Investigating the Importance of UK Government Support for Offshore Wind: The Impact of Higher CfD Strike Prices on Developers' Share Returns

Rosie Alexandra Ward*

* Associate Fellow, Centre for International Sustainable Development Law, Canada; MPhil (Environmental Policy), University of Cambridge, UK

KEYWORDS

CfD AR6, offshore wind, strike price announcement

ABSTRACT

This paper uses stock market reactions to the Contracts for Difference Allocation Round 6 (CfD AR6) offshore wind strike price announcement to investigate the recent importance, or lack thereof, of the UK's CfD scheme for offshore wind. Specifically, it takes the form of an event study, estimating the impact of the government's AR6 offshore wind strike price announcement on offshore wind developers' share prices. This is important, as any increase in share prices attributable to the AR6 strike price announcement should indicate the CfD scheme's present-day relevance and ability to incentivise offshore wind development. If the CfD programme is instead redundant, then the AR6 strike price announcement should not have significantly affected developers' share prices. Ultimately, this paper uncovered evidence supporting the continued relevance of the CfD scheme. While it appears that most offshore wind developers' share prices did not significantly increase immediately after the government's formal AR6 strike price announcement, there is evidence that investors reacted to leaked information about the offshore wind AR6 strike price in the week prior to the government's announcement. Many of the sample firms experienced statistically significant positive abnormal returns following the first identifiable AR6 strike price information leak, and positive abnormal returns were particularly significant when aggregated across the sample and over the time period from the first instance of leakage to the government's formal announcement. These results suggest that the CfD scheme increases the value of offshore wind developments today and indicate the scheme's present-day relevance and ability to incentivise development.

I. Introduction

The United Kingdom aims to install 50 gigawatts (GW) of offshore wind by 2030.[1] This is an ambitious goal, and achieving it will require a major acceleration of current offshore wind development rates. As of December 2023, 14.7 GW of offshore wind was

[1] Hassan, Munir, and Dalia Majumder-Russell. *Renewable Energy in United Kingdom*. CMS Legal, Feb. 2022.

installed in British waters, and 8 GW was under construction.[2]

Government subsidies have formed a part of the revenue stream of every British offshore wind farm developed to date.[3] Since the passage of the Energy Act 2013, large-scale renewable projects in the UK have been supported through the Contracts for Difference (CfD) scheme. This renewable energy auction programme awards renewable energy developers long-term contracts to supply energy at a fixed price per MWh, and this price has historically been set above current and forecasted wholesale electricity prices.[4] Six CfD auction rounds, referred to as “allocation rounds” (AR), have taken place since 2014,[5] collectively supporting 26 GW of offshore wind.[6]

While the UK government has historically played a significant role in incentivising renewable energy development, this role may be unnecessary today. The cost of developing an offshore wind farm fell 60% from 2010 to 2022,[7] and energy prices have more than doubled in the UK since 2020.[8] Should price trends continue, developers’ projects may be profitable without subsidy. There has also been an increase in corporate power purchase agreements (CPPAs).[9] Under CPPAs, which are structured similarly to CfD contracts, offshore wind developers enter into long-term agreements with large corporations to supply renewable energy at a pre-determined price. If corporations remain keen to purchase clean power at a fixed price, CPPAs may eventually replace the CfD scheme.

Nonetheless, recent events suggest that offshore wind subsidies are key in the UK today. Arguably, the event most indicative of the CfD scheme’s continued relevance occurred in September 2023. As background, in March 2023, the UK government announced the AR5 offshore wind ‘strike price’, which is the maximum price, in £/MWh, developers can bid to receive through a CfD contract.[10] When the AR5 bidding window closed and auction results were released in September 2023, it surfaced that no offshore wind developers participated in AR5.[11] Instead, the British offshore wind industry criticised the UK government for setting the maximum strike price too low to cover development costs and called for a higher strike price in AR6.[12] On 16 November, the UK government responded to these pleas, announcing an increase in the strike price from £44/MWh in AR5 to £73/MWh in AR6.[13] Politicians, energy organizations, trade associations, and offshore wind developers praised this move.[14]

This paper uses stock market reactions to the AR6 offshore wind strike price announcement to investigate the recent importance, or lack thereof, of the UK’s CfD scheme for offshore wind. Specifically, this paper conducts an event study to estimate the impact of the government’s AR6 offshore wind strike price announcement on offshore wind developers’ share prices. Event studies aim to isolate and identify changes in share prices caused by an

[2] Jaspert, Gus. *UK Offshore Wind Report 2023*.
[3] The Crown Estate. *Project Listings*. Mar. 2024.
[4] Watson, Nicole, and Paul Bolton. *Contracts for Difference*. House of Commons, 13 Sep. 2023.
[5] DESNZ. “Contracts for Difference.” *GOV.UK*, 16 Nov. 2023.
[6] The Crown Estate (n 3) *supra*.
[7] Boedt, Geert, et al. *Offshore Wind Energy: Patent Insight Report*. Nov. 2023.
[8] Office of National Statistics. *Quarterly Energy Prices*. 27 June 2024.
[9] BloombergNEF. “Corporate Clean Power Buying Grew 12% to New Record in 2023, According to BloombergNEF.” 13 Feb. 2024.
[10] Shapps, Grant. “Contracts for Difference (CfD): Budget Notice for the Fifth Allocation Round, 2023.” 16 Mar. 2023.
[11] DESNZ. “Contracts for Difference Allocation Round 5 Results.” *Press Release*, 8 Sep. 2023.
[12] “Renewable Energy Auction Results in No Bids for Offshore Wind.” *Catapult Offshore Wind Energy (ORE)*, 8 Sep. 2023; *Energy UK Analysis: Allocation Round 5*. Energy UK, 2023.
[13] Coutinho, Claire. “Contracts for Difference (CfD): Core Parameters for the Sixth Allocation Round, 2024.” 16 Nov. 2023.
[14] ibid.

event from general stock market movements.[15] To do so, event studies construct a measure of a firm's 'abnormal returns', the difference between a stock's measured return (the daily change in a share price) and 'expected returns'. The expected returns serve as a 'counterfactual', a hypothetical construction of what would have happened to a firm's share price absent an event. Thus, barring the presence of concurrent events which also affect a firm's share price, any difference between a firm's expected and actual returns should be attributable to the event. There are multiple models for estimating a firm's expected and abnormal returns, but this article chose to employ the market model.

Isolating the impact of the AR6 strike price announcement on offshore wind developers' share prices should help illuminate the CfD scheme's present-day role. If the AR6 strike price will cover developers' expected costs, an outcome suggested by industry stakeholders' positive response to the price announcement, then the AR6 strike price announcement essentially represented the return of the CfD scheme as a financially viable route to developing an offshore wind project. Thus, any increase in share prices attributable to the AR6 strike price announcement should suggest that the option of developing a bankable project through the CfD scheme increases the value of offshore wind developments today. In other words, an increase would indicate the CfD scheme's present-day relevance and ability to incentivise development. Instead, if the CfD programme is redundant and market participants expect developers to achieve higher profits through wholesale markets or CPPAs, then the AR6 strike price announcement should not have significantly affected developers' share prices.

As the UK government attempts to achieve its stated goal of deploying 50 GW of offshore wind by 2030, it is important to understand the CfD scheme's present-day role. If government subsidies appear relevant and attractive versus revenue alternatives, the government should support development by setting the strike price and budget at sufficiently high levels. If instead the CfD scheme appears redundant, the UK government's role may be restricted to one of ensuring a positive regulatory environment for offshore wind, with expedited planning, consents, grid connection, and seabed lease acquisition processes.

Ultimately, this paper uncovered evidence supporting the continued relevance of the CfD scheme. While it appears that most offshore wind developers' share prices did not significantly increase immediately after the government's formal AR6 strike price announcement, there is evidence that investors reacted to leaked information about the offshore wind AR6 strike price in the week prior to the government's announcement. Many of the sample firms experienced statistically significant positive abnormal returns following the first identifiable AR6 strike price information leak on 9 November, and positive abnormal returns were particularly significant when aggregated across the sample and over the time period from the first instance of leakage to the government's formal announcement. These results suggest that the CfD scheme increases the value of offshore wind developments today and indicate the scheme's present-day relevance and ability to incentivise development.

This article opens with a discussion of the CfD scheme and the AR6 strike price announcement. A literature review follows next, examining literature establishing the economic theory behind event studies, papers establishing and critiquing event study methodologies, and event studies evaluating similar policy changes. Next, the paper outlines the sample of firms evaluated in this study and the data sources used in this paper. An extensive methodology section follows, contextualising the succeeding results.

[15] Brooks, Chris. *Introductory Econometrics for Finance*. 4th ed., Cambridge University Press, 2019; MacKinlay, A. "Event Studies in Economics and Finance." *Journal of Economic Literature*, vol. 35, no. 1, 1997, pp. 13–39.

Finally, the article presents a discussion of the results, a brief conclusion, and a reflection on potential avenues for further research.

II. **Background**

A. *The Contracts for Difference Scheme*

The United Kingdom initiated its current renewable energy auction scheme, the CfD programme, in 2013.[16] Under the scheme, renewable energy developers competitively bid for 'contracts for difference', which guarantee developers a fixed price per MWh of energy they produce for 15 years. Specifically, when the wholesale price of electricity is below the contractually decided support price, the renewable energy developer receives the agreed CfD price, and if wholesale prices surpass the CfD price, developers must return the excess revenues to the government. Multiple renewable technologies have been supported in each CfD round, including geothermal energy, hydroelectricity, tidal energy, solar PV, and onshore and offshore wind.

To win a support contract in a competitive auction, developers should be incentivised to bid to receive the lowest price at which they can cover the upfront and running costs of their renewable energy development.[17] This amount is the "levelized cost of energy" (LCOE) of a project, which is an estimate of the average cost of generating a unit of electricity over the expected lifetime of an energy project.[18] This is important for understanding the role of the CfD scheme and interpreting the event study results. Specifically, the higher strike price should not have represented an opportunity to generate windfall profits through the CfD scheme, a scenario which should have resulted in share price increases regardless of whether the CfD scheme is necessary to developing a bankable wind project today. Instead, the higher strike price should have represented the return of the CfD programme as a financially viable route for developing offshore wind.

