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Navigating Energy Scarcity Risks: The Dual Impact of Geopolitical Uncertainty on Indonesia's Transition to Renewable Energy

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ABSTRACT

As the world's fourth most populous country and Southeast Asia's largest economy, Indonesia faces unique challenges in balancing economic growth, energy security, and environmental sustainability. The research aims to provide insights into how geopolitical risks and energy consumption patterns influence the adoption of renewable energy sources, particularly in the context of Indonesia's evolving energy policies. The study employed the Autoregressive Distributed Lag (ARDL) model to analyse time-series data from 1990 to 2017. The ARDL model is particularly suited for examining short-term and long-term relationships between variables. The research found that geopolitical risks and immediate energy security concerns increased fossil fuel consumption in the short term. However, in the long term, these risks accelerated investments in renewable energy sources, driven by the pursuit of energy independence and environmental sustainability. The error correction term for renewal energy consumption (REC) is -97.179, indicating a rapid adjustment to equilibrium deviations. Energy consumption (EC) showed a positive long-term relationship with REC (4.893), suggesting that higher energy demand correlates with increased renewable energy adoption over time. Fossil fuel consumption (FFC) also exhibited a positive long-term relationship with REC (101.588), which may reflect initial reliance on fossil fuels to stabilise the economy before transitioning to renewables. The result highlighted the importance of balancing short-term energy security needs with long-term sustainability goals. The findings contributed to the broader understanding of energy economics in developing countries, offering valuable insights for navigating the global energy transition amidst geopolitical uncertainties.

Keywords: Energy, Renewables, Geopolitics, Transitions, Indonesia.

INTRODUCTION

The global energy transition represents a significant challenge of the 21st century, especially for developing nations such as Indonesia, where economic growth is closely linked to energy demand. Indonesia, the fourth most populous nation globally and Southeast Asia's largest economy, faces distinct challenges in reconciling immediate energy security requirements with long-term sustainability objectives. The country's dependence on fossil fuels for economic growth has resulted in a situation where the need to satisfy increasing energy demand frequently clashes with the necessity to lower carbon emissions and transition to renewable energy sources. Recent geopolitical tensions in Europe and the Middle East have intensified these challenges, revealing the susceptibility of energy systems to external shocks and emphasising the necessity for a robust energy transition strategy. Oil has historically been the dominant source. Gas and coal consumption has steadily increased. However, more minor in share, hydropower and renewables have shown consistent growth, especially since the 2000s. The figure highlights the persistent dominance of fossil fuels despite rising renewable energy contributions, underscoring the challenges in transitioning to a more sustainable energy mix.

This paper examines a critical subject in the global energy transition dialogue: the influence of energy shortage threats and geopolitical uncertainty on the trajectory of renewable energy, especially in emerging nations such as Indonesia. Indonesia, confronted with intricate energy challenges—including significant reliance on fossil fuels, uneven energy distribution, and susceptibility to global market fluctuations—highlights the pressing necessity for strategies that harmonize immediate energy security with long-term sustainability objectives. Geopolitical conflicts and supply interruptions often necessitate a reversion to fossil fuels, hence hampering decarbonization efforts. Nonetheless, these same forces may also act as catalysts for expediting investments in renewable energy if handled with forethought. Using a comprehensive analytical approach, this research seeks to elucidate how Indonesia may address these intersecting risks to develop a more resilient and future-oriented energy sector. The study is anticipated to provide practical insights for reconciling energy needs with sustainability, providing strategic assistance for policymakers confronting analogous challenges in other emerging countries.

This study posits that energy scarcity risks and geopolitical uncertainties fundamentally influence Indonesia's energy transition. In the short term, these risks result in a heightened dependence on fossil fuels to mitigate immediate energy security issues. In the long term, investments in renewable energy are accelerated as the country aims for energy independence and reduced vulnerability to external shocks. This dual impact illustrates the complex relationship between immediate energy requirements and enduring sustainability objectives, providing a detailed understanding of the elements influencing energy transitions in developing economies. This study uses an Autoregressive Distributed Lag (ARDL) model to analyse time-series data from 1990 to 2017 to address the scientific problem. This method facilitates the analysis of both short-term and long-term relationships among renewable energy consumption, fossil fuel consumption, and significant economic indicators. This study employs a decomposition analysis utilising the Logarithmic Mean Divisia Index (LMDI) to ascertain the primary factors influencing changes in energy consumption in Indonesia.

