak of around 3500 in late 2023. After that, the price was relatively stable with a slight decline, illustrating solid growth and relative stability. WIKA.JK shows a consistent downward trend throughout the period. From a high of around 1600 at the beginning of the period, the price continued to decline until it reached around 600 at the end of the period.

3.2. Daily stock returns



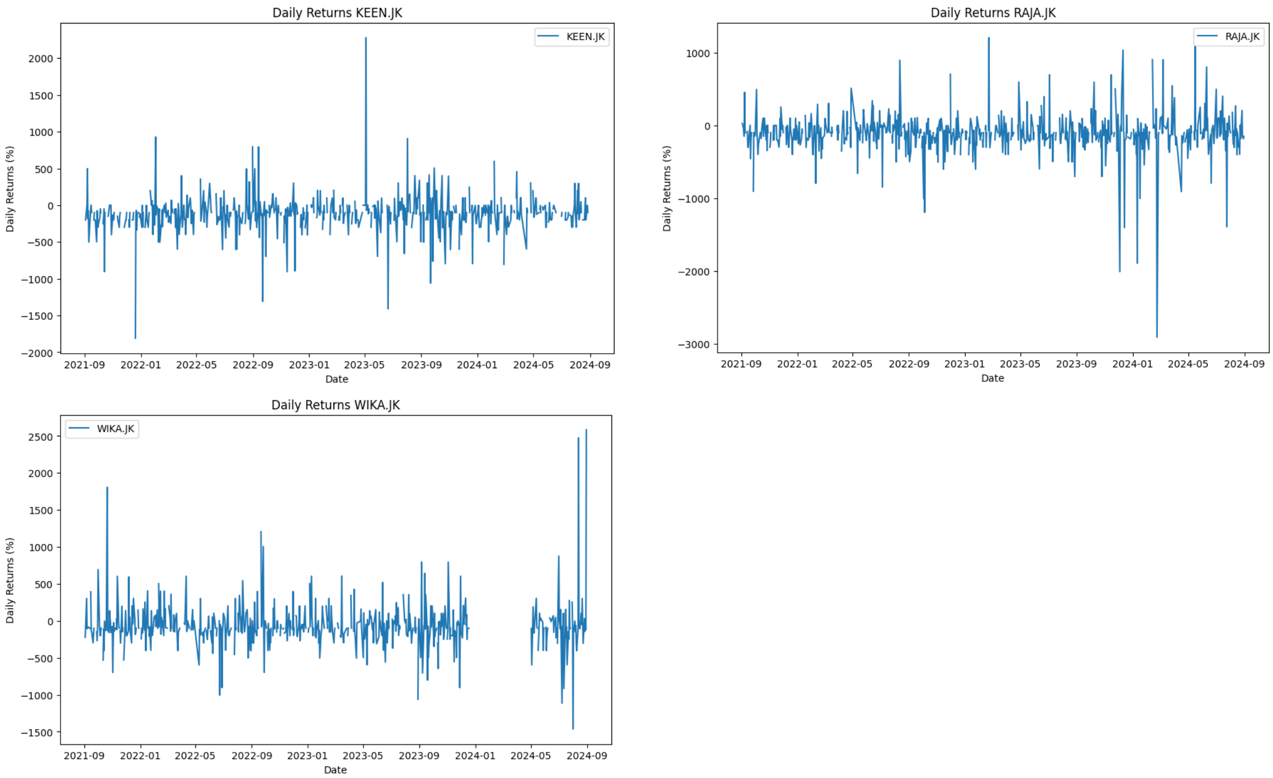


Figure 2: Daily stock returns

Figure 2 shows Daily stock returns using the Google Collabs visualization tool. INDY.JK and KEEN.JK appear to have some of the most extreme spikes, with daily moves reaching over 2000% on several occasions. BUMI.JK and RAJA.JK show more moderate but still substantial volatility, while WIKA.JK has had some isolated sharp spikes.

3.3. Variance and covariance

Table 2:Variance and covariance

	BUMI.JK	INDY.JK	KEEN.JK	RAJA.JK	WIKA.JK
BUMI.JK	0.001464	0.000498	0.000130	0.000156	0.000202
INDY.JK	0.000498	0.000958	0.000072	0.000218	0.000141
KEEN.JK	0.000130	0.000072	0.000864	0.000047	0.000125
RAJA.JK	0.000156	0.000218	0.000047	0.001526	0.000015
WIKA.JK	0.000202	0.000141	0.000125	0.000015	0.001613

Based on Table 2 Variance and Covariance, between stocks shows the correlation and volatility relationship of each stock. The largest variance was recorded in RAJA.JK stock with a value of 0.001526, which reflects a higher level of price fluctuation compared to other stocks. Meanwhile, the stocks with the smallest variance are KEEN.JK and WIKA.JK, with values of 0.000864 and 0.001613, respectively. The covariance between INDY.JK and RAJA.JK stocks shows a closer relationship with a value of 0.000218, while the lowest correlation is between RAJA.JK and WIKA.JK (0.000015), indicating a very weak price relationship.