Since 2014, the UK government has held 6 CfD rounds.[19] Each AR has featured a different offshore wind strike price and a different total budget, which determines the capacity supportable at the strike price. In each round, support contracts are awarded to the lowest price bidders until the total budget has been exhausted, and each awardee is offered the support price submitted by the highest-bidding winner.[20] Based on UK government estimates of offshore wind LCOEs, CfD strike prices have decreased with each round, falling from £155 in AR1 to £105 in AR2, £56 in AR3, and £46 in AR4.[21]

While there was a concurrent decrease in offshore wind LCOEs, developers increasingly warned the UK government that, should strike prices continue to fall at a similar pace, projects would become financially unviable.[22] Nonetheless, the UK government cut prices further for AR5 in 2023, setting a price of £44. At the same time, supply chain shocks and high interest rates and inflation increased the cost of developing an offshore wind farm, and ultimately, no offshore wind developers participated in AR5.[23] Wind industry, energy, environment, and political groups criticised the AR5 strike price and called for the government to re-evaluate and increase the strike price in AR6.[24]

B. *The Event of Interest: The AR6 Strike Price Announcement*

Following the failure of AR5, the UK government consulted with offshore wind industry leaders, trade associations, energy sector analysts, and renewable energy organisations regarding how to support offshore wind in AR6.[25] After an "extensive

[16] Watson and Bolton (n 4) *supra*.

[17] Kell, Nicholas, et al. "Methodology to Prepare for UK's Offshore Wind Contract for Difference Auctions." *Applied Energy*, vol. 336, 2023, p. 120844.

[18] Beiter, Philipp, et al. *An Assessment of the Economic Potential of Offshore Wind in the United States from 2015 to 2030*. National Renewable Energy Laboratory (NREL), Mar. 2017.

[19] DESNZ (n 5) *supra*.

[20] Watson and Bolton (n 4) *supra*.

[21] ibid.

[22] ibid.

[23] ibid.

[24] Catapult ORE (n 12) *supra;* Energy UK (n 12) *supra*.

[25] Watson and Bolton (n 4) *supra*.

review of the latest evidence, including the impact of global events on supply chains," on 16 November 2023, the government announced a new, higher strike price for offshore wind in AR6, increasing the strike price by 66% to £73/MWh.[26]

The UK government's announcement of a higher strike price for offshore wind is the 'event' investigated in this event study. To be suitable for investigation under the event study methodology, an event must be both 'relevant' and 'novel'.[27] Regarding the latter, a relevant event is one which market participants believe will change the future financial value of a firm, and it will thus be reflected in share prices. Events must also present new information that the market is yet to react to, or investors will have already priced the information into their evaluation of a company's shares.

1. Event Relevance

Previous studies suggest changes to renewable energy support schemes are relevant. Liu et al.[28] and Crowley et al.[29] both found that share prices are sensitive to changes in feed-in tariff policies which, like the CfD scheme, provide generators a fixed subsidy per unit of energy supplied to the grid. News articles have also recently highlighted fluctuations in offshore wind developers' share prices concurrent with offshore wind policy announcements. For instance, in October 2023, multiple newspapers reported that Orsted's share price dropped 8% following the New York government's decision not to adjust Orsted's US subsidy payments for inflation.[30]

2. Novelty and Information Leakage

Regarding the novelty of the price announcement, nominally the strike price for each CfD AR is unknown by the market until the government's formal announcement.[31] Nonetheless, regulatory events are rarely a full surprise due to information leakage.[32]

If the AR6 offshore wind strike price was leaked to market players before 16 November, the market's reaction is likely spread from the first instance of information leakage through the government's formal announcement, diminishing or removing any share price reaction on the formal announcement day.[33] There is evidence the AR6 offshore wind strike price was leaked to the market in the week preceding 16 November. Specifically, on 9 November, a Bloomberg article announced that people "familiar with the matter" knew that the AR6 offshore wind strike price would sit between £70/MWh and £75/MWh.[34] This rumour soon spread, quickly published on an array of prominent news sites.[35] Then, on the morning of 15 November, multiple news sites, including Sky News and Utility Week, announced the AR6 offshore wind strike price would be £73/MWh.[36]

[26] Coutinho (n 13) *supra*.

[27] Datsenko, Ruslana. *Policy Shifts and Stock Market: Lessons from the US and China*. Norwegian University of Life Sciences, 2017.

[28] Liu, Chang, et al. "How Does the Capital Market Respond to Policy Shocks? Evidence from Listed Solar Photovoltaic Companies in China." *Energy Policy*, vol. 151, 2021, p. 112054.

[29] Crowley, Meredith, et al. "Policy Shocks and Stock Market Returns: Evidence from Chinese Solar Panels." *Journal of the Japanese and International Economies*, vol. 51, 2019, pp. 148-69.

[30] Disavino, Scott, and Nichola Groom. "New York Rejects Orsted, Equinor, BP Requests to Charge More for Offshore Wind." *Reuters*, 12 Oct. 2023; Gillespie, Todd, and Allegra Catelli. "Orsted Slumps as US Wind Cost Ruling Stokes Writedown Fear." *Bloomberg*, 13 Oct. 2023; Hill, Joshua S. "Ørsted Shares Plunge Again as New York Knocks Back Cost Adjustment for Offshore Wind." *Renew Economy*, 17 Oct. 2023.

[31] Coutinho (n 13) *supra*.

[32] Datsenko (n 27) *supra*.

[33] Brooks (n 15) *supra*.

[34] Gillespie, Todd, and Ellen Milligan. "UK Prepares to Hike Wind Farm Prices as Developers Struggle." *Bloomberg*, 9 Nov. 2023.

[35] AF Marketwire. "Ørsted Helped by Rumors of UK Willingness for Higher Subsidies for Offshore Wind." *EnergyWatch*, 10 Nov. 2023; Ambrose, Jillian. "UK Subsidies for Offshore Windfarms Likely to Increase amid Rising Costs." *The Guardian*, Nov. 2023; "UK Wind Power Still a Better Deal than Gas." *reNews*, 13 Nov. 2023.

[36] Horgan, Robert. "Higher CfD Strike Price Will 'Restore Confidence' in Offshore Wind." *Utility Week*, 15 Nov. 2023; Kelso, Paul. "Government Set to Hike Prices to Put Offshore Wind Auction Back on Track." *Sky News*; "UK to 'Increase Offshore CfD Strike Price Cap'." *reNews*, 15 Nov. 2023.

With evidence of leakage, this article evaluated changes to offshore wind developers' share prices every day from 10 to 17 November and also evaluated the cumulative change to developers' share prices from 10 to 17 November. Further explained in Section V, the latter calculation is referred to as a firm's 'cumulative abnormal returns' (CAR) and is commonly employed to evaluate policy announcements with leakage.[37]

III. **Literature Review**

After establishing the general suitability of the event study methodology, this article provides an extensive literature review to guide finer methodological decisions. The first published event study is usually traced to Dolley,[38] who evaluated the impact of 95 stock splits from 1921 to 1931 on firms' share prices. However, the market model approach to conducting an event study was introduced 30 years later in papers by Ball and Brown[39] and Fama and colleagues.[40] Their studies, focused on the effect of earnings reports and stock splits on prices, respectively, outlined the market model methodology that is employed in this paper and most event studies today.[41]

A wave of research focused on refining event study methodology followed these initial papers. Particular emphasis has been placed on developing test statistics better suited to stock returns, which sometimes exhibit non-normality, cross sectional dependence, and event-induced increases in volatility.[42] Other authors proposed or evaluated alternative methods to the market model for modelling expected share returns, including the constant mean returns model,[43] the capital asset pricing model (CAPM) model,[44] the Fama-French 3-factor model,[45] the Fama-French-Momentum 4-factor model,[46] and the Fama-French 5-factor model.[47]

Discussed further in Section V, this article's modelling decisions were strongly influenced by the above methodological discussions as well as more recent papers examining similar policy events. Over the past few decades, an abundance of event study papers has been published examining the impact of firm- and country-level events on companies' shares. A 2022 review of four leading, peer-reviewed international finance journals discovered 700 event study papers, and close to 15% of these papers evaluated the impact of legislative changes on share prices.[48]

Of greatest relevance to this event study, several recent papers evaluate the impact of renewable energy subsidy policies. Both Liu et al.[49] and Crowley et al.[50] employed the market

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[37] Benninga, Simon, and Tal Mofkadi. *Financial Modeling*. 5th ed., MIT Press, 2021.
[38] Dolley, J. "Characteristics and Procedures of Common Stock Split-Ups." *Harvard Business Review*, vol. 11, 1933, pp. 316-326.
[39] Ball, Ray, and Philip Brown. "An Empirical Evaluation of Accounting Income Numbers." *Journal of Accounting Research*, vol. 6, no. 2, 1968, p. 159.
[40] Fama, E, et al. "The Adjustment of Stock Prices to New Information." *International Economic Review*, vol. 10, no. 1, 1969, pp. 1-21.
[41] Brooks (n 15) *supra*.
[42] Boehmer, E. "Event-Study Methodology under Conditions of Event-Induced Variance." *Journal of Financial Economics*, vol. 30, no. 2, 1991, pp. 253-72; Brown, Stephen, and Jerold Warner. "Measuring Security Price Performance." *Journal of Financial Economics*, vol. 8, no. 3, 1980, pp. 205-58; Corrado, Charles. "A Nonparametric Test for Abnormal Security-Price Performance in Event Studies." *Journal of Financial Economics*, vol. 23, no. 2, 1989, pp. 385-95; Cowan, Arnold Richard. "Nonparametric Event Study Tests." *Review of Quantitative Finance and Accounting*, vol. 2, no. 4, 1992, pp. 343-58; Kolari, James, and Seppo Pynnonen. "Nonparametric Rank Tests for Event Studies." *Journal of Empirical Finance*, vol. 18, no. 5, 2011, pp. 953-71; Patell, James. "Corporate Forecasts of Earnings per Share and Stock Price Behavior: Empirical Test." *Journal of Accounting Research*, vol. 14, no. 2, 1976, p. 246.
[43] Brown, Stephen, and Jerold Warner. "Using Daily Stock Returns." *Journal of Financial Economics*, vol. 14, no. 1, 1985, pp. 3-31.
[44] Sharpe, William. "Capital Asset Prices: A Theory of Market Equilibrium under Constructions of Risk." *Journal of Finance*, vol. 19, no. 3, 1964, pp. 425-42.
[45] Fama, Eugene, and Kenneth French. "Common Risk Factors in the Returns on Stocks and Bonds." *Journal of Financial Economics*, vol. 33, no. 1, 1993, pp. 3-56.
[46] Carhart, Mark. "On Persistence in Mutual Fund Performance." *Journal of Finance*, vol. 52, no. 1, 1997, pp. 57-82.
[47] Fama, Eugene, and Kenneth French. "A Five-Factor Asset Pricing Model." *Journal of Financial Economics*, vol. 116, no. 1, 2015, pp. 1-22.
[48] El Ghoul, Sadok, et al. "Event Studies in International Finance Research." *SSRN Electronic Journal*, 2022.
[49] Liu et al. (n 28) *supra*.
[50] Crowley et al. (n 29) *supra*.

