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RESEARCH ARTICLE

Green Sukuk Investment and Renewable Energy Consumption for Sustainable Development Growth

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ABSTRACT

This study investigates the pivotal role of green sukuk investment in promoting renewable energy (RE) consumption as a pathway to achieving sustainable development goals. By analyzing data from 2000 to 2023, the paper explores the interplay between sukuk issuance and key macroeconomic variables, including market risks, economic stability, and financial health, with a specific focus on RE consumption. The findings highlight the potential of green sukuk as an innovative financing instrument that aligns economic growth with environmental sustainability. It emphasizes the critical need for robust regulatory frameworks, private-sector engagement, and technological advancements to scale renewable energy adoption. Through theoretical grounding in the Ecological Modernization Theory and Social Responsibility Investment Theory, the paper underscores the significance of balancing profitability and ecological preservation with a significant association findings. Practical implications suggest that green sukuk can bridge the financing gap for RE projects, mitigate climate risks, and foster economic resilience. These insights contribute to the broader discourse on sustainable finance, offering actionable recommendations for policymakers, investors, and issuers in the Islamic finance ecosystem.

INTRODUCTION

Renewable Energy (RE) is one of the national ambition to cut the resource (i.e., gas and coal) that may harm the nature because take long time to depletion and release CO2 emission (Salam & Khan, 2018). According to Malaysia Energy Statistics Handbook (MEIH), Malaysia heavily relies on coal (43.4%) and natural gas (39.1%) in generating electricity. Both sources are non-renewable, which has limited source and the cost is expensive due to scarce. In addition, International Energy Agency (IEA) stressed up that the advantage of non-renewable required long period to replenish, thus, it dangers to human health and environment impact. In 2018, government have revised the sustainability target to achieve 20% of mix RE consumption, for instance; solar, biomass, wind, biogas and hydro in 2030. To achieve this future target, sukuk (Islamic bonds) financing become more popular among other debt instrument in supporting our government agendas in sustainable development growth initiatives via green technology masterplan Malaysia (2017-2030). In addition, Malaysia is not only pioneer in sukuk market establishment (since 1990) but also market leader in sukuk issuance denominations in Malaysian Ringgit (MYR).

According to World Bank, RE is referred as clean and sustainability energy. The source of RE derived from abundant of natural resources capable to replenish constantly, such that waves, sun, plants, and wind) (Heim & Knera, 2020; Vaka et al., 2020). Also, the development of technology innovation have expand the dimension of energy generation parallel with the “Green Finance” (Bull, 2001). Moving forward, the source of energy generation can be diversified, since the country have RE as an option

to shift the traditional coal and natural gas towards more green and sustainability manners (Morrison et al., 2017).

Green finance has emerged as a pivotal mechanism in addressing environmental challenges while promoting sustainable economic development. It encompasses a range of financial products and services aimed at directing capital towards projects via sukuk investment that foster environmental sustainability, including RE, energy efficiency, and low-carbon initiatives. The intersection of green finance and economic growth has garnered significant attention in recent research. Thus, sukuk investment is increasingly recognized as a catalyst for sustainable economic growth, enabling investments in environmentally friendly projects that contribute to job creation and technological innovation. Chengbo, Lei, and Mansoor (2023) emphasize that substantial investments in green initiatives are essential for achieving carbon neutrality and promoting sustainable economic growth. The authors also emphasize that robust regulatory frameworks are necessary to enhance the availability of green finance and facilitate the integration of carbon-neutral practices. Additionally, Liu and Xia (2022) highlight that green finance serves as a form of corporate social responsibility (CSR), where financial institutions engage in environmentally beneficial activities that contribute to overall economic development. The positive correlation between green finance and economic development has been evidenced in various studies, particularly in ASEAN countries, where green investments especially sukuk have been linked to enhanced national economic growth (Hu & Wang, 2022).

In Malaysia, Suruhanjaya Tenaga Malaysia (Energy Commission) have concerned in addressing the Energy Trilemma (Security, Affordability, and Sustainability) for the economic and social needs, while mitigating the environment harms. One of the agendas is enhancing RE adoption, as to ensure clean energy will be consumed. To respect with the government concern, government have encouraged more private sector to generate clean energy. The involvement of the private investor eventually will assist the government ambition in achieving 20% of mix renewable energy in 2025. Vakulchuk et al., (2020) discuss that, in order to scale up the investment in RE, the government must enhance the awareness for government to measure the performance in green energy. Adding to that, the investor would wish to have a clear information on the return will gain in term of financial and non-financial profit. According to Kazlova and Collan (2020), the more transparency of information can lead to an increase confidence level in investing and become more attractive investment in RE via sukuk investment.

Furthermore, sustainability is a one if not the only core principle of green finance, which aims to balance economic development with ecological preservation. Pearce and Turner (1989) first introduced the concept of a green economy, advocating for an economic model that prioritizes environmental health alongside societal well-being. Green finance facilitates sustainability by funding projects that promote RE, energy efficiency and resource conservation. Cilliers, Diemont, Stobbelaar, and Timmermans (2010) suggest that green credit instruments can support urban planning efforts, enhancing environmental value while fostering sustainable economic development. By financing energy-efficient technologies and practices, green finance using sukuk investment not only reduces operational costs for businesses but also contributes to broader sustainability goals.

