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# EU Go Green: Is It Impacted by Carbon, Crude Oil, and Non-Renewable Stock Index?

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**ABSTRACT**

**Abstract:** This research investigated the impact of carbon pricing, crude oil prices, and non-renewable stock indices on the price dynamics of renewable energy stock indices within the European Union. The objective was to analyze how these factors influence price fluctuations and further enhance investment growth in the renewable energy sector. The Rebalancing Aggregate Real Carbon Price (GRCP) was proposed as a novel independent variable representing carbon price indicators alongside the European Union Allowance (EUA). This research used daily time series data, thus applying Ordinary Least Squares (OLS) with robust standard error as the methodology. OLS with robust standard error is a standard method to ensure the reliability of regression analysis. The results showed that crude oil prices and the EUA exhibit an insignificant negative effect on renewable energy stock returns. Meanwhile, the non-renewable energy stock index showed a positive and significant impact on renewable energy stock returns ($p<0.01$), indicating that better performance in the non-renewable energy sector increases the influence of environmental issues. GRCP also positively impacted renewable energy stocks, $p<0.01$ for OMX and $p<0.05$ for ERIX. This study showed that renewable energy investments can be a solid alternative to non-renewable stocks for investors. For policymakers, strengthening carbon pricing policies across sectors and regions was critical to supporting the transition to renewable energy, as GRCP plays an essential role in shaping stock price dynamics. Thus, in the future, the effectiveness of carbon pricing policies needs to be analyzed to improve global environmental strategies.

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## A. INTRODUCTION

Growing awareness of climate change and environmental issues has prompted a paradigm shift towards sustainable practices (Igeland et al., 2024), benefiting the renewable energy sector (Alagoz & Alghawi, 2023). As acknowledged globally, emissions from fossil fuel combustion contribute significantly to the rising concentrations of greenhouse gases (GHG), posing a threat to the atmosphere (Kweku et al., 2018). In response, there has been a global commitment to reduce the intensity of carbon emissions, mainly through adopting renewable energy (Llanos et al., 2022). Renewable energy has been proposed as an alternative to achieve a sustainable economy due to its ability to drive economic growth while mitigating harmful emissions (Apergis & Payne, 2012).

Regardless of global economic uncertainty, renewable energy investment reached a record high of USD 622.5 billion in 2023, establishing it as one of the fastest-growing sectors (Dutta et al., 2018; REN21, 2024). Various economic, political, and environmental factors have propelled this progress. Nevertheless, funding from investors remains crucial to ensuring the transition plan proceeds as planned (Reboredo et al., 2017). Hence, a comprehensive understanding of the different factors affecting the price dynamics of renewable energy will further enhance investment growth in this sector (Igeland et al., 2024).

As one of the most widely adopted energy sources globally, the price of crude oil plays a crucial role in impacting costs, profitability, and overall market valuation across various industries (Kumar et al., 2012). Previous studies have thoroughly explored the connection between crude oil prices and the performance of renewable energy stocks (Dawar et al., 2021; Dutta et al., 2020; Reboredo et al., 2017). Generally, crude oil price volatility could generate a substitution impact, encouraging potential investment in the renewable energy sector (Spelta & De Giuli, 2023). Consequently, we aim to determine the impact of crude oil prices on renewable energy stocks. This research also considers the stock prices of companies engaged in the non-renewable sector to enrich our coverage.

Besides the affordability issue of non-renewable energy sources, government policy regarding carbon pricing also encourages the shift towards renewable energy (Kumar et al., 2012). However, research on this topic is still understudied (Dutta et al., 2018). Most prior studies only examined the European Union Allowance (EUA) price as a proxy for carbon pricing (Kumar et al., 2012; Yilanci et al., 2022). Hence, our study addresses the knowledge gap by proposing a novel independent variable, the Rebalancing Aggregate Real Carbon Price. Monash University and C2Zero developed this index to assess the potential impact of carbon price adjustments on the financial market. The Rebalancing Aggregate Real Carbon Price distinguishes itself from other commonly used carbon pricing measures by offering a deeper understanding of the actual cost of carbon. It aggregates various instruments that form the basis of carbon pricing implementation across Europe (*The Monash/C2Zero Real Carbon Price Index*, 2021). As it stands, the influence of this index remains unexplored. Thus, we address the knowledge gap by considering its influence on renewable energy stock indices.