model to estimate the reaction of solar PV companies to feed-in tariff policy changes in China. They found that firms experienced statistically significant abnormal returns after a policy was announced, with the direction of the return dependent on the favourability of the policy update to solar firms. Also using the market model, Datsenko[51] analysed a set of renewable energy policy announcements in the US and China, finding that the impact of policies varied significantly by sector. Each of these papers serves as a proof-of-concept that renewable energy firms' share prices are influenced by energy policy announcements and that this effect can be examined through an event study. Additionally, this study made many of the same methodological choices as the above papers, including employing the market model and many of the same significance tests. These choices are discussed further in Section V.

IV. **Data and Sample**

In the United Kingdom, private companies own, develop, and operate offshore wind farms and thus bear the cost, or reap the benefits, of generated wind energy.[52] This group of 'offshore wind developers' with ownership stakes in operational or planned UK projects is therefore the focus of this study. However, because this event study evaluates the impact of the AR6 strike price announcement on share prices, the sample of offshore wind developers evaluated in this paper was limited to publicly listed companies. In March 2024, there were twenty-seven publicly listed companies with ownership stakes in operational, consented, or planned offshore wind projects.[53]

Nonetheless, not all of these developers owned stakes in projects eligible to receive a government support contract in AR6. To participate in an auction round, the project a developer aims to receive support for must have applicable government planning consents, electricity grid connection agreements, and a seabed lease from the Crown Estate providing rights to operate in British waters.[54] Eleven projects met these criteria for AR6, and eight publicly listed developers held a stake in one or more of these eleven eligible projects. CfD regulations also only obligate a developer to build 75% of their project's contracted capacity, so developers awarded a contract for a project in AR5 could receive an AR6 contract for 25% of their project's capacity.[55] Four projects were eligible for a 25% capacity rebid, and five publicly listed developers held full or partial ownership stakes in these.[56] In total, there were eleven unique developers with ownership stakes in a project fully, or partially, eligible for a support contract in AR6.

Of these eleven companies, six were included in the final sample: EDP Renewables, ENGIE, Iberdrola, Orsted, RWE, and SSE. Following the suggestion of Escoffier[57] and Shane and Spicer[58] to remove firms likely affected by other events or announcements concurrent with the event being studied, this paper did not include HexiconAB, SDIC Power Holdings, Siemens, Tenaga Nasional Berhad (TNB), or TotalEnergies in the final sample analysed in this paper. Described in greater detail below, each of these firms was likely affected by events or announcements concurrent with AR6, so including these firms was likely to introduce omitted variables bias into the results.

Qualitative and quantitative descriptive statistics for each of the eleven AR6-eligible firms are displayed in Table 1, below, including each company's primary industry, primary stock market listing, and market

[51] Datsenko (n 27) *supra*.
[52] The Crown Estate. *Guide to an Offshore Wind Farm*. Jan. 2019.
[53] The Crown Estate (n 3) *supra*.
[54] DESNZ. *Schedule 5: Application Checks to Be Carried Out by the Delivery Body*. Mar. 2024.
[55] May, Jordan. "Ørsted Ignites Rebidding Frenzy in Allocation Round 6." *TGS*, 26 Feb. 2024.
[56] The Crown Estate (n 3) *supra*.
[57] Escoffier, M. "How Financial Markets React to Total's Strategy of Becoming a Responsible Energy Major?" Working Papers HAL-04159687, HAL, 2020.
[58] Shane, P, and B Spicer. "Market Response to Environmental Information Produced Outside the Firm." *Accounting Review*, vol. 58, 1983, pp. 521-538.

capitalisation in September 2023, as well as the total capacity of projects owned by each developer eligible for participation in AR6.[59] The six final sample firms are listed first and feature an asterisk by their name.

All company share price data employed in this article was downloaded from Yahoo!Finance, a global financial news and data provider. Each of the share price indices analysed and used in this paper came from S&P Dow Jones Indices.[60] Finally, market capitalisation data in Table 1 came from Finbox,[61] a financial data and modelling platform.

Regarding HexiconAB and TNB, these companies were removed as their ownership stake in projects wholly or partially eligible for participation in AR6 was less than 30 MW.[62] With such a small ownership stake, it is unlikely that these firms' share returns were affected by the AR6 share price announcement. Instead, any change in these companies' share prices around 16 November was likely caused by other market events.

Regarding SDIC Power Holdings, Siemens, and TotalEnergies, these companies were removed as they earn most of their revenues in non-renewable energy markets and were likely affected by confounding events around 16 November. Specifically, the majority of TotalEnergies's revenues come from fossil fuels, and crude oil prices fluctuated widely in November 2023.[63] Of particular note, crude oil prices dropped to their lowest level since June 2023 on 17 November 2023, leading to a more than 2% decrease in global oil and gas share price indices.[64]

Siemens primarily operates in the industrial automation and manufacturing industries, and its ownership stake in AR6 eligible projects is small.[65] Any major firm-level announcement or event in Siemen's primary industries around 17 November is therefore likely to have caused a greater change to Siemen's share price than the AR6 strike price announcement. Evidence of a confounding event is why Siemens was ultimately removed from the sample: Siemens held its annual press conference on 16 November.[66]

SDIC primarily operates in Asian energy and utility markets and, like Siemens, SDIC's ownership stake in British offshore wind projects is small. The share prices of Asian energy and utility companies have also largely followed a separate trajectory to European- and North American-domiciled companies.[67] This makes it difficult to assess whether movements in SDIC's share prices were caused by AR6 or instead by events in Asian markets, especially since any impact of the AR6 strike price announcement on SDIC's shares was likely small given its ownership stake. TNB also primarily operates in Asian markets, reinforcing the decision to remove TNB from the final sample.

As confirmation of the sample choice, plotting the share returns of the six included firms reveals striking similarities; each followed the same general trends from June 2023 to June 2024 and track an index of major clean energy firms closely.[68] Additionally, a search for significant firm-level events affecting each sample company yielded no major findings. Specifically, this study skimmed the first twenty news articles that surfaced in a Google News search for the name of each firm. The search was tailored to only include articles published from 5 to 20 November, and the

[59] If a company has a partial ownership stake in an eligible project, only the portion of the project owned by the listed developer is included in the AR-6 Eligible Capacity metric.

[60] Wharton Research Data Services (WRDS). "Historical S&P Dow Jones Indices." Wharton University of Pennsylvania.

[61] "Data Explorer." *Finbox*, 2024.

[62] The Crown Estate (n 3) *supra*.

[63] Fanzeres, Julia, and Mia Gindis. "Oil Plunges to July Low as Algorithms Amplify Supply-Driven Drop." *S&P Global*, 2024.

[64] ibid.

[65] "Siemens Report for Fiscal 2023." *Siemens*, 2024.

[66] "Annual Press Conference 2023." *Siemens*, 16 Nov. 2023.

[67] *S&P China A 300 Utilities (Sector) Index*. S&P Global, 2024.

[68] *S&P Global Clean Energy Select Index*. S&P Global, 2024; Yahoo!Finance. "Market Data."

search results were presented by Google in order of 'relevance'.

In contrast to the six final sample firms, none of the excluded firms' share returns over the past year track the Clean Energy Index or each other. This suggests that the excluded firms' share returns are primarily driven by events external to the global renewable energy industry and the British offshore wind industry.

V. **Methodology**

A. *Daily Share Price Returns*

This paper estimated the impact of the AR6 strike price announcement on companies' daily share price returns. There are a couple of different methods for calculating daily share price returns. The simplest approach to calculating share returns is to find the percentage change in a company's share price between two days.[69] The formula for doing so is:

$$r_t = \frac{P_t}{P_{t-1}} - 1$$

where P_t is the share price on a given day.

Alternatively, it is possible to calculate continuously compounded share returns.[70] Continuously compounded share returns are calculated as follows:

$$r_t = \ln\left(\frac{P_t}{P_{t-1}}\right)$$

This paper calculated continuously compounded returns. While both methods yield near-identical results, the latter is favoured in finance literature for its advantageous mathematical properties: daily returns can be added together to obtain the return over a longer period.[71]

Finally, this paper used daily opening share prices to calculate returns. This means that the impact of an announcement materialising on a given day will be reflected in the share return calculated for the following day.

B. *Abnormal Returns Model Selection*

Described in Section III above, researchers have developed several models for estimating expected and abnormal returns in event studies. These primarily include the constant mean returns model, the CAPM, and the Fama-French 3-, 4-, and 5-factor models.

The constant mean returns model is the simplest model to employ. However, Brown and Warner[72] compared the accuracy of estimated abnormal returns from the constant mean returns model to the market model and found that the constant mean returns model has lower statistical power and suffers more from misspecification than the market model. As such, this study favoured use of the market model over the constant mean returns model.