Thus, green finance plays an instrumental role in this transition by providing the necessary funding for projects aimed at RE consumption. Ali, Li, Zhang, and Chisti (2024) argue that green finance promotes technological advancements and energy transitions that facilitate reductions in carbon intensity across economies. The implementation of policies supporting green finance is essential for achieving zero carbon targets. Governments are increasingly utilizing instruments such as green sukuk and sustainable investment frameworks to incentive private sector participation in RE projects for low-carbon initiatives (Mohsin, Iqbal and Iram, 2023). These measures not only align financial incentives with environmental outcomes but also enhance the overall effectiveness of RE consumption.

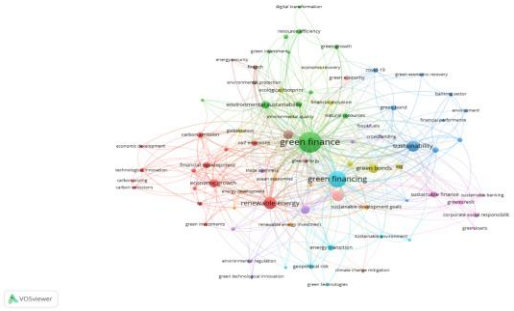
Next, the relationship between size of sukuk green finance and issuer firm performance especially sukuk tenure or years to maturity as well as other factors is increasingly recognized as an important area of study. Research indicates that firms engaging in green financing activities often experience improved financial performance due to enhanced market reputation and investor confidence. For instance, studies have shown that companies adopting environmentally sustainable practices tend to attract more investors, leading to increased capital inflow (Zhang & Mei, 2022). This shift underscores the importance of aligning firm strategies with sustainability objectives to enhance long-term performance depending on economic stability and financial health of the issuer country. Therefore, sukuk investment in green RE projects could represents a transformation approach to financing that aligns economic development with environmental sustainability. As the global economy continues to confront pressing environmental challenges, advancing green sukuk finance will be crucial for achieving sustainable development goals and fostering a resilient economy capable of mitigating climate change.

The reminder of this paper will be discuss the past studies, research methodology applied, findings discussions and concluding remark.

META-LITERATURE REVIEW DISCUSSIONS

A Connectedness of Sukuk in Green Finance

The provided search results include a dataset from Scopus focusing on green finance and its relationship with various economic indicators. The dataset contains a range of keywords related to environmental sustainability, economic growth, and green technologies. The dataset highlights key terms such as "green finance," "sustainable development," "renewable energy investment," and "green loans." These keywords indicate a strong emphasis on financing mechanisms that support environmentally friendly projects. The presence of terms like "economic growth" and "economic development" suggests an exploration of how green finance contributes to broader economic outcomes. This indicates a potential link between sustainable financial practices and regional or national economic performance. Meanwhile, keywords such as "energy efficiency," "zero carbon emissions," and "climate change mitigation" reflect the dataset's focus on achieving specific environmental goals through financial means. This aligns with global efforts to address climate change and promote sustainable practices. Terms like "green technological innovation" and "digital transformation" indicate that the dataset may explore how advancements in technology can enhance the effectiveness of green finance initiatives. The inclusion of keywords such as "geopolitical risk" and "environmental regulation" suggests that the dataset may also address the challenges facing green finance, including regulatory hurdles and external risks that could impact investment decisions. Overall, the dataset provides a comprehensive overview of the intersection between green finance and various economic indicators. It underscores the importance of sustainable financial practices in fostering economic growth while addressing environmental challenges. The insights derived from this analysis can inform policymakers, investors, and researchers about the critical role of green finance in promoting a sustainable future.



The concept of green investment also is referred to the sustainable investment that care about environment, governance responsible investment, socially responsible investments (Junkus & Berry,

2015; Darghouth et al., 2011). It must include every parties to develop a strong investment structure. Chiltimiea et al., (2021) criticized that the impact over investment made by government resulting demotivation of the investment participation from private parties. Consequently, the supply change will not make any improvement without the private investment. Similarly, Magnoni and Bassi (2009) study the successful story in remote location Denmark is due to the mutual relationship between policy maker and public to develop a strategy on renewable energy to develop a clear understanding. Hence, the purpose of the green financing is to encourage resource conservation and enhance the social responsibility.

Green Sukuk Investment in Renewable Energy (RE)

It is the time to save planet more and shift to renewable energy bu using green sukuk investment. Wahab et al., (2019) and Mohd Saad et.al (2023) state that sending money for RE investment is part of example of sukuk responsible investment, while people desire to balance between profit return and environment protection. According to Pienitz (2020), the sustainable issues (i.e emission carbon) have pushed the investor to be responsible and develop technology green financing. Tran et al., (2021) believed that the green investment made to improve the environment while reduce air pollution and greenhouse emission without affecting the consumption and production. According to Kathirgugan (2021), energy production have led to around 70% of greenhouse emission in 2005, and the situation become worst as it climbed up to 80% in 2014, indicating the depending to coal source. According to World Health Organization (WHO), the air pollution have danger to human life and impact to elder and children health. Thus, it will impact to the cost of medical cares, insurance bills and productivity in long term. The essential factors tend to sukuk responsible investment decision in RE are important for green environment and sustainable development growth in Malaysia.