In this study, we emphasize our focus on the European Union (EU) context, as it is the region with the biggest economy in the world, partnering with more than 80 countries as the largest exporter. The selection of the European Union is also relevant, as policies aimed at decarbonizing the economy and minimizing environmental damage have been well implemented. This is reflected in the policies that facilitate the EU's transition to a circular economy, where production and consumption processes are planned to create closed material cycles, prevent waste, retain resources within the system, and minimize environmental impact (Alberich et al., 2023). The European Green Deal also aims to make the EU the first climate-neutral continent by transforming it into a modern, resource-efficient, and competitive economy (*The European Green Deal: Striving to Be the First Climate-Neutral Continent*, n.d.). Thus, Europe could be a benchmark for economic

practices that balance profitability and sustainability. The following section of this paper is structured as follows: Section 2 provides a comprehensive overview of previous research literature. Section 3 explains the data and methodology applied. In Section 4, the results of the data analysis are interpreted and discussed. Section 5 closes with conclusions and implications for the findings.

## B. LITERATURE REVIEW

### 1. Renewable Energy Stock Indices Price

Energy consumption has significantly influenced economic growth (Nathaniel et al., 2021; Ulucak et al., 2020). However, prior studies also showed that, despite acting as a catalyst for economic growth, the usage of non-renewable energy increases carbon emissions and harms the environment (Bhat, 2018). Therefore, renewable energy has been proposed as an alternative to achieve a sustainable economy (Apergis & Payne, 2012; Owusu & Asumadu-Sarkodie, 2016). With this growing concern, the renewable energy sector benefits due to its potential for higher returns and alternative investment during non-renewable energy scarcity (Dawar et al., 2021; Managi & Okimoto, 2013). We use two dependent variables representing renewable energy: the Nasdaq OMX Clean Energy Europe index (OMX) and the European Renewable Energy Index (ERIX). OMX and ERIX are indices that track the performance of companies, both focusing on producing renewable energy across Europe. However, OMX also included the distribution of clean energy (Nasdaq, 2020). These indices are chosen because they represent the performance of the renewable energy sector in the European market. The connectedness between them will be explored further in the following subchapter.

### 2. Carbon Pricing

Carbon pricing is one of the main factors contributing to the growth of the renewable energy sector (Alagoz & Alghawi, 2023). In this study, we use the EU-ETS Carbon Allowance Price (EUA) traded in the EU Emission Trading System, a cap-and-trade program to reduce greenhouse gas emissions in the EU (*EU Emissions Trading System (EU ETS)*, 2024). A literature study showed the negative impact of EUA on financial instruments after the structural break 2011 due to rising oil prices (Yilanci et al., 2022). The issue of carbon leakage also supports the negative effect in practice, with industries moving to regions with lower carbon prices to avoid EU-ETS costs. Thus, higher carbon prices do not automatically increase renewable energy investment in the EU (Zachmann & Mcwilliams, 2020). A similar result was also identified, indicating that carbon prices negatively affected green bonds and renewable energy stocks (Tiwari et al., 2022).

