THE CAUSAL IMPACT OF RUSSIA-UKRAINE WAR OF OIL PRICES AND CLEAN ENERGYMARKETS: PRE-POST PERIOD ANALYSIS

Abstract

This chapter aims to analysis the pre-post period causal impact of Russia-Ukraine war of oil and clean energy markets,usingcausal impact inference model,theenergy market proxied by brent oil,solar, wind, biofuels and geothermalenergymarket, in the period 2013-2023.The findings indicate that Russia-Ukraine war had an average significant positive impact of 0.51% on oil prices and clean energy markets, where increase of the energy market remains inside the 95% confidence interval during the war. These findings provideimportant insights for investors, policy makers and other energy markets participants.

Keywords: Oil price, clean energy,energy market,Russia-Ukraine war, causal impact.

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I. INTRODUCTION

The world's energy structure is at a crossroads, making it more crucial than ever to address climate change, provide sustainable energy security, and meet the increasing need for energy supplies without relying on fossil fuels, which release a lot of carbon dioxide when burned (Qadir et al.,2021). In recent decades, nations all around the world start taking serious steps to shift in low carbon alternativeenergies through enormous investment push in the clean energy markets (CEM), with anticipation of two thirds of all energy investments worldwide will be in renewable energy sources alone by 2040 (Yahya et al., 2021).In 2019, CEM witnessed investments of 363.3 billion USD comparing to 120.1 billion USD in 2009, with average growth of 5% per year in 2009-2019 period, surpassing 1.7% annualgrowthof fossil fuelsmarket in the same period, especially after 2015 Paris Climate Agreement (Fahmy, 2022; Yousaf et al., 2022).

The massive investments in CEM led to significant increase inrenewable energy consumption, with 758,626 megawatts (MW) power generated in 2019, mainly by solar and wind energy(Sayigh, 2020). Besides environmental advantages of the rising in renewable energy consumption, there are also economic advantages,renewable energy consumption has significant positive impact on economic growth of many countries worldwide, as already proven by many studies (e.g., Pao and Fu, 2013; Rahman and Velayutham, 2020; Destek and Sinha, 2020).

However, the conventional energies continue to be the dominant sources for basic energy consumption, despite the renewable energy tremendous production rise. In addition,the development and sustainability of the clean energy market cannot be separated from fossil fuels energy markets since it’s seen as an alternative for conventional energies (Xia et al., 2019).

Moreover, the rise of fossil fuels energies prices has a significant negative impact on stock prices especially oil prices (OP). Nevertheless, such impact might vary per industry given that there are a number of industries that can potentially benefit from increasing OP.CEM can be one of these exceptions (Dutta, 2017).Although many studies have investigated the linkage between OP and CEM, (e.g., Henriques and Sadorsky, 2008;Reboredo, 2015; Kocaarslan and Soytas, 2019; Xia et al., 2019) they found that rising of OP hasa significant impact on clean energies. In the other hand,some studies provide evidence of strong connectedness among OP and clean energy market indices(e.g., Naeem et al., 2020; Nasreen et al., 2020; Umar et al., 2022; Farid et al., 2023).Meanwhile, Pham (2019) study showed that not all CEMrespond equally to OP,where biofuel has stronger correlation withOP comparing to solar, wind and geothermal energy market.

By the beginning of 2022, the world faced massive economical, geopolitical, and humanitarian crisis due to Russian invasion of Ukraine (Ozili and Arun, 2023). Since Russia and Ukraine areconsidered as major commodities exporters; the agricultural, metal, and energy market’s volatility is greatly increased by the escalation of the Russia-Ukraine conflict(Fang and Shao, 2022). Thus, how does Russia-Ukraine war impact oil prices and clean energy markets?

To answer the previous question, this study aims to examines the war's causal impact on oil prices and four clean energy market sectors (solar, wind, biofuels and Geothermal) using pre-post period analysis.