Several studies on green investment in renewable energy have been conducted in literature. Green investment have widely use as reference for definition (Chiltimiea et al 2021; He et al., 2019; Magnoni & Bassi, 2009) for its benefit, identifying the challenges (Hesary 2019) and proposing a few of initiatives to encourage more green investment (Tran et al., 2021; Hesary & Yoshino, 2019; Sontic et al., 2018). He et al., (2019), point out the green investment as the financial form that properly allocate for natural resource and manage accordingly the capital flow for low pollution, high energy efficiency and environment friendly. Adding to, the financial resource are consists of green financing, green sukuk, green bond, green insurance to establish win-win situation, resulting the environment protection and business profitability.

The interest of engaging in RE investment have been supported globally. As reported by International Renewable Energy Agency (IRENA) that the investment trend increase approximately 44.4% from USD167.8 billion to USD301.7 billion over a decade (REN21, 2020). Looking to report, solar and wind represent the top new investment in renewable energy at USD141 billion and USD 142.7 billion respectively, with total 94% of sum of solar and wind. Saad et al., (2021c) point out that the growth of development in renewable energy explaining the serious ambitions to shift conventional source of generating electricity towards environment friendly, especially reducing footprint impact due to mass consumption.

According to Zhang et al., (2015), the initial investment decision involved the cash used in investor to construct the fixed asset, intangible assets and other long-term asset. Understanding to that, the investor need to consider the risk, return and policy regulatory policy implemented while engaging with the green investment. Tran et al., (2021) study on the factors contributing to the green investment in Vietnam. The study point out the crucial decision for the sustainable development is based on legal framework (tax on technology), financial resource (i.e. bond/sukuk, microfinance, green stimulus funds), awareness (education and communication), and consumer behaviour. The authors elaborate based on survey to 208 business, the investor is motivated to invest as there are special incentives on green investment.

In addition, the Bergek et al., (2013) investigate the investor put an expectation for return based on three oriented purposed; profit; technology; solution. Aliyu and Tekbiyi-Ersoy (2019) point out, in

order to get optimum profit, the investor must identify the potential resource based on location, technology, and meteorology (sun position). The study case in Nigeria found that, investigate the level of optimum solar capacity should be installed while minimizing the cost of installation have strong relationship with the RE source.

According to Camello and Reichelstein (2017), the cost of solar PV is affordable as long as the tariff rate are above the threshold of breakeven. Adding to that, the government must consider the capacity factor or the ability of solar PV while adjusting the tariff rate. Razali et al., (2020) criticized the small capacity installed is not competitive cost compare to the large size. The study found that the cost of solar PV is expensive, thus the solar generation is not capable to compensate with the investment. Thus, the investor must know the profile load of consumption before deciding to install green technology, solar rooftop (Ospino-Castro et al., 2020).

Meanwhile, Taghizadeh-Hesary and Yoshino (2019) argued that the green investment have high of risk and the potential rate is relatively lower than alternative energy investment (coal and gas). Hence, the study proposed to provide credit guarantee and tax allowance in order to welcome private participation in green investment and finance. Chiltimiea et al (2021) discuss the determinants of the interest to allocate the financial resource contributing to green investment. According to the study, the investor preference, financial performance, reputational considerations (corporate social responsibility) and efficiency gains as sustainable development growth (Mohd Saad et al., 2021; Ramli et al., 2020; Peng & Liu, 2018).

Underpinning of Theories: Ecological Modernization Theory & Social Responsibility Investment Theory in Sukuk Green Investment

The theory of ecological modernization was pioneered by Joseph Huber in 1982, inspired by the environment policy for greener country (Pushpakumara et al., 2018). The introduction green tools mainly is to cure the issue of climate safety. The innovation policy measures must be explored by combining the environment and economic feasibility. Sezgin (2013) believe that the need exploring the clean and green technology are to capture the efficiency production and decouple the environment damage, increase of employment and thus, solve the problem of pollution across the state. The common policy can be traced in the international environment onwards. While fighting with the climate change, ecological modernization aims to provide win-win situation between profitability and environment (Weber, 2020).

Zahari and Ramayah (2017) study the performance of business based on the green innovation. Without the changes of process in green innovation, the environment would not benefit from it. Green innovation thus involve the consideration of investment to expand the ability and performance. The findings support the government agendas for sustainable development growths by exploring green innovation by using green sukuk financing. Furthermore, Sidhu and Gibhon (2021) observed that the green innovation able to reduce the cost of environment, resulting in reducing the cost maintenance, enhancing the revenue and improving the quality of production by adopting the green technology, such as solar PV (RE) (Darghouth et al., 2011).

The concept of consumption and production can be rearranged with the ecological belief goals into the institutional organization. Basically, the theory guides people to consider environment as function of the daily activity. The concern of environment impact have push the household to recheck daily activities. The theory implies the potential of environment for the economic development without harming the nature. The needs of green management can provide goods and services to fulfil demand of consumer. Moreover, the effective of the coordination is important to deliver good lifestyle and successful management. According to Pushpakumara et al., (2018), an integration of stakeholder and ecological theory will improve the organizational performance, since it have unique competition that differentiate from the rivals.