The anticipated outcomes of the study are twofold. The research predicts a short-term rise in fossil fuel consumption due to immediate energy security issues influenced by geopolitical risks and energy scarcity. The study aims to identify a long-term trend of increased investment in renewable energy as Indonesia pursues energy independence and aims to reduce its carbon footprint. The findings will enhance understanding of the intricate relationship among economic growth, energy security, and environmental sustainability, providing essential insights for policymakers in Indonesia and other developing nations facing comparable challenges. This research seeks to develop strategies that reconcile immediate energy requirements with enduring sustainability objectives, facilitating a resilient and inclusive energy transition.

LITERATURE REVIEW

The transition to renewable energy is a critical global challenge, particularly for developing countries like Indonesia, where economic growth and energy demand are deeply intertwined. As a field, energy economics examines the complex interplay between energy economics and sustainable development, highlighting the need to balance economic growth and environmental preservation. [1]. Historically, industrialisation and economic growth have been fuelled by fossil fuels, but these resources' finite nature and environmental impact have necessitated a shift toward renewable energy [2]. For developing nations, the energy transition requires balancing technology, society, and policy to achieve energy security, economic stability, and environmental sustainability [3]. Recent geopolitical events, such as the energy conflicts in Europe and the Middle East, have underscored the vulnerability of energy systems to external shocks. The sharp rise in natural gas and crude oil prices and supply disruptions have forced many countries to reconsider their energy policies, often reverting to fossil fuels in the short term to ensure energy security [4]. These events highlight the complex relationship between geopolitical risks, energy security, and the transition to renewable energy.

The global push for net-zero emissions, as outlined in the COP26 commitments, has further intensified the need for clean energy adoption. However, the transition to renewable energy is fraught with challenges, particularly for developing countries. High initial investment costs, technological barriers, and the need for significant policy reforms are major obstacles. Moreover, the lack of coordinated policies and unconsolidated government initiatives often impede progress in renewable energy adoption [5]. For Indonesia, these challenges are compounded by its archipelagic geography, which complicates energy distribution and infrastructure development [6] [7].

Research has shown that clean technologies can mitigate fossil fuel consumption but face significant adoption barriers. High initial costs are a major obstacle, particularly in developing countries [8]. Environmental policies play a crucial role in promoting clean technology innovation and adoption. Market-based policies, such as carbon taxes and subsidies, are moderately effective in encouraging renewable innovation, particularly in countries with higher relative competencies in green technologies. Command-and-control policies, on the other hand, tend to discourage fossil fuel-based innovation [9]. For universities, state-level financial incentives like grants, tariffs, and net metering are positively correlated with renewable energy deployment [10]. Various incentives, including carbon taxes, feed-in tariffs, and research investments, have been implemented globally to promote green energy [11].

However, challenges remain, such as some countries' continued provision of fossil fuel subsidies. The effectiveness of different incentive types varies; for example, feed-in tariffs and tax rebates have different impacts on solar panel investments [12]. Government incentives are crucial in accelerating the transition to renewable energy sources and addressing climate change.

The role of stakeholders, including governments, investors, and industry players, is crucial in driving the energy transition. Governments, in particular, need to strengthen the general investment environment and align it with climate mitigation policies to mobilise investment and innovation in renewable power [13]. However, the divergent interests of stakeholders often lead to conflicting priorities, making it challenging to implement cohesive energy policies. In Indonesia, the government's strong influence on energy policy decisions has positive and negative implications for the transition to renewable energy [14]. This study examines the dual impact of energy scarcity risks and geopolitical uncertainties on Indonesia's transition to renewable energy. Specifically, the research aims to analyse how these factors influence short-term energy security needs and long-term investments in renewable energy, providing insights into the complex dynamics of energy transitions in developing economies. This study hypothesises that *"geopolitical risks and energy scarcity lead to a short-term increase in fossil fuel consumption as a response to immediate energy security concerns (**H1)**"*. In the long term, *"geopolitical risks and energy scarcity accelerate investments in renewable energy as Indonesia seeks to achieve energy independence and reduce its vulnerability to external shocks (**H2)**"*.