This study is organized with the following structures: in the section 2 we cover the related literature on the topic. In section 3 we describe methodology employed in the study and dataset. In section 4 we illustrate empirical results and related discussion. The final section concludes the study

II. LITERATURE REVIEW

1. **Overview of oil prices and clean energy markets:** The literature on energy markets provides a comprehensive overview of impact of OP movements on different financial markets (e.g., Jones and Kaul, 1996; Kilianand Park, 2009; Kang et al., 2015; Kocaarslan et al., 2017). Furthermore, the study of Henriques and Sadorsky (2008) was one of first researches that provide evidence of the relationship between OPand CEM, they examine the causal relationship between oil, interest rates, technology and clean energy stocks, using vector autoregression model andGranger causality test. The resultsshow thatOP, interest ratesand technology stock (TS)movements have a significantcausality with theclean energy stock movements,as well as, TSshock has a larger impact onclean energy stocks than OP shock. Following the same method,Kumar et al. (2012) test if the rising inconventional energies prices will lead to more investment in CEM, using three clean energy indices, theyfound asignificant impact of OP and TSonCEM,while, carbon prices doesn'thave any impacton the market.Similarly, Managi and Okimoto (2013) use Markov-switching vector autoregressive models.They findthat there was a major structural change in late 2007,which was a period of sharply rising OP, in addition to significant positive impact on CEMthat follows structure breaks.Additionallyit appears that the market's response to the prices of renewable energy and TS is similar.Reboredo (2015) used in his study copulas model to determine the dependence structure and to estimate the conditional value-at-risk as a measure of systemic risk among OPand CEM. The results reveal that OP and CEM are significantly time-varying average and symmetric tail dependent, with 30% contribution of oil price dynamics to clean energy market 'sdownside and upside risk.

   Bondia et al (2016) use the co-integration test to investigate the multivariate structure of the long-term interaction among OP and CEM, the findings show two endogenous structural breaks co-integrations among OP and CEM. although clean energy market is caused by OP, technology stock prices, and interest rates in the short run,there is no long run. causal relationship running towardsCEM. Reboredo et al. (2017) studied co-movement and causality between oil and clean energy indices, using wavelet coherence analysis and linear and non-linear wavelet-based Granger causality. Theyfind that the co-movement between oil and clean energy indices was weak in the short-term, nevertheless gradually became stronger in the long-term. While causality tests show evidence in support of both unidirectional and bidirectional linear causality at lower frequencies and against linear causality at higher frequencies, moreover, there is a causal relationship between oil prices and clean energy indices, as well as, over a range of time periods, there is consistent proof of non-linear causality between oil prices and clean energy indices. The study of Ferrer et al. (2018) analyzed the time and frequency dynamics of relationships between the American CEM, OP and a variety of important financial variables.The findings indicate thatthe majority of these relationships are made in the very short time, while the long-term playing just a modest impact. OP do not seem to be a significant factor onthe performanceof CEM for both short-term and the long-term. Meanwhile, there is a strong bilateral relationship between CEM and technology stock prices, particularly in the short term.Maghyereh et al. (2019) study the co-movement between OP and clean energy indices using wavelet-based DCC-GARCH approach. They discover a major risk and return transfers from technology and OP to clean energy indices, where longer time horizons are proven to have stronger transmissions, which underline how crucial it is for the long-term expansion of renewable energy resulting predictability and stability in the OP and TS.Kocaarslan and Soytas (2019) study dynamic conditional correlations (DCCs) between OP and TS and CEM, also how variations in the value of the reserve currency (the US dollar) affect DCCs using autoregressive distributed lag. The results reveal how the US dollar's rise has been the primary factor in boosting DCCs.Using Multivariate Generalised Auto-Regressive Conditional Heteroscedasticity models and wavelet coherency analysis.,Nasreen et al. (2020) find a minor correlation between OPand CEM, as well as, all series move in cycles, where technology companies' stocks lead OP and CEM. Moreover. technology companies'stocksare responsible for transmitting volatility across all frequencies and time periods to the other markets.Attarzadeh and Balcilar (2022) analyze the volatility spillover of sectors of stock markets. The study shows that the oil market is a net recipient of volatility, with spillover effects being larger during periods of severe positive and negative shock than during those of medium shock, and increasing during crisis periods.Bouoiyour et al (2023) examines the relationship between crude oil and different sectors of clean energy market by applying wavelet coherency and wavelet-based Granger causality. The findings indicate that there is a non-linear and somewhat multidimensional connection between crude oil and clean energy indices. Additionally, the relationship between wind and crude oil is less intense comparing to geothermal and biofuel energies. where the COVID-19 pandemic appears to have increased this relationship, which varies across scales and is strong over the long term but weak over the short term. Furthermore, the wavelet-based Granger causality test confirmsthese findings.