As previous literature noted, technology have offered the escape from the destruction. However, some criticize the technology lead to problematic. While pursuing successful achievement,

urbanization have lead deforestation and harms the nature. Technology seem to contribute to the air pollution and green footprint issue. Thus, the role of governance is important to underline the environment policy to avoid undesired issue. Ecological Modernization Theory proposed to the society to be aware in preserving the nature through the advance technology (Keho, 2019). As above review, the jungle have been explored to build more building and home for residential. Since no space to restore the jungle, human must think how to minimize the carbon emission and climate change. Instead of assuming technology as disaster, the human must integrate the innovation with aim for environment benefit (Zahari & Ramayah 2017).

The concerns of natural disaster have inspired people to restructure plans and action in repairing the environment. Solar PV, is one of alternative while using natural source instead of coal and gas. The incentive has educated people to be creative while managing the source of pollution (Mastrangelo & Aguiar, 2019). The environment and development have be linked together, but the regular policy rules the direction towards positive or negative impact.

DATA COLLECTIONS & RESEARCH METHODOLOGY

This study relies on secondary data collected from various sources, as outlined in Table 1.for each of the variables from year 2000 to 2023 with full number of observations, N of 2840 observations.

Table 1: Data Description, Proxy/Measurement, Predicted Sign and Sources of Data

No.	Variables	Description	Proxy/Measurement	Predicted sign (+/-/?)	Data Sources
	Dependent:				
1	Sukuk Value Issuance	lnSIZE	Log of total value of sukuk issuance for the tranche in the ith year.		Bondinfo Hub, RAM & Workspace Refinitiv
	Independent:				
2	Renewable Energy	RE	Renewable energy consumption (% of total final energy consumption)	+	World Database & MEIH
	Control:				
	Market Risks:				
3	Market capitalization	MCap	Market capitalization of listed domestic companies (current US$)	+	World Database, BloombergBursa Malaysia & DOSM
4	Risk premium on Lending	RP	Lending rate minus treasury bill rate, %	-	
	Economic Stability:				
5	Gross Domestic Product	GDP	GDP growth (annual %)	+	World Database, BloombergBursa Malaysia & DOSM
6	Interest rate spread	IR Spread	Lending rate minus deposit rate, %	-	
	Financial Health:				
7	Bank capital to assets ratio	BCAR	Bank capital divided by assets ratio, %	+	World Database & DOSM

Measurement of the sukuk value issuance is based on the total value of tranche issuance in Malaysian Ringgit (MYR). The figure has been logged (lnSIZE) because the data provided is in millions. This variable becomes a dependent variable in many previous studies whereby RE consumption is depending on its total value of financing in green investment or represent a percentage of total final energy consumption. The controlling factors that influence the sukuk value issuance based on literature study considered are market risks, economic stability and financial health proxies by

variables shown in table 1. Chen et al. (2016) found a significant positive relationship between loan spreads and the GDP macroeconomic factor. This finding aligns with Figlewski, Frydman, and Liang (2012), who documented that measures of the macroeconomic environment, such as inflation, real GDP, and GDP growth, were highly significant variables in modeling downgrade transitions. However, these factors provided no explanatory power for upgrades from speculative to investment-grade categories. Wilson (2008) reported greater payment stability for sovereign debt in Saudi Arabia when GDP growth was used as a proxy for bond returns instead of interest rates. Similarly, Ramly (2013) examined the relationship between corporate governance and the cost of debt, using the log of GDP as a control variable to represent the macroeconomic environment and economic growth. His findings revealed a significant negative relationship between GDP and the cost of debt, indicating that debt financing becomes more affordable during periods of economic expansion. Bokpin (2010) further emphasized that the impact of financial market development on financing sources varies systematically in both magnitude and direction depending on the maturities involved. He noted that firms must monitor macroeconomic indicators, such as GDP growth, when timing securities issuance while also considering firm-level characteristics, which are equally critical as external factors. Batten, Jacoby, and Liao (2014) analyzed Canadian bond index data using various models incorporating both nominal and real interest rates. Their findings revealed no significant relationship between yield spreads and government yields for economically non-callable bonds. Similarly, Ahmad, Muhammad, and Masron (2009) examined the Malaysian bond market, focusing on Malaysian Government Securities (MGS) and corporate bonds with maturity periods of one month, three months, and five months, spanning January 2001 to December 2008. Their study showed that interest rates significantly influenced yield spreads across all maturity periods. However, they also found that the KLCI index did not influence conventional bonds with three- and five-month maturities or MGS.