The CAPM calculates expected returns as a function of the risk-free interest rate and a stock-specific risk premium.[73] However, this model has largely been discredited in the literature, with researchers noting structural issues which likely prohibit accurately estimating returns.[74]

The Fama 3-, 4-, and 5-factor models add explanatory variables to the CAPM and thereby predict returns with greater accuracy.[75] However, the Fama-French models are usually employed on portfolios of firms, not individual companies.[76] The models have also rarely been employed to study small

[69] Brooks (n 15) *supra*.

[70] Benninga and Mofkadi (n 37) *supra*.

[71] Brooks (n 15) *supra*.

[72] Brown and Warner (n 43) *supra*.

[73] Kothari, S, and Jerold Warner. "Econometrics of Event Studies." *Handbook of Empirical Corporate Finance*, edited by B Espen Eckbo, North Holland, 2009, pp. 3-36.

[74] Ball and Brown (n 39) *supra*; Banz, Rolf. "The Relationship between Return and Market Value of Common Stocks." *Journal of Financial Economics*, vol. 9, no. 1, 1981, pp. 3-18; Basu, S. "Investment Performance of Common Stocks in Relation to Their Price-Earnings Ratios: A Test of the Efficient Market Hypothesis." *Journal of Finance*, vol. 32, no. 3, 1977, pp. 663-82; Brooks (n 15) *supra*.

[75] Fama and French (n 45) *supra*.

[76] Kothari and Warner (n 73) *supra*.

samples, and when attempted, the models have lost their ability to accurately predict share returns.[77]

Given the above issues with the CAPM and Fama models, and the benefits of the market model over the constant mean returns model, this paper employed the market model. This is the most commonly used model in the literature.[78] The market model is also employed by Crowley et al.,[79] Datsenko,[80] and Liu et al.,[81] whose work is closest aligned with the content of this paper.

C. *The Market Model*

1. Equation and Theory

The market model assumes a stable linear relationship exists between a firm's share returns and a market index's returns, and it uses this relationship to predict a firm's returns given a market index's returns.[82] Specifically, the market model takes the following form:

$$R_{it} = \alpha_i + \beta_i R_{mt} + u_{it}$$

where R_{it} is a firm's observed share returns, α_i is a constant, β_i is a coefficient which estimates the relationship between a firm's share returns and the market index's returns, R_{mt} is the market index's returns, and u_{it} is an error term. α_i and β_i are estimated by running the above regression with share and index price data from before an event, and this study estimated them in Microsoft Excel.

Once an estimate of α_i and β_i is calculated for a firm, it is possible to use the market model formula to predict R_{it} given observed returns to R_{mt}. R_{it} then becomes a measure of a firm's expected share returns given R_{mt} data.

With estimates of a firm's expected returns and data on a firm's actual returns, abnormal returns can be calculated by subtracting the firm's expected returns from their actual returns:

$$\mathrm{AR}_{it} = R_{it} - (\alpha_i + \beta_i R_{mt})$$

Theoretically, abnormal returns isolate the portion of a firm's returns which cannot be explained by general market movements. AR estimates should therefore capture the share price impact of events that affect a firm differently than the underlying market, such as the AR6 strike price announcement.

2. Market Index Selection

After selecting the market model, one of the first necessary methodological choices was choosing a suitable market index. This paper tested the fit of seven share price indices from S&P Global: S&P's Global Clean Energy Index, Clean Energy Select Index, North America and Europe Clean Energy Index, World Unities Sector Index, Global 1200 Utilities Index, Utilities Select Sector Index, and Global BMI Utilities Sector Index. It also tested using two 'control' firms as the market index: Greencoat UK Wind and The Renewables Infrastructure Group (TRIG). These firms are involved in the British offshore wind industry but did not have ownership stakes in AR6-eligible projects.

Ultimately, this paper selected the S&P Global Clean Energy Select Index, which measures the performance of the thirty largest clean energy-related businesses from both developed and emerging markets.[83] Using this index resulted in the highest average R^2 values in the market model regressions, indicating that changes in this index best predict changes in the sample firms' share returns. Furthermore, in a well-specified model, a firm's abnormal returns over the estimation window should average to zero. This held true for all six sample firms when the Global Clean Energy Select Index was used as the market index.

[77] Saucedo, Eduardo, and Jorge González. "The Effect of Macroeconomic Variables on the Robustness of the Traditional Fama–French Model: A Study for Mexico Using Different Portfolios." *Journal of Economics, Finance and Administrative Science*, vol. 26, no. 52, 2021, pp. 252-67.

[78] Benninga and Mofkadi (n 37) *supra.*

[79] Crowley et al. (n 29) *supra.*

[80] Datsenko (n 27) *supra.*

[81] Liu et al. (n 28) *supra*

[82] Brooks (n 15) *supra;* MacKinlay (n 15) *supra*

[83] *S&P Global Clean Energy Select Index* (n 68) *supra.*

3. Estimation and Event Windows

Another necessary methodological choice was determining the model estimation and event windows. The estimation window is the period evaluated to determine the 'normal' behaviour of a company's shares absent an event: α_i and β_i are estimated using share price data from this window.[84] Estimation windows typically range from 100 to 300 trading days.[85] However, there is a trade-off between increasing the precision of the market model coefficients by lengthening the estimation window and potentially biasing the model, because historical data captures share price relationships which may have changed.[86] Due to the volatility in clean energy markets over the past couple years, and the potential for this to significantly alter the relationship between a firm's share returns and a market index,[87] this study erred on the side of caution and selected a shorter estimation window of 120 daily stock estimations. Specifically, the estimation window used in this article spans from 17 May 2023 to 7 November 2023. To avoid contaminating the expected returns estimates with any share price changes caused by information regarding the AR6 strike price, this window does not include 17 November or the ten days preceding it.

After deciding the estimation window, it was also necessary to determine the 'event window', the period over which an event's impact is estimated.[88] The government announced the AR6 offshore wind strike price on 16 November. If this caused an increase in developers' share prices, abnormal returns should be detectable on 17 November. However, as described above, it is likely that developers anticipated strike price increases in the week prior to 16 November. Thus, this paper estimated abnormal returns on 17 November and over a longer event window. Specifically, the first evidence of leakage was on 9 November, so this paper set 10 November as the first day in the event window. There is no evidence in the media, or in firms' share returns, that the market's reaction to the AR6 strike price continued past 17 November. Thus, this paper decided to analyse an event window spanning from 10 to 17 November.

D. *Abnormal Returns Metrics*

1. Firm-Level Daily Abnormal Returns

Abnormal returns can be evaluated at the individual firm and event day level or aggregated across a sample and / or event window.[89] This paper first estimated each of the sample firm's abnormal returns (AR) on each trading day in the event window using the equation described in Section V.C.1:

$$\mathrm{AR}_{it} = R_{it} - (\alpha_i + \beta_i R_{mt})$$

To test the statistical significance of the AR estimates, the variance of each estimate was also calculated. The variance of each firm's AR is equal to the variance of the residuals from the market model over the estimation window:

$$\sigma^2(\mathrm{AR}_{it}) = \frac{1}{T-2}\sum_{t=1}^{T} {u_{it}}^2$$

where σ^2 is the symbol for variance, u_{it} is the residual for a firm on a given day (the difference between a firm's expected share return and observed share return), and T is the number of observations in the estimation period.[90]

[84] Benninga and Mofkadi (n 37) *supra*.
[85] ibid.
[86] Kinnunen, Rasmus. *Markets and Analysts' Reactions to Green Hydrogen Investments in European Oil Refiner and Steel & Iron Industry Enterprises*. LUT School of Business and Management, 2023; Peterson, Pamela. "Event Studies: A Review of Issues and Methodology." *Quarterly Journal of Business and Economics*, vol. 28, no. 3, 1989, pp. 36–66.
[87] Brown, K, et al. "An Examination of Event Dependency and Structural Change in Security Pricing Models." *Journal of Financial and Quantitative Analysis*, vol. 20, no. 3, 1985, pp. 315–334; Fisher, L, and J Kamin. "Forecasting Systematic Risk: Estimates of 'Raw' Beta that Take Account of the Tendency of Beta to Change and the Heteroskedasticity of Residual Returns." *Journal of Financial and Quantitative Analysis*, vol. 20, no. 2, 1985, pp. 127–149.
[88] Brooks (n 15) *supra*.
[89] ibid.
[90] ibid.

2. Daily Average Abnormal Returns

To better understand sample-wide trends and reduce the chance that any AR results were driven by random variability or confounding events, this paper also aggregated abnormal returns across firms. This yields a measure of the 'average abnormal returns' (AAR) on a given day. AAR is calculated as follows:

$$\mathrm{AAR}_t = \frac{1}{N}\sum_{t=1}^{N}\mathrm{AR}_{it}$$

where N is the number of firms in the sample.[91]

The variance of the AAR metric is calculated by averaging the variances of each firm's AR and dividing by N.[92]

$$\sigma^2(\mathrm{AAR}_t) = \frac{1}{N^2}\sum_{i=1}^{N}\sigma^2\,(\mathrm{AR}_{it})$$

3. Firm-Level Cumulative Abnormal Returns

To capture the impact of leakage, it is also possible to aggregate abnormal returns across days instead of across firms. Briefly alluded to above, such temporal aggregation yields a firm's 'cumulative abnormal returns' (CAR). CAR can be calculated over two or more days using the following formula:

$$\mathrm{CAR}_i(T_1, T_2) = \sum_{t=T_1}^{T_2}\mathrm{AR}_{it}$$

where T_1 is the first day included in the metric and T_2 is the last day.[93] The variance of CAR estimates takes the following form:[94]

$$\sigma^2(\mathrm{CAR}_i(T_1, T_2)) = (T_2 - T_1 + 1)\sigma^2(\mathrm{AR}_{it})$$

This paper calculated CAR for each firm over a three-day period spanning from 15 to 17 November and a six-day period spanning from 10 to 17 November.[95] The three-day CAR should capture any effects of the 15 November information leaks as well as the government's formal AR6 strike price announcement, and the six-day event period should additionally capture the effect of any price information leaked after 9 November.