2. **Geopolitics risks and energy market:** Numerous studies have looked into the relationship between global uncertainty and theenergy market, where some show that large shocks in oil prices typically precede worldwide recessions (e.g., Park and Ratti, 2008;Kilian and Park, 2009; Broadstock et al., 2012; Oliyide et al., 2021). Where others proved the significant impact of geopolitical risks (GPR) on energy market (e.g., Qin et al., 2020; Jin et al., 2023; Chishti et al., 2023).Furthermore,the study of Su et al. (2021)examines the relationship between global GPR and renewable energy using vector auto-regression (VAR) model and rolling window causality test. The findings demonstrate a two-way causality between geopolitical risks and renewable energy which is dispersed across different sub-samples. On the other hand, geopolitical concerns are significantly impacted by renewable energy, indicating that there is a reciprocal relationship between both of them.Sweidan (2021) investigates whether the GPR leads to greener production and ecological sustainability or not, through autoregressive distributed lag model. He discovers that geopolitical risk has a significant positive impact on the adoption of renewable energy in the USA. Yang et al. (2021) investigates the risk spillovers from GPR to five clean energy markets. The findings show a significant risks spillover from GPR to CEM, while there is no discernible pattern to the risk spillovers' behavior. Dutta

and Dutta (2022) use a two-state Markov regime switching framework to examine how GPR affects the cost of renewable energy assets.Theresults imply that consumers of crude oil, who are more susceptible to GPR, frequently consider renewable energy as a substitute for traditional energy sources when the risk factor increases. As a result, the share prices of renewable energy companies increase, further reducing volatility.Flouros et al. (2022) used quantitative approach to examines how clean energy could be impacted by GPR. The study suggests that geopolitical risk has a significant short-term and long-term impact on boosting the clean energy investments. Ghosh (2022) analyzes the Covid-19 pandemi's effect on CEM using quantile regression methods. The findings show that the Stocks of clean energy firms are effective diversifiers, in addition, the pandemic has a significant negative effect on the volatility index among quantiles. Lin et al. (2022) examinesifsustainable finance,geopolitical risk and economic growth increase clean energy investments in China. They reveal that clean energy investmentsnegatively impacted byGPR, meanwhile, sustainable finance and economic growth have a positive effect on it. Zhao et al. (2023) study the impact of GPR on clean energy demand in 20 member countries in Economic Co-operation and Development, as well as, the impact of CO2 emissions, economic globalization, natural resources rents and GDP per capita growth through panel system GMM analysis. GPR are proven to decrease the demand for clean energydemand and endanger climate change mitigation strategies. Moreover, CO2 emissionsand natural resources rents have a significant negative impact on clean energy demand, while economic globalization and GDP per capita growth have a positive impact.Zhang et Al. (2023) examine the relationship among energy transition, GPR and natural resources extraction. they found that the GPR have a significant negative impact on energy transition, additionally, coal and forest rents have a negative impact on the energy transition, in other hand, the mineral and oil rents have a positive impact on it.

Furthermore, Russia-Ukraine war (RUW)is considered as the recent globalgeopolitical risk which led to massive disrupting on the global supply chains, rising the commodity prices and financial sanctions (Orhan 2022). Moreover, the war significantly impacts energy prices (Inacio et al., 2023; Chen et al., 2023). The study of Aslam et al. (2023) investigates how the RUW has affected the performance of the energy markets using multifractal detrended fluctuation analysis. Results show significant changes in multifractal strength as caused by the conflict, confirming the existence of multifractality in energy markets and showing a drop in intraday efficiency for oil markets.Nerlinger and Utz (2022) study the impact of the RUW on thestock prices of energy firms. They discover that the stock prices of energy firm's cumulative average abnormal returns were positive during the time of the invasion, with energy companies outperforming the stock market. North American businesses outperform those in Europe and Asia more often. Liao (2023) analyzes how the European clean energy market responds to RUW. The results reveal thatEuropean companies that create or buy more renewable energy ex-ante have smaller falling in stock returns during the war. Mohammed et al. (2023) examines the reaction of different CEM to the RUW using (VAR) analysis. They reveal that whereas traditional energy markets were severely impacted in the post-war period, CEM had positive and large accumulated irregularities. Additionally, there is a greater pairwise return connectivity following the announcement event compared to both before and throughout the RUW. Where The markets for full cells and geothermal energy are the most reliable net information transmitters to CEM's sectors.Karkowska and Urjasz (2023) Study on how the RUWimpacted the volatilityspillovers of the clean and dirty energy markets on global stock indices. they founnd that the cost of hedging in CEM is greater compared to non-renewable energy indices, although clean energy indices usually exhibit lower risk than global stock markets.