The impact of financial market development systematically varies in magnitude and direction depending on the maturities of the sources of financing, which may be influenced by a firm's financial health. Furthermore, macroeconomic indicators such as GDP should be closely monitored by firms when timing securities issuance, while firm-specific characteristics must also be considered equally important alongside external factors (Bokpin, 2010). Supporting this, several studies, including Bissoondoyal-Bheenick (2005), Bissoondoyal-Bheenick, Brooks, and Yip (2006), Xiao (2007), Ellis (2012), Said and Grassa (2013), and Afonso and Nunes (2014), have used GDP as a proxy for macroeconomic factors to control conventional bond yields, particularly through issuance size. Ibrahim (2015) further highlighted the prohibition of interest rates in Shariah-compliant transactions, raising questions about whether interest rates are priced into Islamic stocks. Shamsuddin (2014) and El-Mosaid and Boutti (2014) addressed this issue by evaluating the exposure of Dow Jones Islamic equity indexes to interest rate risk, finding statistically significant associations. Despite these findings, research on factors influencing sukuk issuance remains relatively limited compared to conventional bonds, highlighting a gap in the literature that requires further exploration.

With regards to the regression test, there are three model regression equations have been developed representing by model 1 for fixed effect, model 2 for random effect and model 3 for robust regression to investigate the relationships between sukuk size of issuance with RE and its control variables.

The model 1 (fixed effect) used is when λ_i is correlated with X_{it} and within variation in the data only, but is the most flexible in that it allows for the endogeneity of regressors. The individual specific effects are assumed to be specific intercepts to be estimated or more crucially when,

$$Corr(\lambda_i, X_{it}) \neq 0$$

This model also treats λ_i as a constant value for each tranche of issuances. Here, when the covariance between the individual specific effect and any regressor is not zero, neither pooled ordinary least square nor random effects estimators provide consistent estimators. The fixed effect estimator

eliminates unobserved effects by removing them from the model. Running pooled ordinary least square on the resulting fixed effect estimators, are as follows:

$$\ln SIZE_{it} = (\beta_{fe} + \lambda_i) + \beta_{fe_1}(RE_{it}) + \beta_{fe_2}(Mcap_{it}) + \beta_{fe_3}(RP_{it}) +$$

$$\beta_{fe_4}(GDP_{it}) + \beta_{fe_5}(IRspread_{it}) + \beta_{fe_6}(BCAR_{it}) + u_{it} \quad \text{.....model eq. 1}$$

Where:

β_{fe} = the coefficient estimates in fixed effect of the explanatory variables

$(\beta_{fe} + \lambda_i)$ = the intercept for fixed effect,

$\ln SIZE_{it}$ = the sukuk size of issuance of the companies for the year,

RE_i = the renewable energy consumption for the year,

$Mcap_i$ = the market capitalization for the year,

RP_i = the risk premium for the year,

GDP_i = the gross domestic product growth for the year,

$IRspread_i$ = the interest rate spreading for the year,

$BCAR_i$ = the bank capital to asset ratio for the year, and

u_{it} = the error term for fixed effect.

Econometricians have long debated the choice between fixed effects and random effects models for regression analysis, as each provides distinct advantages and addresses different assumptions (Baltagi, Bresson, & Pirotte, 2003). The random effects model assumes exogeneity of all regressors, producing regression results based on random individual effects. In contrast, the fixed effects model allows for endogeneity among the regressors, incorporating individual effects by using the means of strictly exogenous regressors as instruments for the time-invariant regressors correlated with individual effects (Mundlak, 1978; Baltagi, 2001).

In this study, the random effects model assumes that each tranche of sukuk issuance has its own intercept while restricting the slope to remain homogeneous across sukuk sizes. This model treats the value of sukuk within a tranche as being subject to liquidity movements, making the random effects approach appropriate. Said, Suhaimi, and Haris (2013) similarly applied these regression techniques to account for heterogeneity in their research. To address this heterogeneity, the random effects model decomposes the error term (ε\varepsilonε) into two components: one reflecting individual-specific random effects and the other representing general error. This decomposition ensures that variability specific to individual sukuk issuances is captured while maintaining consistency in the overall model structure.

$$\varepsilon_{it} = \lambda_i + u_{it}$$

Besides, λ_i the tranche issuance effect, which represents unobserved heterogeneity, is assumed to be time-invariant. As a result, it is unnecessary to include the year index in the model. The model assumes that is identically and independently distributed with a mean of zero and a variance of . More importantly, it is presumed to be uncorrelated with the regressors. This assumption is critical for ensuring that the random effects σ_μ^2 model produces unbiased and consistent estimates, as shown in the following equation:

$$u_{it}$$

$$Corr(\lambda_i, X_{it}) = 0$$

Due to that, the autocorrelation ordinary least square will be inefficient and the ordinary least square standard errors will be invalid. In this circumstance, the random-effect estimator is required to estimate and transform ordinary least square model resulting estimator, as follows:

$$y_{it} - \theta\bar{y}_t = \alpha + \beta(x_{it} - \theta\bar{x}_i)$$

β_{re}

The random-effect estimator uses a weighted average of the within and between variations in the data which has the same intercept, $\sigma_\lambda^2 = 0$ and, $\theta = 1 - \sqrt{\frac{\sigma_u^2}{T\sigma_\lambda^2 + \sigma_u^2}}$. Consequently, the $\theta = 0$ random-effect estimator becomes pooled ordinary least square in this observations. The random effect model equation can be represented as follows:

$$\ln SIZE_{it} = \beta_{re} + \beta_{re_1}(RE_{it}) + \beta_{re_2}(Mcap_{it}) + \beta_{re_3}(RP_{it}) +$$

$$\beta_{re_4}(GDP_{it}) + \beta_{re_5}(IRspread_{it}) + \beta_{re_6}(BCAR_{it}) + (\lambda_i + u_{it}) \quad \text{.....model eq. 2}$$