RESEARCH METHODOLOGY

The study encompasses a time series of data regarding energy consumption. Consequently, the energy data comprised a series of observations of the designated variable at regular intervals over a specified timeframe. A time series is deemed to have a unit root when it exhibits non-stationarity. In econometrics, the unit root test determines the stationarity of a time series. This study employed the Logarithmic Mean Divisia Index (LMDI) decomposition index to pinpoint the key factors affecting variations in energy consumption. The study analysed the results after implementing the Logarithmic Mean Divisia Index (LMDI). We offered econometric models for time series using the ARDL approach upon the LMDI. Based on LMDI analysis, we found that economic variables were the primary factors that worsened the shift in renewal energy use. The LMDI identity is a widely used method for studying significant energy and environmental problems on a global scale. It establishes the connection between the economy, policy, energy usage, and carbon emissions. This methodology has been referenced in several studies, including [6] and [15]. The LMDI method is now being used by the International Energy Agency (IEA) and is subsequently adopted by most energy researchers.

In the ARDL model, the study set the basis for understanding the contradicting effects of the renewal energy consumption (REC) variable on nine other independent variables at varying time horizons. The ARDL findings linked the short- and long-run effects to a significant predictive framework regarding the impacts of REC effects. Our econometric approach focused on estimating the short-run effects pertinent to the REC variable. By reconfiguring equation (1) presented below into an ARDL (p, q, ..., q) framework.

$$\text{REC-effect}_t = \alpha + + \emptyset \text{REC} - \text{effect}_{t-1} + \sum_{j=1}^{k} \beta_j X_{j.t-1} + \sum_{j=1}^{q} \alpha_I \Delta \text{RECeffect}_{t-1} + \Sigma_{j=1}^{k} \Sigma_{i=0}^{q} \delta_{j,t} \Delta X_{j.t-1} + \varepsilon_t. \quad (1)$$

We include an Error Correction Model (ECM) into an Autoregressive Distributed Lag (ARDL) model with p and q lags to meet the specified criteria. The ECM model was used to evaluate non-stationary multivariate time series data, which may be expressed as:

$$\lambda_1 \text{ECT}_{t-1} = Y_{t-1} - \beta_0 - \beta_1 X_{t-t} \quad (2)$$

The dataset in this study presents vital metrics on Population, labour population, energy consumption, industry value added, and GDP from 1990 to 2017 across four sectors: Transportation, Commercial, Household, and Industrial. The data includes values such as Population (Mio), Labour Population (Mio), Sectors Energy Consumption (koe), Industry Value Added (US$), Gross Domestic Product National, Energy Primer Consumption (Mtoe), Renewal Energy Consumption (hydro & Geo), Fossil Fuel consumption (Oil & Gas), and Gross Fixed Capital Formation (US$). To examine trends and the different effects of changes in fossil fuel energy and consumption of renewable energy on energy use, it is necessary to use an LMDI decomposition model. By using a decomposition model, it is possible to identify the following:

$$\text{Primary Energy Consumption} = \text{PopulaPopulation} \ \frac{GDP}{Population} \text{ x } \frac{Sectors\ Consumption}{GDP} \text{ x } \frac{Renewal\ Energy\ Consumption}{Sectors\ Consumption} \text{ x } \frac{Fossil-Fuel\ Energy\ Consumption}{Renewal\ Energy\ Consumption} \text{ x } \frac{Gross\ Fixed\ Capital}{Fossil-Fuel\ Energy\ Consumption} \text{ x } \frac{Labor\ Force}{Gross\ Fixed\ Capital} \text{ x } \frac{Industry\ value\ Added}{Labor\ Force} \text{ x } \frac{Primary\ Energy\ Consumption}{Industry\ Value\ Added}$$

The LMDI formula can be rewritten as follows:

- $REC^T = Pop^T \text{ x } \frac{GDP^T}{Pop^T} \text{ x } \frac{SC^T}{GDP^T} \text{ x } \frac{PEC^T}{SC^T} \text{ x } \frac{FF^T}{PEC^T} \text{ x } \frac{GFC^T}{FF^T} \text{ x } \frac{LF^T}{GFC^T} \text{ x } \frac{IVA^T}{LF^T} \text{ x } \frac{REC^T}{IVA^T}$
- $REC^T = Pop^T \text{ x } GDP^T \text{ x } SC^T \text{ x } PEC^T \text{ x } FF^T \text{ x } GFC^T \text{ x } LF^T \text{ x } IVA^T \text{ x } REC^T$
- $REC^T = Pop^T_{effect} \text{ x } GDPeffect \text{ x } SC^T_{effect} \text{ x } PEC^T_{effect} \text{ x } FF^T_{effect} \text{ x } GFC^T_{effect} \text{ x } LF^T_{effect} \text{ x } IVA^T_{effect} \text{ x } REC^T_{effect}$