3.4. Investment allocation

Tabel 3: Investment allocation

Stock	Investment value (Rp)	Percentage (%)
BUMI.JK	17.075.844	17,08%
INDY.JK	5.825.852	5,83%
KEEN.JK	33.766.798	33,77%
RAJA.JK	43.084.876	43,08%
WIKA.JK	246.630	0,25%

The investment allocation in Table 3 is optimal in the portfolio. RAJA.JK shares received the largest allocation, which is 43.08% of the total investment of Rp100,000,000. This may be related to its high variability. Meanwhile, WIKA.JK shares only received an allocation of 0.25%, indicating that this stock has a less significant risk or return compared to the others.

3.5. Optimal portfolio

Table 4: Optimal portfolio

μ	$Variance\ (\sigma^2)$	$Ratio$
0.00146	0.000497	4.17

The optimal portfolio consisting of these stocks produces an expected return (μ) of 0.00146 with a variance of 0.000497, giving a risk-return ratio of 4.17. This ratio indicates that this portfolio has a relatively good return profile for its risk level.

3.6. Sharpe ratio and risk ratio

Table 5:Sharpe ratio and risk ratio

Sharpe Ratio	Daily Returns	Daily risk
4,17	0,0021	0,0005

The Sharpe Ratio is 4.17, indicating that this portfolio has good returns relative to the risk taken. Daily returns of 0.0021 and daily risk of 0.0005 indicate stable daily performance. This high Sharpe Ratio reflects the efficiency of investment in maximizing returns against market volatility.

4. Conclussion

The investment allocation of the analyzed stocks provides an overview of the portfolio distribution that tends to be concentrated in two main stocks, namely RAJA.JK with an allocation of 43.08% and KEEN.JK with 33.77%. The two stocks collectively absorb more than 75% of the total investment funds, indicating high confidence in the prospects of the companies concerned. Meanwhile, BUMI.JK (17.08%) and INDY.JK (5.83%) stocks also received quite significant allocations, although in smaller portions. In contrast, WIKA.JK only received an allocation of 0.25%, indicating that these stocks are considered to have a higher risk or lower potential return.

References

Aktar, M. A., Alam, M. M., & Al-Amin, A. Q. (2021). Global economic crisis, energy use, CO2 emissions, and policy roadmap amid COVID-19. *Sustainable Production and Consumption*, *26*, 770-781.

Alotaibi, I., Abido, M. A., Khalid, M., & Savkin, A. V. (2020). A comprehensive review of recent advances in smart grids: A sustainable future with renewable energy resources. *Energies*, *13*(23), 6269.

Bai, L., Liu, Y., Wang, Q., & Chen, C. (2019). Improving portfolio performance of renewable energy stocks using robust portfolio approach: Evidence from China. *Physica A: Statistical Mechanics and its Applications*, *533*, 122059.

Dwivedi, R., Gupta, K. D., Sharma, T., Raizada, R., Yadav, S., & Bhatia, V. E. E. P. S. A. (2022). Analysing Trading Strategies and Forecasting Stock Prices Using LSTM. *Journal of Theoretical and Applied Information Technology*, *100*(15).

Fauzi, N. A. M., Ismail, M., Jaaman, S. H., & Kamaruddin, S. N. D. M. (2019, April). Applicability of TOPSIS Model and Markowitz Model. In *Journal of Physics: Conference Series* (Vol. 1212, No. 1, p. 012032). IOP Publishing.

Islam, R., & Sultana, N. (2015). Day of the week effect on stock return and volatility: Evidence from Chittagong stock exchange. *European Journal of Business and Management*, *7*(3), 165-172.

Ivanova, M., & Dospatliev, L. (2017). Application of Markowitz portfolio optimization on Bulgarian stock market from 2013 to 2016. *International Journal of Pure and Applied Mathematics*, *117*(2), 291-307.

Kyritsis, E., & Serletis, A. (2019). Oil prices and the renewable energy sector. *The Energy Journal*, *40*(1_suppl), 337-364.

Lee, H. S., Cheng, F. F., & Chong, S. C. (2016). Markowitz portfolio theory and capital asset pricing model for Kuala Lumpur stock exchange: A case revisited. *International Journal of Economics and Financial Issues*, *6*(3), 59-65.

Leković, M. (2021). Historical development of portfolio theory. *Tehnika*.

Longo, S., Hospido, A., & Mauricio-Iglesias, M. (2023). Energy efficiency in wastewater treatment plants: A framework for benchmarking method selection and application. *Journal of Environmental Management*, *344*, 118624.