Then, with respect to model 3 for robust regression test, it was regress using random effect approach which was decomposes the error term into two composite error term with robust.

$$\ln SIZE_{it} = \beta_{robust} + \beta_{robust_1}(RE_{it}) + \beta_{robust_2}(Mcap_{it}) + \beta_{robust_3}(RP_{it}) +$$

$$\beta_{robust_4}(GDP_{it}) + \beta_{robust_5}(IRspread_{it}) + \beta_{robust_6}(BCAR_{it}) + (\lambda_i + u_{it}), robust \quad \text{.....model eq. 3}$$

Where:

β_{robust} = the coefficient estimates in robust effect of the explanatory variables, and

$\lambda_i + u_{it}$ = the error term decomposed the ε into two composite error term for unobserved heterogeneity and it is identically and independently distributed.

RESULTS AND DISCUSSION

An Analysis of Descriptive Statistics Results

Table 2. Results of Descriptive Statistic

Variable	N	Mean	Std. Dev.	Min	Max
lnSIZE	2,840	17.894	1.778	12.342	23.249
RE	2,795	3.487	1.090	2	7.5
MCap	2,797	3.96e+11	8.06e+10	1.13e+11	5.00e+11
RP	2,630	1.927	.506	1.457	4.812
GDP	2,840	4.785	1.714	-5.457	8.859
IR Spread	2,840	1.869	.541	1.431	4.311
BCAR	2,772	8.755	.526	6.968	9.236

Table 2 show the results of descriptive statistics for the sukuk issuance, RE and its robust determinant factors for the year 2000 up to 2023 in Malaysia. Minimum size of sukuk issuance in Malaysian Ringgit (MYR) currency has been log in value since it was indicate by millions with

different tranche of issue during the issuance year. The dataset provides a detailed view of the variables influencing Sukuk value, offering insights into their distribution and variability. The natural logarithm of sukuk value issuance (lnSIZE) has a mean of 17.894 with a standard deviation of 1.778, indicating moderate variability in valuations across the dataset. The range spans from 12.341 to 23.249, reflecting the diversity of Sukuk issuances, from smaller-scale instruments to high-value sukuk likely tied to large infrastructure or government-backed projects. This variability underscores the adaptability of sukuk to meet a broad spectrum of financing needs in the Islamic financial market.

As regards to the RE, the range of its consumption between 2% to 7.5% with an average of almost 3.5%. It means that this RE consumption is still low as compare to non-RE such as coal usage in generating energy in Malaysia. MCap value represent the market capitalization of listed domestic companies (current US$) indicate in huge value. As for GDP, the minimum value show in negative value (-5.457%) indicate that the economic performance is not good at certain point in time; for instance during economic recessions in 2008 and COVID-19 pandemic in 2019 & 2020, however in overall performance as represent by mean value from year 2000 to 2023 is 4.785% with highest at 8.859%. GDP exhibits a standard deviation of 1.714, indicating that GDP growth (annual %) is moderate variability. Besides, the range extends from -5.457% to 8.859% reflecting periods of economic contraction or recessions and signaling strong economic growth from the period of 2000 to 2023 in Malaysia. This range captures diverse macroeconomic conditions represented in the dataset. Positive GDP growth is typically associated with improved sukuk value issuance performance up to years of maturity, as it enhances investor confidence in RE projects and reduces credit risks, whereas negative growth may signify economic instability that could affect market sentiment.

Other controlling factors for market risk, economic stability and financial health shows a positive value in minimum, mean and maximum value respectively. For instance, the value of interest rate spread in range of min, .541%, mean, 1.431% and max 4.311% show such a good and bad factors in influencing the sukuk value of issuance. Since this wide range highlights the sensitivity of sukuk markets to interest rate changes, although their asset-backed and profit-sharing structures provide resilience compared to other debt financing in capital market, such as corporate bonds and government or sovereign bonds.

An Analysis of Normality Test and Correlations Results

Table 3. Skewness and Kurtosis tests for normality & Pairwise Correlations Results

Variable	Pr(skew)	Pr(kurtosis)	Adjchi2	Prob>chi2	lnSIZE	RE	MCap	IRSpread	RP	BCAR
lnSIZE	0.0009	0.0022	18.78	0.0001	1.0000					
RE	0.0000	0.0000	313.29	0.0000	-0.3169	1.0000				
MCap	0.0000	0.0000	231.73	0.0000	0.0684	-0.2186	1.0000			
IR Spread	0.0000	0.0000	629.43	0.0000	-0.0330	-0.3556	-0.5867	1.0000		
RP	0.0000	0.0000	801.73	0.0000	-0.0430	-0.2133	-0.7575	0.9436	1.0000	
BCAR	0.0000	0.0000	849.46	0.0000	-0.0508	0.4150	0.2632	-0.7567	-0.6474	1.0000