Whereas:

- POP = Population effect
- GDP = Gross Domestic Products effect $\frac{GDP^T}{POP^T}$
- SC = Ratio Sectors Energy Consumption effect $\frac{SC^T}{GDP^T}$
- PEC = Primary Energy Consumption - Energy Substitution, Ratio Primary Energy effect $\frac{REC^T}{EPC^T}$
- FFC = Fossil Fuels - Renewal Energy Substitution, Ratio Fossil Renewal Energy effect $\frac{FF^T}{REC^T}$
- GFC = Investment Efficiency - Ratio Gross Capital Stock over Renewal Energy $\frac{GFC^T}{FF^T}$

- LF = Capital Labour substitution - Ratio Capital labour $\frac{LF^T}{GFC^T}$
- IVA = Ratio Number Industry Value Added over labour Force $\frac{IVA^T}{LF^T}$
- REC = Ratio Renewal Energy Consumption over industrial value added $\frac{REC^T}{IVA^T}$
- $\Delta REC^T = (\Sigma_{t=1}^{K}\Delta REC)$; if undecompensed
- $(\Delta REC = (\Sigma_{t=1}^{K}(\Delta POP + \Delta GDP + \Delta SC + \Delta PEC + \Delta FFC + \Delta GFC + \Delta LF + \Delta IVA + \Delta PEC)$; if decompensed

Renewal Energy consumption (REC) can be decomposed using the LMDI Approach as follows:

$$\left(\Sigma L(REC^t, REC^0)Ln\left(\frac{POP_{effect^t}}{POP_{effect^0}}\right)\right)+\left(\Sigma L(REC^t, REC^0)Ln\left(\frac{GDP_{effect^t}}{GDP_{effect^0}}\right)\right)+$$
$$\left(\Sigma L(REC^t, REC^0)Ln\left(\frac{SC_{effect^t}}{SC_{effect^0}}\right)\right)+\left(\Sigma L(REC^t, REC^0)Ln\left(\frac{PEC_{effect^t}}{PEC_{effect^0}}\right)\right)+$$
$$\left(\Sigma L(REC^t, REC^0)Ln\left(\frac{FFC_{effect^t}}{FFC_{effect^0}}\right)\right)+\left(\Sigma L(REC^t, REC^0)Ln\left(\frac{GFC_{effect^t}}{GFC_{effect^0}}\right)\right)+$$
$$\left(\Sigma L(REC^t, REC^0)Ln\left(\frac{LF_{effect^t}}{LF_{effect^0}}\right)\right)+\left(\Sigma L(REC^t, REC^0)Ln\left(\frac{IVA_{effect^t}}{IVA_{effect^0}}\right)\right)+$$
$$\left(\Sigma L(REC^t, REC^0)Ln\left(\frac{EPC_{effect^t}}{EPC_{effect^0}}\right)\right) \tag{3}$$

Table 1 displays the results of descriptive statistical tests for ten variables. The analysis presents the average for each variable, along with the maximum and minimum values and the standard deviations for each decomposition variable. The dataset, which spanned from 1990 to 2017, comprised 864 observations.

EMPIRICAL RESULT

ARDL analysis is a statistical technique for modelling and investigating the influence between one or more independent variables on one dependent variable. We examine the results obtained from the LMDI KAYA (Kaya & Yokobori, 1997) analysis was performed. The research used ARDL time series analysis for more accurate and dependable data outcomes. The ARDL model was adequate when the data was either strictly I(0), purely I(1), or a combination of both but not I(2). Both unit root checks I(1) were performed on all variables (table 2).