Besides EUA, we also utilize the Rebalancing Aggregate Real Carbon Price (GRCP) as a novel independent variable. GRCP, a variable constructed by Monash University and C2Zero, captures a broader set of actual or hypothetical instruments that might influence the carbon price (*The Monash/C2Zero Real Carbon Price Index*, 2021). This index is rebalanced periodically to account for updated jurisdiction and regulations. In essence, GRCP is a more comprehensive index that reflects the actual implementation of carbon pricing. Thus, the influence might differ from that of EUA, making it more sensitive to

fossil energy and enhancing the competitiveness of the renewable energy market (Bassi et al., 2009). For carbon pricing indicators, we put forward the following hypothesis:

$H_1$: EUA affects renewable energy stock indices prices negatively

$H_2$: GRCP affects renewable energy stock indices price positively

### 3. Crude Oil Price

We consider crude oil prices as independent variables due to their significant consumption across various industries, allowing oil price fluctuations to influence economic growth and investment performance (Elder & Serletis, 2010). This study uses the West Texas Intermediate (WTI) crude oil, internationally acknowledged as a global standard for oil price benchmarking (Niu, 2021). However, an empirical study found that WTI price volatility negatively correlates with renewable energy stock indices. (Dutta et al., 2020). Research conducted in Russia and Iran also proved that oil prices negatively affect renewable energy consumption (Karacan et al., 2021; Mukhtarov et al., 2022). From these viewpoints, we suggest that fluctuations in WTI prices may also negatively affect the renewable energy stock indices.

Besides WTI, we consider the Brent Crude Oil (BREN) as a proxy for crude oil price due to its significant contribution to the global oil supply. Another study found that oil shocks resulting from supply and aggregate demand disruption tend to negatively influence stock returns across most market conditions (Mishra & Acharya, 2024) Consequently, we may also anticipate a negative impact of BREN on renewable energy stocks, as fluctuations in crude oil prices can lead to shifts in market dynamics across all sectors. Hence, we put forward the following hypothesis:

$H_3$: WTI affects renewable energy stock indices prices negatively

$H_4$: BREN affects renewable energy stock indices prices negatively

### 4. Non-Renewable Energy Stock Indices Price

We utilize the MSCI Europe Energy Index (MSCI) as a variable representing non-renewable energy stock prices. MSCI is designed to capture the large and mid-cap segments across 15 developed markets (MSCI Inc., 2015). Investors widely follow MSCI to track the efficiency of companies involved in the oil, gas, and coal sectors. Earlier studies have shown a significant positive correlation in the right time scale between non-renewable stock indices and the renewable energy market (Spelta & De Giuli, 2023). This is due to the positive influence of environmental responsibility initiatives on the financial performance of non-renewable energy companies (Lee, 2021). The positive effect is also driven by the close relationship between the energy and renewable energy sectors, as transitioning to a low-carbon economy requires significant investments in renewable energy (Reboredo et al., 2017). Consequently, we put forward the following hypothesis:

$H_5$: MSCI affects renewable energy stock indices price positively

## C. METHODS

### 1. Data

Following the explanation in the literature review, we employed seven variables in this study: two dependent variables (OMX and ERIX) and five independent variables (EUA, GRCP, WTI, BREN and MSCI). Our observations consist of daily data from January 2, 2021, to December 29, 2023, for 760 observations. The data was transformed into a return since we aim to prevent stationarity problems. The overview and descriptive statistics of each variable are presented in Table 1. To analyze the relationships between variables, we applied a regression model that quantifies the influence of each independent variable on the dependent ones, as discussed in the following section.

### 2. Ordinary Least Square (OLS) Model

This study employed the Ordinary Least Square (OLS) regression model to analyze the connection between independent and dependent variables. OLS is a frequently used estimation technique, especially in multiple regression analysis (Chumney & Simpson, 2006). In ensuring the accuracy of this technique's estimates, one of the assumptions that should be met is homoskedasticity or constant error variance (Burton, 2021). If the assumption is violated (i.e., if heteroskedasticity is present), the OLS estimates can still be unbiased, but they may no longer be efficient, leading to inaccurate standard errors and hypothesis tests (Fox, 2015). Thus, we anticipated this using robust standard error introduced by Halbert White (White, 1980).