The study was run 3 normality tests to reconfirm the data for estimation model developed, that are skewness, kurtosis and pairwise correlations. Checking for skewness and kurtosis in the error components is crucial for ensuring the validity of testing and estimation procedures in data models (Alejo et al., 2015). Specifically, kurtosis plays a critical role in assessing multivariate normality, serving as a key measure in generalized tests and their estimators (DeCarlo, 1997). Tabachnick and Fidell (2007) further emphasized that to evaluate the standard scores for skewness and kurtosis, the value of the statistic should be divided by its standard error. They suggested that a resulting $p<0.001p < 0.001p<0.001$ in a two-tailed test indicates acceptable levels of skewness and kurtosis, which helps justify the use of parametric statistical techniques in data analysis. The natural logarithm of Sukuk value (n=2,840) exhibits significant skewness (p=0.0009) and kurtosis (p=0.0022), with an adjusted chi-square statistic of 18.78 (p=0.0001). These results confirm that the distribution of lnSIZE deviates significantly from normality. The positive skewness suggests an asymmetrical stretch

toward higher values, while the elevated kurtosis reflects heavy tails, indicating a higher frequency of extreme values than expected under normality. These features are common in financial data, where market volatility and investor behavior contribute to non-normal distributions. Addressing these characteristics requires robust regression methods or data transformations, such as logarithmic transformations, to ensure accurate and unbiased results. Thus, results of these both tests, skewness and kurtosis were shown the dependent and independent as well as control variables data for estimation model developed is acceptable as shown by p value were significant at 99% confidence level. Therefore, this normality data can be proceed for regression tests.

As regards to the pairwise correlations test, it was conducted to check the multicollinearity problem exists among variables. As shown in the correlation matrix in Table 2, the results reveal a mix of positive and negative correlations among the explanatory variables. These variations indicate the diverse nature of the relationships between the variables, reflecting potential complexities and interactions within the dataset. Such mixed correlations highlight the need for careful interpretation, as they may influence the direction and strength of the associations in subsequent regression analyses. Such a negative correlation between RE, RP, IR spread and BCAR with sukuk size of issuance, -0.3169, -0.0430, -0.033 and -0.0508 respectively reflects sukuk's unique characteristics compared to conventional fixed-income instruments. Unlike bonds, sukuk are less sensitive to interest rate changes due to their asset-backed and profit-sharing structures, which tie returns to tangible assets rather than fixed interest payments. Mohd Saad, et. al (2020), Alam and Ozturk (2022), Mohd Saad, et al (2023; 2025) claimed that sukuk retain value better than conventional bonds during periods of rising interest rates, offering stability in volatile monetary environments. This resilience makes sukuk an attractive option for institutional investors during periods of monetary tightening or fluctuating interest rates. Issuers should highlight sukuk's stability in such environments, particularly when targeting risk-averse investors.

Table 4: Regressions Test Results

Regression Model	**Model 1(Fixed Effect)**		**Model 2(Random Effect)**		**Model 3(Robust Effect)**	
DV [lnSIZE]	t	P>|t|	t	P>|t|	t	P>|t|
RE	-6.59***	0.000	4.93***	0.000	-5.51***	0.000
MCap	-3.57***	0.000	11.57***	0.000	-3.14***	0.002
RP	-1.23	0.221	-2.15**	0.031	-0.76	0.445
GDP	2.69***	0.001	3.06***	0.003	.111	1.48
IR Spread	-1.35	0.178	8.26***	0.000	-1.78*	0.075
BCAR	-0.83	0.404	17.18***	0.000	-0.51	0.607
_cons	15.77***	0.000	-	-	15.63***	0.000
RMSE	1.644		1.720		-	
R-square	3.8%		99.1%		-	-
F-Stat	18.87***		2491.72***		13.52***	
Issuance Effect	Fixed/Constant		Random/non-constant		Dynamic	

Notes:***,** and * represent the significant level at 99%, 95% and 90% respectively.

All three regression models—fixed effects (Model 1), random effects (Model 2), and robust regression (Model 3)—have been tested to confirm that they provide a best-fit approach to explaining the relationship between Sukuk issuance size and renewable energy (RE) consumption,

while controlling for factors such as market risks, economic stability, and financial health. Firstly, the fixed effects model (Model 1) demonstrates a valid relationship at a 99% confidence level, with an FFF-value of 18.87, suggesting that the explanatory variables significantly influence Sukuk issuance size under the fixed effects framework.

In comparison, the random effects model (Model 2) shows higher accuracy, evidenced by an FFF-value of 2491.72, also significant at a 99% confidence level. This result highlights the superior explanatory power of the random effects model in capturing variability in Sukuk issuance size while accounting for random individual effects. Lastly, the robust regression model (Model 3) further validates the relationship between Sukuk issuance size and the included variables. The FFF-value of 13.52, significant at a 99% confidence level, confirms that the model is fit and the included variables collectively explain the variability in Sukuk size among Malaysian issuer firms. Together, these results indicate that all three models effectively capture the underlying dynamics of Sukuk issuance, with the random effects model offering the highest accuracy in explaining these relationships. Here, robust regression results provide a comprehensive assessment of the determinants of sukuk issuance (lnSIZE) while addressing potential outliers and heteroscedasticity in the data.