Table 1: Descriptive Analysis

Description	EC effect	PEC effect	FFC effect	GDP effect	GFC effect	IVA effect	L.P. effect	POP effect	REC effect
Mean	264,44	-178,37	-335,10	494,78	275,50	419,86	-860,68	398,93	323,12
Median	113,45	-31,96	-129,68	359,29	168,69	320,65	-1211,51	397,75	125,62
Maximum	7958,89	5916,00	16723,51	17285,67	7905,49	10183,30	21183,50	809,57	23293,02
Minimum	-8001,31	-6944,45	-23980,57	-9323,84	-17810,90	-16458,03	-7320,69	15,10	-16277,83

Std. Dev.	2087,07	1671,37	5274,20	3059,45	3439,77	3073,76	3547,64	261,31	5107,07
Jarque-Bera	111,59	81,73	103,51	457,68	541,18	465,78	1306,81	7,84	105,81
Probability	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,02	0,00

The findings presented in Table 3 indicate a cointegration relationship between the dependent and independent variables. Consequently, the independent and dependent variables demonstrated a long-term relationship. This indicated that a short-term disturbance would eventually stabilise over time in the long term. The investigation subsequently employed the ARDL and ECM models, guided by the bounded cointegration test. The framework can be characterised as an error-correction model (ECM), in which the short- and long-run effects derived from an ARDL model were assessed about one another.

Table 3: Bounded Cointegrated Test

F-Bounds Test		**Null Hypothesis: No levels of relationship**		
Test Statistic	**Value**	**Sign in.**	**I(0)**	**I(1)**
			Asymptotic: n=1000	
F-statistic	19,4452	10%	1,95	3,06
k	8	5%	2,22	3,39
		2,50%	2,48	3,7
		1%	2,79	4,1

By reformulating Eq. (1) above as an ARDL (p, q, ..., q) model. ARDL model, as a forecasting model for targeting **Renewal Energy Consumption as a Dependent Variable**, can be written as follows:

$$\Delta REC_{it} = \alpha + + \emptyset \Delta REC_{it-1} + \sum_{j=1}^{k} \beta_j X_{j.t-1} + \sum_{j=1}^{p} \alpha_I \Delta REC_{it} + \Sigma_{j=1}^{k} \Sigma_{i=0}^{q} \delta_{j,t} \Delta X_{j.t-1} + \lambda_3 ECT_{t-1} + u_{it} \quad (4)$$

And

$$\lambda_1 ECT_{t-1} = Y_{t-1} - \beta_0 - \beta_1 X_{t-t} \quad (5)$$

Note:

- k-1 = Optimal lags (-1)
- β_1, α_1, δ_j = short-run, dynamic coefficient & long-run equilibrium
- λ_I = speed of adjustment
- ECT_{t-1} = the error correction term
- U_{it} = error

The result showed that the Akaike Information Criterion (AIC) and Schwarz Bayesian Criterion (SBC) yielded four lag durations that are considered best (table 4). The authors choose the maximum 'lag four' to implement the Panel Error Correction Model (ECM).

Null Hypothesis:	**ADP test statistic**	**Level**	**1st Difference**
		Test critical values:	**Test critical values:**

	t-Statistic	Prob.*	1% level	5% level	10% level	1% level	5% level	10% level
PEC has a unit root	-5,628	0,000	-3,496	-2,890	-2,582	-	-	-
FFC has a unit root	-2,572	0,103	-3,503	-2,893	-2,584	-	-	-
	-4,966	0,000	-	-	-	-3,503	-2,893	-2,584
GDP has a unit root	-2,636	0,089	-3,498	-2,891	-2,583	-	-	-
	-8,854	0,000	-	-	-	-3,498	-2,891	-2,583
GFC has a unit root	-5,081	0,000	-3,497	-2,891	-2,582	-	-	-
IVA has a unit root	-3,432	0,012	-3,498	-2,891	-2,583	-	-	-
L.P. has a unit root	-3,671	0,006	-3,498	-2,891	-2,583	-	-	-
POP has a unit root	-1,972	0,299	-3,494	-2,889	-2,582	-	-	-
	-9,536	0,000	-	-	-	-3,495	-2,890	-2,582
REC has a unit root	-2,571	0,103	-3,503	-2,893	-2,584	-	-	-
	-4,981	0,000	-	-	-	-3,503	-2,893	-2,584