Before running the regression, we conducted a pretest using the Augmented Dickey-Fuller (ADF) test to check if the series was stationary (Dickey & Fuller, 1979). Stationarity is essential in time-series analysis because non-stationary data can lead to spurious regression results. In such cases, relationships between variables appeared significant due to trends rather than actual connections (Gimeno et al., 1999). The application of Dickey-Fuller seemed relevant due to gaps in our data (i.e., stock market closure during holidays and weekends). Leaving the gaps without interpolation in regular Dickey-Fuller has still produced accurate unit root test results (Ryan & Giles, 1998).

**Table 1.** Descriptive Statistics and unit root test results

| Variable | Obs. | Mean | Std Dev. | Min. | Max. | ADF |
|---|---|---|---|---|---|---|
| OMX | 760 | -.0000645 | .0142306 | -.0495992 | .0601507 | -23.370*** |
| ERIX | 760 | -.0003094 | .0196867 | -.0739952 | .1054965 | -25.108*** |
| EUA | 760 | .0014934 | .0270964 | -.1623273 | .1757597 | -26.037*** |
| GRCP | 760 | .0009323 | .0219994 | -.1350463 | .1200048 | -25.328*** |
| WTI | 760 | .0007248 | .0248976 | -.1271773 | .1073966 | -23.549*** |
| BREN | 760 | .0006822 | .0157604 | -.0812305 | .0557567 | -23.814*** |
| MSCI | 760 | .0008642 | .0161108 | -.0692383 | .0561398 | -26.134*** |

*Note.* *** p<.01, ** p<.05, * p<.1; all variables were sourced from Bloomberg terminal

Table 1 presents the descriptive statistics and unit root test for all daily return series. The mean returns across all variables are approximately zero, consistent with the Efficient Market Hypothesis (EMH), which suggests the absence of consistent long-term

trends. Volatility varies across markets, with EUA exhibiting the highest standard deviation, indicating more significant risk, while BREN shows the lowest. The broad range of minimum and maximum returns for EUA and WTI underscores their sensitivity to external factors. The ADF test results confirm that all return series are stationary, ensuring the stability of statistical properties over time. This stationarity is crucial for applying Ordinary Least Square (OLS) with robust standard errors, as it enhances the reliability of regression analysis by preventing spurious results and allowing for accurate estimation of market relationships.

## D. RESULTS AND DISCUSSION

The OLS model showed consistent results for the two dependent variables representing renewable energy stock indices returns (OMX and ERIX). Both crude oil price indicators (WTI and BREN) have a negative and insignificant relationship with renewable energy stock returns. Meanwhile, MSCI non-renewable energy stock and GRCP exhibit a statistically positive effect on renewable energy stock returns. However, slightly different results are identified in EUA, which shows a negative influence on OMX at a 10% significant level but is insignificant for ERIX. Detailed results are provided in Table 2.

**Table 2.** OLS results

| **Dependent Variables** | **OMX** | **ERIX** |
|---|---|---|
| | **OLS** | **OLS** |
| EUA | -.81*** | -.216 |
| | (.094) | (.134) |
| GRCP | 1.084*** | .301* |
| | (.114) | (.164) |
| WTI | -.039 | -.014 |
| | (.049) | (.077) |
| BREN | -.047 | -.04 |
| | (.072) | (.108) |
| MSCI | .245*** | .22*** |
| | (.04) | (.059) |

*Note.* *** p<.01, ** p<.05, * p<.1; robust standard errors are in parentheses

The findings in Table 2 indicate that the rise in crude oil prices harms the return of renewable energy stock indices. Under the circumstances where crude oil prices rise, production costs and energy bills in numerous industries will be impacted. This situation will disrupt the firm's ability to invest in renewable energy sources and technology (Karacan et al., 2021). However, the influence is not statistically significant. This finding aligns with existing studies, suggesting that as the renewable energy market experiences a bullish trend, its dependence on crude oil diminishes (Dawar et al., 2021). Other literature further implies that the transition to renewable energy is more influenced by environmental degradation, technological innovation, and oil supply disruptions than oil price volatility (Bondia et al., 2016).