Majid, M. (2020). Renewable energy for sustainable development in India: current status, future prospects, challenges, employment, and investment opportunities. *Energy, Sustainability and Society*, *10*(1), 1-36.

Mangram, M. E. (2013). A simplified perspective of the Markowitz portfolio theory. *Global journal of business research*, *7*(1), 59-70.

Mba, J. C., Ababio, K. A., & Agyei, S. K. (2022). Markowitz mean-variance portfolio selection and optimization under a behavioral spectacle: New empirical evidence. *International Journal of Financial Studies*, *10*(2), 28.

Neto, D. P., Domingues, E. G., Coimbra, A. P., de Almeida, A. T., Alves, A. J., & Calixto, W. P. (2017). Portfolio optimization of renewable energy assets: Hydro, wind, and photovoltaic energy in the regulated market in Brazil. *Energy Economics*, *64*, 238-250.

Miskolczi, P. (2016). Differences between mean-variance and mean-cvar portfolio optimization models.

Odeh, R. P., Watts, D., & Flores, Y. (2018). Planning in a changing environment: Applications of portfolio optimisation to deal with risk in the electricity sector. *Renewable and Sustainable Energy Reviews*, *82*, 3808-3823.

Olabi, A. G., & Abdelkareem, M. A. (2022). Renewable energy and climate change. *Renewable and Sustainable Energy Reviews*, *158*, 112111.

Olabi, A. G., Elsaid, K., Obaideen, K., Abdelkareem, M. A., Rezk, H., Wilberforce, T., ... & Sayed, E. T. (2023). Renewable energy systems: Comparisons, challenges and barriers, sustainability indicators, and the contribution to UN sustainable development goals. *International Journal of Thermofluids*, *20*, 100498.

Osman, A. I., Chen, L., Yang, M., Msigwa, G., Farghali, M., Fawzy, S., ... & Yap, P. S. (2023). Cost, environmental impact, and resilience of renewable energy under a changing climate: a review. *Environmental chemistry letters*, *21*(2), 741-764.

Owusu, P. A., & Asumadu-Sarkodie, S. (2016). A review of renewable energy sources, sustainability issues and climate change mitigation. *Cogent Engineering*, *3*(1), 1167990.

Pambudi, N. A., Firdaus, R. A., Rizkiana, R., Ulfa, D. K., Salsabila, M. S., Suharno, & Sukatiman. (2023). Renewable energy in Indonesia: current status, potential, and future development. *Sustainability*, *15*(3), 2342.

Putri, V. Y. (2018). Effectiveness of portfolio selection using Markowitz model and broker recommendation in Indonesia Stock Exchange (mining, agriculture, and infrastructure industry). *KnE Social Sciences*, 1603-1615.

Rachmat and Nugroho. (2013). Portfolio Determination and Markowitz Efficient Frontier in Five Indonesian Industrial Sector, *Journal of Business and Management, Vol. 2,* No.1, 116-131.

Radović, M., Radukić, S., & Njegomir, V. (2018). The Application of the Markowitz's Model in Efficient Portfolio Forming on the Capital Market in the Republic of Serbia. *Economic Themes*, *56*(1), 17-34.

Rahman, A., Farrok, O., & Haque, M. M. (2022). Environmental impact of renewable energy source based electrical power plants: Solar, wind, hydroelectric, biomass, geothermal, tidal, ocean, and osmotic. *Renewable and Sustainable Energy Reviews*, *161*, 112279.

Saculsan, P., & Kanamura, T. (2019). Examining risk and return profiles of renewable energy investment in developing countries: The case of the Philippines.

Supriyanto, E. E. (2024). The Politics of Indonesia's Renewable Energy Policy. *Langgas: Jurnal Studi Pembangunan*, *3*(1), 12-18.

Strielkowski, W., Civín, L., Tarkhanova, E., Tvaronavičienė, M., & Petrenko, Y. (2021). Renewable energy in the sustainable development of electrical power sector: A review. *Energies*, *14*(24), 8240.

Tóth, M., Holúbek, I., & Serenčéš, R. (2016). Applying Markowitz portfolio theory to measure the systematic risk in agriculture. In *Conference: International Scientific Days*.

Verdiyanto, R. (2020). An Empirical Implementation of Markowitz Modern Portfolio Theory on Indonesia Sharia Equity Fund: A Case of Bahana Icon Syariah Mutual Fund. *Journal of Accounting and Finance in Emerging Economies*, *6*(4), 1159-1172.

Zhang, M., Tang, Y., Liu, L., & Zhou, D. (2022). Optimal investment portfolio strategies for power enterprises under multi-policy scenarios of renewable energy. *Renewable and Sustainable Energy Reviews*, *154*, 111879.

Zhang, Y., Li, X., & Guo, S. (2018). Portfolio selection problems with Markowitz's mean–variance framework: a review of literature. *Fuzzy Optimization and Decision Making*, *17*, 125-158.