4. Cumulative Average Abnormal Returns

Finally, to understand the AR6 strike price announcement's average impact on the sample firms' shares across the event window, this paper aggregated abnormal returns across the sample firms and time. This yields a measure of 'cumulative average abnormal returns' (CAAR). This paper calculated CAAR for the same three- and six-day windows as the CAR estimates. CAAR is calculated as follows:[96]

$$\mathrm{CAAR}(T_1, T_2) = \frac{1}{N}\sum_{i=1}^{N}\mathrm{CAR}_i\,(T_1, T_2)$$

The variance of CAAR estimates is equal to the average variance of each firm's CAR divided by N:[97]

$$\sigma^2(\mathrm{CAAR}(T_1, T_2)) = \frac{1}{N^2}\sum_{i=1}^{N}\sigma^2\,(\mathrm{CAR}_i(T_1, T_2))$$

E. *Test Statistics*

1. T-Test

In this paper, the statistical significance of each of the above metrics was first estimated using a simple t-test. This test statistic is calculated by dividing the AR, AAR, CAR, or CAAR estimates by the standard deviation of each. AR and CAR t-test statistics are distributed with $T - 2$ degrees of freedom, where T is the number of observations in the estimation window (120).[98] The CAR and CAAR test statistics are instead distributed with $N - 1$ degrees of freedom, where N is the number of firms in the sample (six).[99]

2. Null and Alternative Hypotheses

Calculating a test statistic allows evaluation of the likelihood of a set of hypotheses regarding offshore wind developers' abnormal returns. The null hypothesis tested in this study was

[91] ibid.
[92] ibid.
[93] ibid.
[94] ibid.
[95] There is no share price data for 11 or 12 November as these days fell over the weekend.
[96] Brooks (n 15) *supra*.
[97] ibid.
[98] ibid.
[99] Muller, Simon. "AAR and CAAR Test Statistics: A Comprehensive Guide to Analyzing Abnormal Returns in Event Studies." *EventStudy.de*, 2024.

that there was no share price reaction to the AR6 strike price announcement; that is, that the abnormal returns are zero:

$$H_0: \mathrm{AR}_{it}, \mathrm{AAR}_t, \mathrm{CAR}_i(T_1, T_2), \mathrm{CAAR}(T_1, T_2) = 0$$

This null hypothesis was tested against the one-sided alternative hypothesis that the returns are greater than zero:

$$H_1: \mathrm{AR}_{it}, \mathrm{AAR}_t, \mathrm{CAR}_i(T_1, T_2), \mathrm{CAAR}(T_1, T_2) > 0$$

A one-sided alternative hypothesis was selected over a two-sided hypothesis because of key stakeholders' positive reaction to the AR6 strike price announcement. Specifically, given the scale of the AR6 strike price increase, as well as the public praise of politicians, offshore wind developers, energy organizations, and industry bodies, it is extraordinarily unlikely that the price announcement would have caused offshore wind developers' share prices to fall. This negates the need to test a two-sided hypothesis.

However, conducting a valid t-test requires satisfying several underlying conditions.[100] There is evidence some of these assumptions are violated in event studies.[101]

F. *Statistical Inference Assumptions*

1. Independence Assumption

First, a t-test assumes abnormal returns are independent across firms. However, because events affect firms at the same time, abnormal returns are generally cross-sectionally dependent, particularly when the sample firms are from the same industry.[102]

When firms' AR and CAR are calculated, cross-sectional dependence is not an issue because these statistics are unique to each firm.[103] However, cross-sectional dependence is an issue when calculating statistics that aggregate abnormal returns across the sample, that is, AAR and CAAR. When calculating these metrics and estimating the statistical significance of each, cross-sectional dependence can lead to biased standard error estimates and over-rejecting the null hypothesis.[104]

2. Crude Dependence Adjustment

To help alleviate the issue of cross-sectional dependence, Brown and Warner[105] proposed a "crude dependence adjustment" (CDA). With this adjustment, the test statistic becomes:

$$t_{CDA} = \frac{\bar{\varepsilon}_0}{\sqrt{\sigma^2}}$$

where:

$$\sigma^2 = \frac{1}{T-1} \sum_{t=1}^{T} (\bar{\varepsilon}_t - \bar{\varepsilon})^2 \ ;$$

$$\bar{\varepsilon} = \frac{1}{NT} \sum_{t=1}^{T} \sum_{i=1}^{N} \varepsilon_{it} \ ;$$

and:

$$\bar{\varepsilon}_t = \frac{1}{N} \sum_{i=1}^{N} \varepsilon_{it} \ .$$

This statistic is t-distributed with $T-1$ degrees of freedom, where T is the number of trading days in the estimation window (120).

Given the potential for cross-sectional dependence, this paper calculated the Brown-Warner CDA test where possible: the test can only be employed to estimate the significance of AAR and CAAR estimates because it is formed using a measure of the average abnormal returns across a sample. However, AR and CAR estimates are unaffected by cross-sectional dependence, negating the need to employ the Brown-Warner CDA test.

3. Normality Assumption

The t-test and Brown-Warner CDA test are parametric tests; they assume firms' abnormal returns are approximately normally distributed. However, extensive research has

[100] Dutta, Anupam. "Parametric and Nonparametric Event Study Tests: A Review." *International Business Research*, vol. 7, no. 12, 2014; Kim, Tae Kyun, and Jae Hong Park. "More about the Basic Assumptions of T-Test: Normality and Sample Size." *Korean Journal of Anesthesiology*, vol. 72, no. 4, 2019, pp. 331-35.

[101] Brown and Warner (n 43) *supra*.

[102] ibid; Campbell, Cynthia, and Charles Wesley. "Measuring Security Price Performance Using Daily NASDAQ Returns." *Journal of Financial Economics*, vol. 33, no. 1, 1993, pp. 73-92.

[103] MacKinlay (n 15) *supra*

[104] Dutta (n 100) *supra*.

[105] Brown and Warner (n 43) *supra*.

found that the distribution of firms' abnormal returns commonly exhibits positive skew and high kurtosis (fat tails).[106]

Because departures from normality can bias parametric tests towards over-rejecting the null hypothesis, this paper also employed two non-parametric tests. Non-parametric tests do not rely on the normality assumption holding true; they are robust to the presence of skewed distributions.[107] Researchers have also found that non-parametric tests have greater statistical power than parametric tests in event studies.[108]

4. Wilcoxon Signed-Rank Test

For its relative simplicity, the first non-parametric test selected for use in this study was the Wilcoxon signed-rank test. This test takes the sign and magnitude of abnormal returns into account when determining whether there is sufficient evidence to reject the null hypothesis and can be employed to estimate the significance of AAR and CAAR.[109]

To conduct the Wilcoxon signed-rank test, the abnormal returns of a sample of firms on a given day, or a set of days, are ranked according to their absolute value, with a higher rank indicating a higher absolute value.[110] Under the null and alternative hypotheses tested in this study, the Wilcoxon signed-rank test statistic takes the following form:

$$W = R^{-}$$

where R^{-} is the sum of the ranks of the negative abnormal returns in a sample.

For a sample of six firms and a one-sided, 5% significance test, the critical value for rejecting the null hypothesis under the Wilcoxon signed-rank test is two. Under a one-sided 10% significance test, the critical value is instead three. In other words, if the W-score equals, or is less than, two or three, then an AAR or CAAR estimate is significant to the 5% or 10% significance level, respectively.

5. Corrado Rank Test

Despite its benefits, the Wilcoxon signed-rank test relies on the assumption that the distribution of a firm's abnormal returns absent an event is symmetrical; that is, that there are an equal number of positive and negative abnormal returns. The literature suggests this may not hold true.[111]

Given this limitation, this study also employs the Corrado rank test, which is commonly calculated in the literature.[112] The Corrado rank test is Z-distributed and is calculated over the estimation and event window (and any time between the two) according to the following formula:

$$Z = \frac{1}{N}\sum_{i=1}^{N}(K_{it} - \bar{K}) \,/\, S(K)$$

where:

$$S(K) = \sqrt{\frac{1}{T}\sum_{t=1}^{T}\left(\frac{1}{N}\sum_{i=1}^{N}(K_{it} - \bar{K})\right)^{2}}\ ;$$

$$K_{it} = \text{rank}(A_{it});$$

and:

$$\bar{K} = \frac{T}{2} + 0.5.$$

In the Corrado rank test, $A_{it} \geq A_{ij}$ implies $K_{it} \geq K_{ij}$, and $T \geq K_{it} \geq 1$. T is the number of trading days over the estimation window, event window, and any days between the two. $\bar{K}$ is the average rank over this entire time period, which can also be calculated as $\bar{K} = \frac{T}{2} + 0.5$.

[106] ibid.
[107] Brooks (n 15) *supra.*
[108] Dutta (n 100) *supra;* Kolari and Pynnonen (n 42) *supra.*
[109] Dutta (n 100) *supra;* Higgins, E, and Peterson, D. "The Power of One and Two Sample t-Statistics Given Event-Induced Variance Increases and Nonnormal Stock Returns: A Comparative Study." *Quarterly Journal of Business and Economics*, vol. 37, no. 1, 1998, pp. 27–50.
[110] McClenaghan, Elliot. "The Wilcoxon Signed-Rank Test." *Technology Networks Informatics*, 20 Feb. 2023.
[111] Corrado (n 42) *supra.*
[112] Kruse, T, et al. "Are Financial Markets Aligned with Climate Action? New Evidence from the Paris Agreement." *LSE GRI Working Paper Series*, no. 333, 2020.

The Corrado test is valuable for its lack of reliance on a firm's abnormal returns following a symmetrical and / or normal distribution. However, in its original form, the test can only be used to examine AAR.