On the contrary, a significant positive correlation was identified between the MSCI and renewable energy stock indices. It suggests that the better performance of businesses in the non-renewable energy sector enhances their impact on environmental problems. This argument is supported by empirical results showing that the ROA (Return on Asset) ratio significantly influences corporate CSR decisions (Kludacz-alessandri & Cygańska, 2021). In this context, product or technology innovation and resource reduction are the most significant environmental responsibilities associated with a company's financial performance (Lee, 2021). For instance, innovations in developing new environmental technology will reduce environmental costs, create new market opportunities, and drive financial growth. Thus, apart from crisis conditions, these two sectors could form a solid unidirectional relationship (De Giuli & Spelta, 2023).

Meanwhile, the European Union Allowance and renewable energy stock indices are found to be negatively correlated, which significantly affects merely OMX. This finding is consistent with a study showing the negative effect of carbon prices on clean energy stocks after the 2011 oil price rise (Yilanci et al., 2022). The increase in carbon allowance price seems to affect the stock market in general, particularly companies with high carbon intensity (Tian et al., 2016). Consequently, this market pressure also impacts the renewable energy market (Tiwari et al., 2022). Regarding significance, ERIX structurally covers a broader range of sub-sectors within the renewable energy industry: geothermal, solar, hydro, marine, biofuels, and wind (Caporale et al., 2023). Meanwhile, most OMX-listed companies focus on wind and energy efficiency-related technologies, making them more sensitive to carbon pricing regulations.

Lastly, the Rebalancing Aggregate Real Carbon Prices positively and significantly influenced renewable energy stock indices. As discussed in the hypothesis framework, GRCP captures a more comprehensive aspect of factors influencing carbon pricing implementations across multiple regions and jurisdictions. In this context, GRCP aggregates carbon prices throughout different constituents, excluding regions without carbon pricing policies (*The Monash/C2Zero Real Carbon Price Index*, 2021). Moreover, the periodic rebalancing process, such as adjustments in jurisdictions and the scope of emissions, provides a dynamic and adaptive representation of carbon pricing. Hence, this index appears to have a more realistic effect and significantly influences the return of renewable energy stock indices.

## E. CONCLUSION AND SUGGESTIONS

This study attempts to figure out whether carbon pricing, crude oil prices, and non-renewable energy stock indices influence the performance of renewable energy stock indices within the European Union. The empirical results revealed that crude oil price indicators and the European Union Allowance have an insignificant negative relationship with the return of renewable energy stock indices. Meanwhile, non-renewable energy stock indices and the Rebalancing Aggregate Real Carbon Price were proven to have a positive relationship with a significant impact. Based on the findings, it is indicated that increases in crude oil prices and the implementation of carbon pricing affect the financial performance of overall companies in the market, thus limiting their ability to adopt

renewable energy sources. However, investing in renewable energy stocks has proven to be a substitute for non-renewable energy stock indices. Furthermore, the Rebalancing Aggregate Real Carbon Price plays a vital role in shaping the price movements of renewable energy stock indices. As broader factors were considered in this index, the Rebalancing Aggregate Real Carbon Price can provide a more comprehensive picture of the implementation of carbon pricing. Thus, the Rebalancing Aggregate Real Carbon Price creates a more supportive environment for renewable energy, which drives increased value and stability of renewable energy companies' stock prices.

## AUTHOR CONTRIBUTIONS

Alexander Daniel Tan – conception, design, project administration, and original draft. Jessica Angelitta Vania – original draft, analysis, and interpretation. Steven Wijaya – data collection, proofreading, editing, and original draft. Shinta Amalina Hazrati Havidz – methodology, review, validation, and supervision.

## DATA AVAILABILITY STATEMENT

The data used in this study cannot be made available due to commercial reason.

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