III. METHODOLOGY

1. **Data:** This study used daily closing prices data of brent oil futures (OIL), four clean energy market indexes:NASDAQ OMX Solar Index (SLR), NASDAQ OMX Wind Index (WND), NASDAQ OMX Biofuels Index (BFL) and NASDAQ OMX Geothermal Index (GTM). All the data was collected frominvesting.com website, in the period from02 January 2013to15July 2023, as displayed in Figure 01.

Solar energy index

Wind energy index

Biofuels energy index

Geothermal energy index

Brent oil futures

Figure 1: Evolution of energy market's prices

2. **Empirical method:** The study applies causal impact inference model that identify the statistical significance of the interventions of RUW on OPand CEM. This model enables estimation of the pointwise discrepancy between the predicted and actual values, as well as,analyze the differences between a specific shock's before and after stages, as other alternative models such as difference-indifference (DID) and impulse-response function models.However,interventions of the Russia-Ukraine conflict depended on complicated responses resulting from a variety of factors, instead of consistent level shifts over the wholeperiod before and after the outbreak of the invasion. Unlikethe traditional models.Causal impact inference mode allowed to estimate the pointwise daily differenceoil prices and clean energy market indices during the war(Sung, 2023).

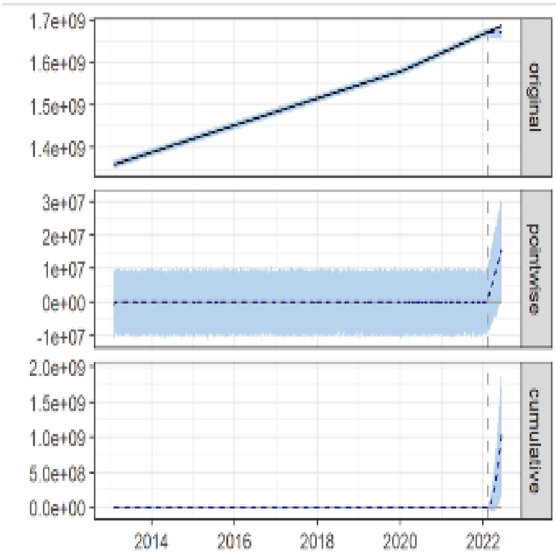
IV. RESULTS AND DISCUSSION

Table.1 presents the results of the customized causal impact of RUW on OP and clean energy market indices. The actual number of OP and CEM was, on average, approximately 1.6B. Without the intervention of the war, the average number of all energy market was expected to be 1.67B. The total cumulative ridership during the war was $2e^{11}$, same as how would have been predicted. As a result, the average daily the energy market prices increased by $8.5e^{06}$ due to the appearance of the war, and its cumulative total number is expected to increase by $1.0e^{9}$. These results indicate RUW had an average significant positive impact of 0.51% on the energy markets prices. The probability of obtainingthis impact by chance of oil prices, solar energy, wind energy,biofuels energy and geothermal energy market was 0.0062, 0.00834, 0.00626, 0.00938 and 0.00938 respectively.

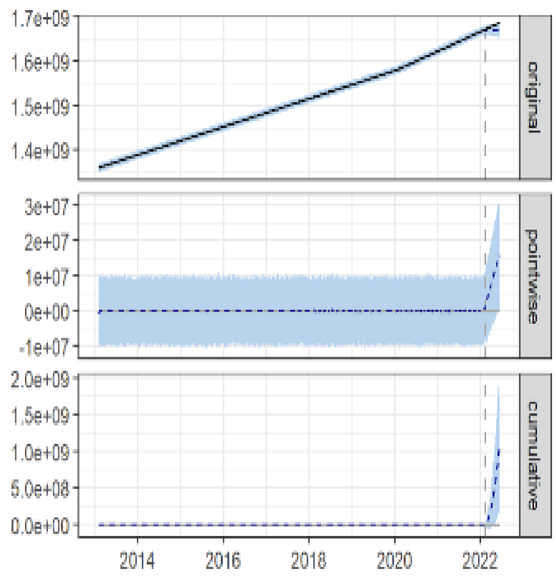
Figure. 1 summarizes the distribution of daily observations (black) and daily predicted values (blue). The pointwise graph shows the daily pointwise difference between these values, and the light blue section shows the 95% confidence interval. Moreover, it reveals that the Russia-Ukraine war's impacts on energy market prices was significant due the increase that remains inside the 95% confidence interval.