6. Corrado-Cowan Cumulated Rank Test

Responding to the limited applicability of the Corrado test, Cowan[113] developed a cumulated rank test now commonly referred to as the "Corrado-Cowan cumulated rank test". The Corrado-Cowan cumulated rank test can be used to examine the statistical significance of CAAR and is also robust to non-symmetrical distributions.[114] The Corrado-Cowan cumulated rank test statistic is Z-distributed and takes the following form:

$$Z_R = \sqrt{d}\,\frac{\overline{K_D} - \bar{K}}{\sqrt{\frac{\sum_{t=1}^{T} T(\overline{K_t} - \bar{K})^2}{T}}}$$

where $\bar{K}$ is the average rank of firms' abnormal returns over the estimation window, event window, and any days between the two, and T is the number of trading days in this time span. Likewise, d is the number of event days included in the CAAR metric, and $\overline{K_D}$ is the average rank over these days. Finally, $\overline{K_t}$ is the average rank of firms' abnormal returns on a given day t.

While the Wilcoxon signed-rank test, Corrado rank test, and Corrado-Cowan cumulated rank test remain validly specified in the presence of non-normality, they are not robust to cross-sectional dependence. Thus, the results from these tests should be critically analysed with the Brown-Warner CDA test results.

7. Homogeneity of Variance Assumption

Finally, the t-test assumes homogeneity of variance.[115] In an event study, this means that the variance of the abnormal returns in the estimation window should be equal to the variance of the abnormal returns in the event window.

However, the variance of a firm's AR typically increases during the event window.[116] Without accounting for this event-induced volatility, the variance used in the t-test (which is estimated from returns in the estimation window only) will be too small, and the null hypothesis may be over-rejected.[117]

Researchers have shown that the Wilcoxon, Corrado, and Corrado-Cowan tests discussed above are robust to event-induced volatility.[118] By contrast, the t-test and the Brown-Warner CDA test do not enjoy this feature and may over-reject the null-hypothesis. This increases the importance of evaluating parametric and non-parametric tests.

8. Drawing Statistical Inferences

Together, the above tests respond to the major identified issues with drawing statistical inferences about firms' abnormal returns. While no test is robust to all the identified problems, analysing each test result with the others should provide a robust view of whether there is statistical evidence that the sample firms experienced positive abnormal returns around the time of the UK government's AR6 strike price announcement.

VI. Results and Analysis

This section presents the AR, AAR, CAR, and CAAR estimates from the market model and all the applicable test statistics above. AR estimates are presented first, followed by AAR, CAR, and finally CAAR results.

A. *Abnormal Returns*

Table 2, below, shows each firm's estimated AR on each day of the event window. t-test results for the significance of each are also shown, with 's' indicating the standard error (s = $\sqrt{\sigma^2}$) and 't' the test statistic. With 118 degrees of freedom, t-values above 1.29 are significant to the 10% significance level, and t-values above 1.66 are significant to the 5% level.

[113] Cowan (n 42) *supra*.
[114] Kolari and Pynnonen (n 42) *supra*.
[115] Brooks (n 15) *supra*.
[116] Brown and Warner (n 43) *supra*
[117] Brooks (n 15) *supra*.
[118] Corrado (n 42) *supra*.

Evaluated under the t-test, the model estimated that several firms experienced statistically significant positive AR on 10, 15, 16, and 17 November.

Specifically, the AR estimates for 10 November are positive and statistically significant for Iberdrola, Orsted, and SSE. These returns range from 1-10% and are significant to the 5% level for Orsted and SSE and to the 10% level for Iberdrola. The remaining three firms also experienced positive abnormal returns on 10 November, although these estimates are statistically insignificant. Bloomberg published its article rumouring an increase in the CfD offshore wind strike price on 9 November, so the estimated abnormal returns on 10 November may capture the market's reaction to that news.

The AR estimates for 13 and 14 November are insignificant for all of the firms. This result is predictable under the efficient markets hypothesis if investors had already reacted to the 9 November price leak and no new information was delivered before these days.

The 15 November AR estimates are positive and statistically significant for EDP, RWE, and SSE, ranging from ~2-4%. The AR estimates are also positive, but insignificant, for Iberdrola and Orsted. Like the 10 November estimates, the 15 November results may reflect information leakage. On the morning of 15 November, Sky News posted an article claiming the AR6 strike price would be £73/MWh. While the impact of any article published on 15 November should be reflected in share returns on 16 November, articles take time to publish. It is conceivable that the information covered by Sky News was leaked to key investors right before markets opened on the 15th and that the 15 November AR estimates reflect this information.

The model only yielded one statistically significant AR estimate on 16 November (SSE), and AR estimates are only positive for half of the sample firms on this day. This could reflect that strike price information reached SSE investors at a different time than it reached investors of the other sample firms. However, it may also mean that SSE's 16 November AR estimate was caused by a confounding event.

The 17 November AR estimates are positive across five firms but only statistically significant for Iberdrola. The lack of significant AR estimates on 17 November could indicate that there was little, or no, market reaction to the AR6 strike price announcement. However, given evidence of leakage and significant abnormal returns in the days prior, it is plausible it instead indicates that the market had already reacted to, and 'priced in', the higher offshore wind strike price after news leaks in the week prior.

Notably, each firm experienced significant positive abnormal returns on at least one of the event days except for ENGIE. This may be driven by the relatively small amount of eligible capacity (110 MW) ENGIE was able to bid into AR6. ENGIE also has the second highest market cap of all the sample firms, so its extensive operations in other industries may shield its share returns from the impact of events in the British offshore wind industry. Adding to the argument that a firm's market cap and ownership stake in AR6-eligible projects may partially determine their AR, the AR estimates for SSE were statistically significant to the 5% level on 10, 15, and 16 November. SSE's AR6 ownership stake was twice as large as ENGIE's, and its market cap is half of ENGIE's.

It is also interesting that the AR estimates for a given day are not uniformly (in)significant across the sample. Briefly alluded to above, this may be the outcome of leakage: rumours of a strike price increase may have reached the sample firms' investors at different times. However, it also supports the possibility that the significant AR above reflect the impact of random variability or firm-level confounding events, not the AR6 strike price announcement.

Evaluating AAR in addition to AR can alleviate some concerns about confounding events. Because returns are aggregated across firms to calculate AAR, the impact of firm-specific confounding events should theoretically average out. The AAR metric is also valuable because AAR can be evaluated with test statistics robust to cross-sectional dependence, event-induced volatility, and non-normality. In contrast, the above t-test results may be inflated if the t-test assumptions were violated.

B. *Average Abnormal Returns*

Table 3, below, presents the AAR estimates for each day in the event window, as well as a t-test, Brown-Warner CDA test, Wilcoxon signed-rank test, and Corrado rank test for the significance of each.

Statistically significant positive AAR estimates are observable under all tests on 10 and 15 November. On 10 November, the estimated AAR is 0.027, and on 16 Nov it is 0.022. This suggests the sample firms' share returns were, on average, 2-3% higher than expected, given normal market trends. Importantly, the significance of the 10 and 15 November AAR estimates across all the tests suggests that the positive results on 10 and 15 November are not simply the result of biased standard errors.

Similar to the AR results, the AAR estimates are statistically insignificant under all tests on 13, 14, and 16 November. This is predictable given the AR estimates on these days.

On 17 November, the AAR estimate is statistically significant to the 5% level under the Wilcoxon test and almost significant to the 10% level under the t-test ($t_{0.1,5} = 1.476$). This is moderate evidence in support of the alternative hypothesis. However, any conclusions about the sample firms' share returns on 17 November should be drawn cautiously given the relatively small magnitude of the AAR estimate and its lack of statistical significance under the Brown-Warner CDA test and Corrado test. Any share price reaction on 17 November also appears small compared to 10 and 15 November, which may be because investors had already reacted to leaked strike price information.

The AAR metric aggregates AR estimates across firms, potentially neutralising the impact of firm-specific confounding events. Thus, the above AAR results may measure the AR6 strike price announcement's impact on the sample firms' share returns more accurately than the AR estimates in Table 2. However, the sample evaluated in this paper is small, so it is also possible that the above results are driven by one or two outlier AR estimates. This is problematic if the outliers were caused by random variability or a confounding event unidentified in the aforementioned Google News search. Nonetheless, the results in Table 2 do not provide strong evidence for this outcome. If outliers are defined as any value that falls outside three standard deviations of a mean,[119] then only one AR estimate in Table 2 is an outlier: the estimate for Orsted on 10 November.

While this outlier provides reason to interpret the 10 November AAR results cautiously, it is probable that it simply reflects the fact that Orsted had the most capacity eligible for participation in AR6: 3,450 MW. Furthermore, the 10 and 15 November AAR estimates are significant under both non-parametric tests employed. Non-parametric tests are more outlier-resistant than parametric tests because, while the largest values are given the highest ranks, the magnitude of the estimates with the highest ranks does not matter.

C. *Cumulative Abnormal Returns*

Table 4, below, presents the model estimates of each firm's three- and six-day CAR, as well as t-test statistics for the significance of each. With 118 degrees of freedom, t-values above 1.29 are significant to the 10% significance level and those above 1.66 are significant to the 5% level.

[119] Wooldridge, Jeffrey. *Introduction to Econometrics*. Europe, Middle East and Africa edition ed., Cengage Learning, 2014.

The three-day CAR should capture any share price movements caused by the AR6 strike price announcement and any information leaked in the three days prior. These estimates are positive and statistically significant for EDP, RWE, and SSE. Additionally, all the firms' estimated three-day CARs are positive, ranging from ~1-6%. This is strong evidence that an event caused the sample firms' share prices to deviate positively from other firms in the clean energy market between 15 and 17 November. However, it is not possible to conclude with any standard level of statistical confidence that the entire sample experienced positive three-day CAR.

The six-day CAR metric should capture any share price movements caused by the AR6 strike price announcement and any information leaked on or after 9 November. Significant positive six-day CARs are observable for Orsted, RWE, and SSE. Additionally, the estimated six-day CAR is positive for all firms but ENGIE, ranging from 3-14%. Like above, this supports the conclusion that an event(s) between 9 and 16 November uniquely affected the sample firms' share prices, but it is not possible to conclude with any standard level of statistical confidence that the entire sample experienced positive six-day CAR.