Secondly, the R-square values are reported for Models 1 and 2 to assess the proportion of variation in Sukuk issuance size explained by the explanatory variables. As shown in Table 4, Model 1 yields an R-square value of 3.8%, indicating that only 3.8% of the variation in Sukuk issuance size is explained by the variation in renewable energy (RE) consumption and the control variables. This relatively low R-square value suggests a weak relationship, implying that additional variables or factors may be necessary to improve the model's explanatory power under the fixed effects framework. In contrast, Model 2 reports a significantly higher R-square value of 99.1%, suggesting that approximately 99% of the variation in Sukuk issuance size is explained by the explanatory variables in the random effects model. This high R-square value validates the robustness of Model 2 in capturing the relationship between Sukuk size and the included variables. While there is no universally accepted threshold for the validity of R-square values in regression analysis, Falk and Miller (1992) suggest a minimum R-square value of 0.015 for significant model testing, while Quaddus and Hofmeyer (2007) recommend a threshold of 0.1. However, Reid (2001) cautions that excessively high R-square values do not necessarily indicate a good fit, as they could result from overfitting or the inclusion of irrelevant variables. Therefore, while Model 2 demonstrates an exceptionally high R-square, care must be taken to ensure that the variables included are theoretically and empirically relevant to Sukuk issuance performance. These findings highlight the importance of balancing statistical significance with theoretical soundness when interpreting regression results.

Therefore, based on the best fit of validity results for model testing revealed by f-test and R-square, the regressions results for model 1, 2 and 3 can be justify further on the relationship between sukuk size of issuance with RE and control variables. From table 4, the results for all models shown a positive and negative relations between dependent and independent variable. In model 1 and 3, the association postulate a significant negative relationship, otherwise in model 2 show a positive at 99% confidence level respectively. A negative relationships would support the government SDG in RE up to year 2023 is still low around 5% even the sukuk investment actively promoting in large size of issuance for green financing. However, the relationship is positive in random effect model suggesting that higher sukuk size of issuance or higher green sukuk financing promoting higher RE consumptions. Similar results revealed by market risks factors, proxy by Mcap whereby support the government targeted in RE via sukuk investment. With regards to the risk premium, it shows that sukuk size only have a significant relationship at 95% confidence level in random effect but insignificant in fixed effect and robust effect model.

With regards to GDP growth, also exhibits a strong positive and statistically significant relationship at 99% confidence level in model 1 and 2 with sukuk size, supported by a t-value of 2.69 and 3.06 respectively, but insignificant in model 3. This indicates that in either fixed or random effect, the GDP factor is significant in influencing the sukuk size of issuance, highlighting the critical role of economic

stability in sukuk valuation. As GDP growth captures the overall economic health of a region, with growth fostering investor confidence and reducing credit risks, which posits that stable economic growth enhances the attractiveness of financial instruments like sukuk. Hossain and Sarker (2022) observed similar findings, noting that GDP growth positively influences sukuk issuance and valuation, particularly in emerging markets. Policymakers should focus on fostering economic growth to support sukuk markets, while issuers can capitalize on periods of positive GDP performance to maximize market interest.

Mixed relationship have been explored for interest rate spread whereby it indicate no relationship in model 1, significant positive relationship in model 2 and significant negative relationship in model 3 with sukuk size. This positive relationship is somewhat counterintuitive, as rising interest rates generally suppress the value of fixed-income instruments. However, sukuk's distinct structure, which ties returns to tangible asset performance (as shown by BCAR) and profit-sharing mechanisms, mitigates sensitivity to interest rate changes. Alam and Ozturk (2022) similarly observed that sukuk retain value better than traditional bonds during periods of monetary tightening, making them appealing to investors navigating fluctuating interest rates. For issuers, highlighting sukuk's resilience to interest rate volatility can enhance their attractiveness in uncertain economic climates. Else, in long-term sukuk issuance, the volatility effects from the lowest to highest yield to maturity give huge spreads on sukuk value. Longer-term of trading exposed the instability of yields since the dynamic changes in price of and sukuk. Morellec (2001) found that greater liquidity increases credit spreads on corporate debt and reduce the optimal leverage.

Conclusion, Policy Impact & Recommendations

This study concludes that green sukuk investment serves as a transformative tool for financing renewable energy projects, driving sustainable development while addressing environmental challenges. The analysis reveals a significant correlation between sukuk issuance and macroeconomic indicators, particularly GDP growth, which underscores the importance of economic stability in fostering green sukuk markets. While renewable energy consumption remains relatively low in Malaysia, the increasing adoption of green sukuk demonstrates the potential to accelerate the transition to low-carbon energy systems. The integration of theoretical frameworks, such as the Ecological Modernization Theory and Social Responsibility Investment Theory, emphasizes the dual objectives of economic profitability and ecological preservation. Policymakers are encouraged to enhance regulatory frameworks and offer incentives to attract private-sector participation, while issuers should leverage sukuk's unique asset-backed structure to enhance market confidence. By addressing challenges such as information transparency and cost optimization, green sukuk can effectively support Malaysia's renewable energy goals, contribute to global carbon neutrality efforts, and serve as a model for other emerging economies.

Contributions of Authors

Authors are contributed equally in data collections, write-up analysis and conclusions.

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