Table1: Posterior inference of the causal impact of Russia-Ukraine war

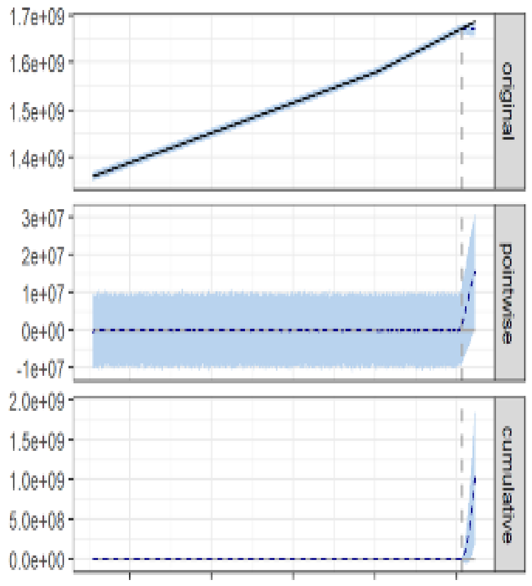
	Average					Cumulative				
	OIL	**SLR**	**WND**	**BFL**	**GTM**	**OIL**	**SLR**	**WND**	**BFL**	**GTM**
Actual	$1.7e^{09}$	$1.7e^{09}$	$1.7e^{09}$	$1.7e^{09}$	$1.7e^{09}$	$2.0e^{11}$	$2.0e^{11}$	$2.0e^{11}$	$2.0e^{11}$	$2.0e^{11}$
Prediction (std)	$1.7e^{09}$ ($3.8e^{06}$)	$1.7e^{09}$ ($3.8e^{06}$)	$1.7e^{09}$ ($3.8e^{06}$)	$1.7e^{09}$ ($3.8e^{06}$)	$1.7e^{09}$ ($3.8e^{06}$)	$2.0e^{11}$ ($4.6e^{08}$)	$2.0e^{11}$ ($4.6e^{08}$)	$2.0e^{11}$ ($4.6e^{08}$)	$2.0e^{11}$ ($4.6e^{08}$)	$2.0e^{11}$ ($4.6e^{08}$)
95% CI	[$1.7e^{09}$, $1.7e^{09}$]	[$1.7e^{09}$, $1.7e^{09}$]	[$1.7e^{09}$, $1.7e^{09}$]	[$1.7e^{09}$, $1.7e^{09}$]	[$1.7e^{09}$, $1.7e^{09}$]	[$2.0e^{11}$, $2.0e^{11}$]	[$2.0e^{11}$, $2.0e^{11}$]	[$2.0e^{11}$, $2.0e^{11}$]	[$2.0e^{11}$, $2.0e^{11}$]	[$2.0e^{11}$, $2.0e^{11}$]
Absolute effect (std)	$8.5e^{06}$ ($3.8e^{06}$)	$8.5e^{06}$ ($3.8e^{06}$)	$8.5e^{06}$ ($3.8e^{06}$)	$8.5e^{06}$ ($3.8e^{06}$)	$8.5e^{06}$ ($3.8e^{06}$)	$1.0e^{09}$ ($4.6e^{08}$)	$1.0e^{09}$ ($4.6e^{08}$)	$1.0e^{09}$ ($4.6e^{08}$)	$1.0e^{09}$ ($4.6e^{08}$)	$1.0e^{09}$ ($4.6e^{08}$)
95% CI	[$1.7e^{06}$, $1.6e^{07}$]	[$1.7e^{06}$, $1.6e^{07}$]	[$1.7e^{06}$, $1.6e^{07}$]	[$1.7e^{06}$, $1.6e^{07}$]	[$1.7e^{06}$, $1.6e^{07}$]	[$2.1e^{08}$, $2.0e^{09}$]	[$2.1e^{08}$, $2.0e^{09}$]	[$2.1e^{08}$, $2.0e^{09}$]	[$2.1e^{08}$, $2.0e^{09}$]	[$2.1e^{08}$, $2.0e^{09}$]
Relative effect (std)	0.51% (0.23%)	0.51% (0.23%)	0.51% (0.23%)	0.51% (0.23%)	0.51% (0.23%)	0.51% (0.23%)	0.51% (0.23%)	0.51% (0.23%)	0.51% (0.23%)	0.51% (0.23%)
95% CI	[0.1%, 0.96%]	[0.082%, 0.97%]	[0.088%, 0.97%]	[0.073%, 0.96%]	[0.086%, 0.96%]	[0.1%, 0.96%]	[0.082%, 0.97%]	[0.088%, 0.97%]	[0.073%, 0.96%]	[0.086%, 0.96%]
Posterior tail-area prob	0.00626	0.00834	0.00626	0.00938	0.00938					
Posterior prob	99.37%	99.16%	99.37%	99.06%	99.06%					