Given the Table 2 results and analysis, it is unsurprising that the three- and six-day CAR estimates are insignificant for ENGIE. Both CAR estimates are also statistically insignificant for Iberdrola, although Iberdrola's CAR was positive under both CAR windows. Like ENGIE, the insignificance of Iberdrola's CAR estimates may be the outcome of Iberdrola's large market cap.

Finally, Orsted's estimated six-day CAR is significant, but the estimate of its three-day CAR is insignificant. This suggests Orsted investors may have trusted early strike price information leaks and fully incorporated this information into their evaluations of Orsted during the first few days of the event window. The opposite may be true for EDP, as only EDP's three-day CAR estimate is statistically significant.

Like the AR results, caution should be taken in evaluating any of the above results as the t-test statistic may be biased upwards due to non-normality and event-induced volatility.

D. *Cumulative Average Abnormal Returns*

Finally, Table 5, below, presents three- and six-day CAAR estimates, as well as a t-test, Brown-Warner CDA test, Wilcoxon signed-rank test, and Corrado-Cowan cumulated rank test for the significance of each.

The three- and six-day CAAR estimates are positive and statistically significant across all four tests. This suggests that the statistical significance of the CAAR estimates is not the outcome of employing faulty test statistics. Instead, it is likely that the significant positive results can be interpreted as evidence in favour of the alternative hypothesis that eligible offshore wind developers experienced positive abnormal share returns around the time of the AR6 strike price announcement.

Specifically, the three-day CAAR statistic is significant across all tests to the 5% level. This is strong evidence that, on average, the sample firms' shares outperformed the clean energy market from 15 to 17 November. Magnitude-wise, it is estimated that the samples' share returns were 3.6% higher than expected, given the market index's returns.

The six-day CAAR statistic is significant across the t-test, Brown-Warner CDA test, and the Wilcoxon test to the 5% level, and it is significant to the 10% level under the Corrado-Cowan test. This is likewise strong evidence that AR6-eligible offshore wind developers' share prices deviated positively from other firms in the clean energy market leading up to, and immediately after, the British government's AR6 offshore wind strike price announcement. Specifically, the six-day CAAR estimate suggests that, on average, the samples' share returns were 5.6% higher from 10 to 17 November than expected, given the market index's returns.

Similarly to the AAR results, the positive CAAR results could be driven by outliers, and this is problematic if the outliers capture the impact of a confounding event(s). However, the CAR estimates in Table 4 present little evidence for this outcome: eleven of twelve estimates in Table 4 are positive, and there are no outliers in Table 4 when defining an outlier the same way as in Section VI.B. Instead, it is probable that the significant CAR and CAAR results in Tables 4 and 5 are the outcome of an event which uniquely affected the sample firms.

VII. **Discussion**

A. *Causal Inference*

The above results provide substantial evidence against the null hypothesis of no abnormal returns in favour of the alternative hypothesis that AR6-eligible offshore wind developers experienced significantly positive abnormal returns over the event window. With the exception of ENGIE, every firm's AR estimate was statistically significant on at least one of the event days, and most of the sample firms' estimated three- or six-day CAR was statistically significant. Statistically significant results were particularly notable when abnormal returns were aggregated across the sample and / or time, and the significance of the AAR and CAAR estimates was generally robust to the statistical test employed. This suggests that the significance of the AAR and CAAR estimates was not due to using mis-specified test statistics.

The next important step in drawing conclusions about the present-day importance of the CfD scheme is attributing the above results to the government's AR6 offshore wind strike price announcement. There are several reasons why the above results should reflect the impact of this announcement. First, the significant abnormal returns align temporally with leaked and announced information about the AR6 offshore wind strike price. Second, and referring back to the theoretical meaning of abnormal returns, the significant AR estimates suggest that an event affected the sample firms differently than other firms in the clean energy market. The AR6 strike price announcement fits this bill. Finally, the aforementioned Google search for confounding events which may explain the AR estimates was fruitless. This is all strong evidence in support of a causal link between the AR6 strike price announcement and the statistically significant positive abnormal returns estimated in this study.

B. *Implications for the CfD Scheme*

Ultimately, this paper aims to shed light on whether the CfD scheme is relevant to the value of a new British offshore wind farm today. If it is assumed that the sample firms' abnormal share returns and the AR6 strike price announcement are causally linked, and it is also assumed that the share prices of a company are a function of a firm's expected financial performance, then it is possible to use the above results to infer whether the CfD scheme is relevant to the value of British offshore wind developments today or is instead redundant given alternative revenue options (for instance, wholesale markets and CPPAs).

To begin by examining the latter possibility, it is important to remember that, due to the competitive nature of CfD auctions, developers should bid to receive an estimate of their LCOE in a CfD round regardless of whether the strike price is set above this level. In other words, the AR6 strike price announcement should not have represented a new opportunity to generate windfall profits but instead the return of a government-supported way to develop a financially viable offshore wind project. Thus, if the CfD scheme is now redundant and investors believed developers could sell power at rates above their LCOEs outside of the CfD scheme, then the AR6 strike price announcement should not have caused abnormal share returns; the price would have been irrelevant. This outcome is not supported by the event study results presented in this paper. Instead, the significantly positive abnormal returns estimated in this paper suggest that investors believed the CfD scheme increases the value of an offshore wind development today versus a world without the CfD programme.

There are several reasons why the CfD scheme may be valuable, or even necessary, for developing offshore wind projects today which support this conclusion. To begin with, if companies are unwilling to pay a premium for renewable energy and wholesale energy prices remain below developers' LCOE, the CfD scheme may be the only route to developing a bankable project. The AR6 strike price announcement would thus have marked the return of a programme critical to offshore wind developers' business operations.

The CfD scheme may also create value in the offshore wind industry today even if it is not strictly necessary for developing a financially viable offshore wind project. Regardless of whether projects are bankable, and would be developed, without the CfD scheme, the scheme may increase the value of a project through lowering its risk and thus its financing costs. To elaborate, because energy prices are fixed under CfD contracts, offshore wind developers' profits are much more predictable under CfD contracts than in wholesale markets, where prices can fluctuate massively. Thus, CfD contracts are often required by banks to provide financing or significantly improve banks' lending terms.[120]

Ultimately, identifying the specific reason(s) why the CfD scheme may increase the value of projects today is beyond the scope of this article. Nonetheless, this discussion should highlight that several explanations for why the CfD scheme creates value today are probable and support the conclusions reached in this article.

C. *Limitations*

While the above AR, CAR, AAR, and CAAR estimates suggest that the CfD scheme is relevant today, it is important to discuss some limitations of this event study's design which may impact the accuracy of the estimates and any subsequent conclusions.

To begin with, this study may suffer from low statistical power, primarily due to the small sample size. MacKinlay[121] simulated an event study to understand how the power of statistical tests varies with sample size. Specifically, he tested 4 levels of abnormal returns (0.005, 0.01, 0.015, and 0.02) and found that, with a sample size of 6 and a 5% significance level, a t-test only detected an actual abnormal return of 0.005 12% of the time. The detection rate improved to 23% for an abnormal return of 0.01, 45% for an abnormal return of 0.015, and 69% for an abnormal return of 0.020. While a power analysis is beyond the scope of this article, MacKinlay's findings suggest that a t-test may have failed to detect some sample firms' abnormal returns. If so, the above event study results are likely a conservative representation of the impact of the AR6 strike price announcement on AR6-eligible developers' share prices.

Nonetheless, some potential power issues should be partially alleviated by employing non-parametric tests. Corrado[122] tested the power of non-parametric tests in detecting abnormal returns and compared his results to t-test results. Ultimately, he found that the sign and rank tests are more powerful than their parametric counterparts. Most of the AAR and CAAR estimates observed in this study were either statistically significant under all the tests employed or none of the tests employed. Nonetheless, the estimated AAR on 17 November was statistically significant under the Wilcoxon test but not the t-test or Brown-Warner CDA test. This discrepancy may be the outcome of the different power of the parametric versus non-parametric tests and gives some credibility to the Wilcoxon test result over the t-test and Brown-Warner CDA test.

Partially discussed in the results section above, evaluating a small sample also increases the chance of introducing bias into the results.[123] With a sample size of only six, each firm's individual AR and CAR can heavily influence the AAR and CAAR, respectively. Thus, if a confounding event caused any one

[120] Beiter et al. (n 18) *supra*.

[121] MacKinlay (n 15) *supra*.

[122] Corrado (n 42) *supra*.

[123] Brooks (n 15) *supra*.

firm to experience positive abnormal returns, the AAR and CAAR metrics will partially reflect this event, not the AR6 strike price announcement. In a larger sample, it is more likely that the effect of confounding events will cancel out.

Additionally, the assumptions underlying statistical tests, such as normality and independence, are less likely to hold true for small samples, and violations of each can result in mis-specified test statistics.[124] Nonetheless, Brown and Warner[125] examined this issue and found that, while the distribution of abnormal returns deviates more from normal in event studies with small samples (n = 5), statistical tests were still properly specified in these studies, with the appropriate probability of a Type 1 error. Nonetheless, the higher potential for misspecification with small samples increases the importance of evaluating non-parametric tests as well as parametric ones.

VIII. **Conclusions and Further Research**

This paper conducted an event study to examine the impact of the UK's AR6 offshore wind strike price announcement on AR6-eligible offshore wind developers' share returns. The results suggest that the majority of examined developers experienced significantly positive abnormal returns in the period from the first AR6 offshore wind strike price information leak to the UK government's formal strike price announcement. The evidence in favour of the alternative hypothesis of significantly positive abnormal returns was particularly strong when abnormal returns were aggregated across firms and / or time. The small sample evaluated in this paper and the potentially low power of the test statistics employed provide reason for interpreting the results with caution. However, the lack of clear outliers in the sample and the robustness of the results across statistical tests alleviate much concern.

Assuming the UK government's AR6 strike price announcement and the abnormal returns estimated in this paper are causally linked, then the event study results suggest that the CfD scheme creates value in the British offshore wind industry today and thereby helps incentivise offshore wind development. This is an important finding given the UK's ambitious offshore wind goals. In 2022, the British government set a goal to deploy 50 GW of offshore wind by 2030.[126] Today, only 14 GW of offshore wind are operational in British waters, suggesting that meeting the government's goals will require a major acceleration of annual offshore wind development rates.[127] Thus, provided that the CfD scheme creates value in the British offshore wind industry today, it is this study's contention that the UK government should continue to support the CfD scheme to the fullest extent possible, at least until the UK government is on track to meet its offshore wind targets. Without an acceleration of offshore wind development rates, the UK government's credibility, UK energy security, and climate stability are at stake.

The significance of the finding that the CfD scheme creates value today may also extend beyond the UK. Both the International Renewable Energy Agency (IRENA) and the International Energy Agency (IEA) stand in consensus that keeping global warming within 1.5 degrees Celsius will require a tripling of global renewable energy capacity by 2030.[128] Many countries have set targets in line with this understanding: 19 countries have 2030 offshore wind targets, and global offshore wind capacity will triple if these are collectively achieved.[129] However, regional industry bodies have been vocal in expressing that, to meet these goals, governments will need to continue de-risking offshore wind projects through CfD schemes or similar revenue stabilisation methods.[130] Leading turbine manufacturers, such as Vestas, have

[124] Kothari and Warner (n 73) *supra*.
[125] Brown & Warner (n 43) *supra*.
[126] Walker, Alan, and Nikki Sutherland. *Floating Offshore Wind*. 15 Nov. 2023.
[127] The Crown Estate (n 3) *supra*.
[128] Altieri, Katye, et al. "Wind Targets are Achievable but Fall Short of a Tripling." *Ember*, 8 Aug. 2024.
[129] ibid.
[130] *Industry Position: Key Elements for Offshore Wind Auction Design*. Wind Europe, 2024.

also publicly advocated for the necessity of supportive government auction schemes.[131] The results in this study reinforce the message shared by stakeholders that CfD schemes are, and will remain, essential for driving utility-scale offshore wind deployment.

Further research could strengthen and expand this article's findings. First, the CfD strike price only partially determines the ability of a CfD allocation round to effectively support offshore wind: the overall budget for each round is also critical, as this determines the total amount of offshore wind that can be developed at a given strike price. The government announced its AR6 budget in March 2024.[132] There is 7,132 MW of offshore wind eligible for participation in AR6 (Table 1), but less than half of this could be supported at the AR6 strike price given the budget. If a market reaction to the budget announcement is detectable, this would support the findings of this article.

Future studies could also examine the impact of the AR6 strike price announcement on broader offshore wind supply chains. The supply chain involved in the British offshore wind industry is extensive, spanning turbine suppliers, offshore foundations manufacturers, cable manufacturers, installation and construction companies, and offshore vessel and port operators, among others. Understanding how far down the supply chain the impact of the AR6 strike price announcement pervaded should build further understanding of the CfD scheme's relevance.

Finally, and looking beyond the CfD scheme, a global analysis of the impact of renewable energy auction policy announcements on offshore wind developers' share prices could be conducted. This could elucidate the relevance of renewable energy auctions globally—a particularly interesting enquiry as offshore wind will likely reach cost parity with traditional generation sources at different times around the world.[133] A comparative analysis of the impact of announcements introducing different types of renewable energy support policies could also help elucidate whether the market reacts more favourably to a specific form of government support. This paper suggests that the CfD scheme adds value to British offshore wind developments today, but whether the CfD scheme is the optimal form of government support remains an open debate.

[131] "This Is Not a Wind Farm: A Guide for Turning Auctions into Action." Vestas, 2024.
[132] Coutinho (n 13) *supra*.

[133] Jansen, Malte, et al. "Offshore Wind Competitiveness in Mature Markets without Subsidy." *Nature Energy*, vol. 5, no. 8, 2020, pp. 614-22.

	Primary Industries	***Primary Stock Exchange (SE)***	***September 2023 Market Cap ($)***	***AR6-Eligible Capacity (MW)***
EDP Renewables*	Clean Energy	Euronext Lisbon	$17,335,000,000	110 MW
ENGIE*	Utilities, Clean Energy	Euronext Paris	$37,185,000,000	110 MW
Iberdrola*	Utilities, Clean Energy	Madrid SE	$69,886,000,000	2,304 MW
Orsted*	Clean Energy	Nasdaq Copenhagen	$22,936,000,000	3,450 MW
RWE*	Energy (Clean and Fossil)	Frankfurt SE	$27,641,000,000	346 MW
SSE*	Clean Energy	London SE	$21,289,000,000	245 MW
HexiconAB	Offshore Wind Technology	Nasdaq Stockholm	$21,645,000	10 MW
Tenaga Nasional Berhad (TNB)	Utilities	Kuala Lumpur SE	$12,314,000,000	29 MW
Siemens	Industrial Automation, Manufacturing	Frankfurt SE	$113,500,000,000	58 MW
SDIC Power Holdings	Energy Infrastructure	Shanghai SE	$12,017,000,000	135 MW
TotalEnergies	Energy, Petroleum	Euronext Paris	$157,900,000,000	335 MW

* Included in Final Sample

Table 1: Offshore Wind Developers

	EDP Renewables	***ENGIE***	***Iberdrola***	***Orsted***	***RWE***	***SSE***
10 Nov	0.000481383	0.010805598	0.014684149	0.100091887	0.009582001	0.025897678
t-test	s=0.0179 t=0.026854	s=0.01139 t=0.94853	s=0.01130 t=1.29993*	s=0.03750 t=2.66923**	s=0.01310 t=0.73132	s=0.01194 t=2.16978**
13 Nov	-0.01039685	-0.00559012	0.003145108	0.022073098	-0.00004272	0.011370312
t-test	s=0.01793 t=-0.57999	s=0.01139 t=-0.49071	s=0.01130 t=0.27842	s=0.03750 t=0.58864	s=0.01310 t=-0.00326	s=0.01194 t=0.95264
14 Nov	-0.01495971	-0.01310751	-0.01059662	-0.02198558	0.009728426	-0.01251336
t-test	s=0.01793 t=-0.83453	s=0.011392 t=-1.15059	s=0.01130 t=-0.93806	s=0.03750 t=-0.58631	s=0.01310 t=0.742492	s=0.01194 t=-1.04841
15 Nov	0.043001557	-0.00418071	0.0080456	0.046523357	0.017057776	0.023663149
t-test	s=0.01793 t=2.39886**	s=0.011392 t=-0.36699	s=0.01130 t=0.71224	s=0.03750 t=1.24068	s=0.01310 t=1.30188*	s=0.01194 t=1.98257**
16 Nov	-0.00185695	0.003096552	-0.0041242	-0.03018878	0.01344937	0.034025214
t-test	s=0.01793 t=-0.10359	s=0.011392 t=0.271818	s=0.01130 t= -0.3651	s=0.03750 t= -0.80507	s=0.01310 t=1.02648	s=0.01194 t=2.85073**
17 Nov	0.016620367	0.008699276	0.018563869	0.024811172	0.005658245	-0.00460299
t-test	s=0.01793 t=0.92717	s=0.011392 t=0.76363	s=0.01130 t=1.64338*	s=0.03750 t=0.66166	s=0.01310 t=0.43185	s=0.01194 t=-0.38565

**.05; *.10

Table 2: Abnormal Returns with T-Test

	AAR	***t-test***	***Brown-Warner***	***Wilcoxon***	***Corrado***
10 Nov	0.02692378	s=0.00799 t=3.36915**	s=0.01249 t=2.15613**	W=0**	$\bar{k}_t$=108.33 z=1.60183*
13 Nov	0.00342647	s=0.00799 t=0.42878	s=0.01249 t=0.27440	W=8	$\bar{k}_t$ =69.5 z=0.18272
14 Nov	-0.0105724	s=0.00799 t=-1.32300	s=0.01249 t=-0.8467	W=20	$\bar{k}_t$ =33.33 s=27.36911 z=-1.13894
15 Nov	0.02235179	s=0.00799 t=2.79702**	s=0.01249 t=1.78999**	W=1**	$\bar{k}_t$ =105.33 z=1.49220*
16 Nov	0.0024002	s=0.00799 t=0.30035	s=0.01249 t=0.19221	W=9	$\bar{k}_t$ =72.5 z=0.29235
17 Nov	0.01162499	s=0.00799 t=1.45471	s=0.01249 t=0.93096	W=1**	$\bar{k}_t$ =94.83 z=1.10849

**.05; *.10

Table 3: Average Abnormal Returns with T-Test, Brown-Warner CDA Test, Wilcoxon Signed-Rank Test, and Corrado Rank Test

	EDP Renewables	***ENGIE***	***Iberdrola***	***Orsted***	***RWE***	***SSE***
15-17 Nov	0.05776497	0.007615118	0.022485264	0.041145752	0.03616539	0.053085372
t-test	s=0.03105 t=1.86048**	s=0.01973 t=0.38594	s=0.01957 t=1.14923	s=0.06495 t=0.63351	s=0.02269 t=1.59361*	s=0.02067 t=2.56785**
10-17 Nov	0.032889794	- 0.00027692	0.029717901	0.141325161	0.055433102	0.077839999
t-test	s=0.04391 t=0.74904	s=0.02791 t=-0.00992	s=0.02767 t=1.07402	s=0.09185 t=1.53862*	s=0.03209 t=1.72720**	s=0.02924 t=2.66246**

**.05; *.10

Table 4: Cumulative Abnormal Returns with T-Test

	CAAR	***t-test***	***Brown-Warner***	***Wilcoxon***	***Corrado-Cowan***
15 - 17 Nov	0.03637698	s=0.01384 t=2.62815**	s=0.02163 t=1.68192**	W=0**	$\bar{k}_D$ =90.89 z=1.67002**
10 - 17 Nov	0.05615484	s=0.01957 t=2.86877**	s=0.03059 t=1.83590**	W=1**	$\bar{k}_D$ =80.64 z=1.44440*

**.05; *.10

Table 5: Cumulative Average Abnormal Returns with T-Test, Brown-Warner CDA Test, Wilcoxon Signed-Rank Test, and Corrado-Cowan Cumulated Rank Test