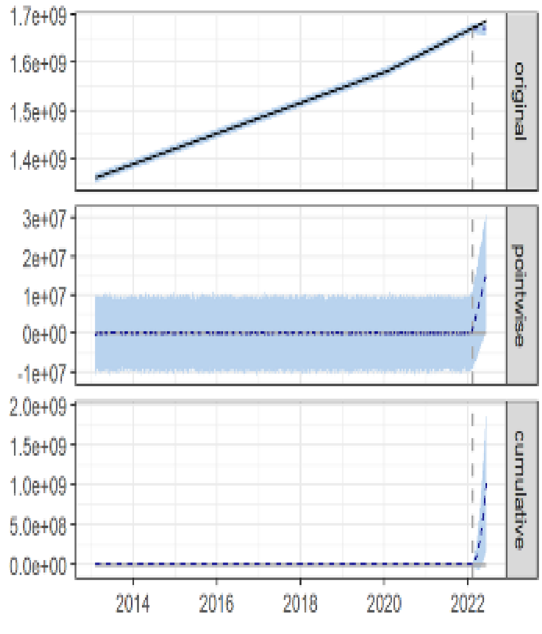
Solar energy index



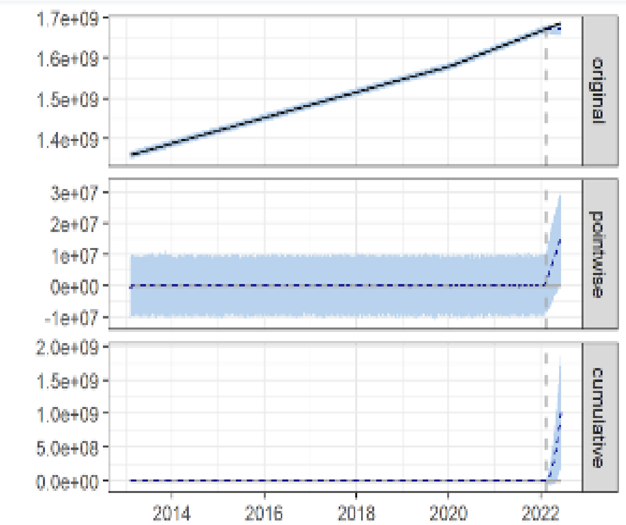
Wind energy index



Biofuels energy index



Geothermal energy index



Brent oil futures

Figure 2: Pointwise prediction and difference in daily ridership of.oil prices and clean energy market indices

V. CONCLUSIONS

In order to understand the causal impact of Russia-Ukraine war on oil prices and clean energy markets, this study usepre-post period analysis by applying causal impact inference modelto determine the effect of the war'sinterventions on oil prices and four clean energy market sectors (solar, wind, biofuels and Geothermal) for the time period 2013-2023.

The results show that Russia-Ukraine war had an average significant positive impact of 0.51% on oil prices and clean energy markets, where the increase of the energy market remains inside the 95% confidence interval during the war.

These findings provide insights for policymakers to handle global geopolitical risk's impact on energy markets and the issues ofenergy transition, as well as, giving investors a better knowledge of the energy markets.

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