Table 4: Lags selection analysis

Lag	**LogL**	**LR**	**FPE**	**AIC**	**SC**	**HQ**
0	-7439,73	NA	9,25E+52	147,4995	147,7325	147,5939
1	-7115,05	585,0665	7,46E+50	142,6742	145,0045	143,6176
2	-6953,57	262,1997	1,57E+50	141,0806	145,5082	142,873
3	-6749,62	294,8163	1,51E+49	138,646	145,1708	141,2874
4	-6480,58	340.9642*	4.40e+47*	134.9224*	143.5445*	138.4128*

* indicates lag order selected by the criterion

In the meantime, the cointegration test (Table 5) displayed the outcomes for various assumed quantities of cointegrating equations, ranging from zero to a maximum of eight. Each hypothesis is accompanied by many statistics, including the eigenvalue, trace statistic, 0.05 critical value, probability, max-eigen statistic, and associated critical values and probabilities. The null hypothesis is rejected when the value of the test statistic surpasses the critical threshold. In this scenario, while considering the "None" hypothesis, both the trace statistic (661.97) and max-eigen statistic (220.89) surpass their respective critical levels (197.37 and 58.43), with a probability of 0.00. Therefore, the authors should reject the null hypothesis of no cointegration. The test statistics are consistently above the crucial levels for several subsequent rows as we go through the table. The max-eigen statistic (32.88) falls below its critical value (33.88) with a probability of 0.07 when we reach "At most 4". These findings indicate the presence of four cointegrating interactions inside the system.

Table 5: Cointegration test

Hypothesised No. of C.E. (s)	**Eigenvalue**	**Trace Statistic**	**0,05 Critical Value**	**Prob.****	**Max-Eigen Statistic**	**0,05 Critical Value**	**Prob.***
None *	0,89	661,97	197,37	0	220,89	58,43	-

At most 1 *	0,76	441,08	159,53	-	144,09	52,36	-
At most 2 *	0,72	296,99	125,62	-	128,06	46,23	-
At most 3 *	0,48	168,93	95,75	-	65,8	40,08	-
At most 4 *	0,28	103,13	69,82	-	32,88	33,88	0,07

To ensure reliability and validity, the authors employed a range of diagnostic tests (table 6), which included an analysis of residual serial correlation in the computed model. The authors employed the Breusch-Godfrey Serial Correlation L.M. test. The test produced a serial correlation test with a Probability F value of 0.6389, statistically significant at a level exceeding 0.05. The results derived from L.M. demonstrate no serial correlation among the independent variables, suggesting that no relationship was observed between these variables. In the meantime, the normality test evaluated the data distribution of the independent and dependent variables within the resulting regression equation to determine if they adhered to a typical or atypical distribution. Regression equations are deemed effective when they incorporate independent variable data and dependent variable data that closely correspond with the anticipated values.

Table 6: Breusch-Godfrey Serial Correlation LM Test

F-statistic	0,63609	Prob. F (4,56)	0,6389
Obs*R-squared	4,38948	Prob. Chi-Square (4)	0,3559

The reliability assessment conducted through the CUSUM test utilised the cumulative sum of 5 per cent regression equation errors, employing critical lines as a benchmark. The findings indicate that the parameters of the equation remain stable as the cumulative errors near the two significant thresholds. The results demonstrated stability as indicated by the CUSUM test. The Squares CUSUM test is performed and evaluated like the CUSUM test, with the sole distinction being the utilisation of recursive duplicated errors instead of recursive errors. Conversely, the authors verify that the homoscedasticity assumption is satisfied to ensure precise regression results.

Under the ARDL model (tables 7 and 8), the result displayed long-term and short-term findings with eight distinct factors and their statistical correlations with the dependent variable. The most notable characteristic is the diverse range of statistical significance seen among these parameters. The association between Fossil Fuel Consumption (FFC) and the given coefficient of -0.970 is quite strong, as shown by the exceptionally high t-statistic of -2894.107. The data suggests a robust inverse correlation between the dependent variable and fossil fuel usage in the long term. Specifically, as fossil fuel consumption falls, the dependent variable (presumably renewable energy consumption) tends to grow. A probability value of 0.000 suggests that this link is very statistically significant. The link between Primary Energy Consumption (PEC) and the coefficient of -0.054, together with a t-statistic of -15.591, is very negative. This is consistent with the anticipation that as the generation of power from coal falls, the use of renewable energy will rise. The variables Gross Fixed Capital (GFC) and Labor Force (LF) exhibit strong negative correlations, with t-statistics of -13.548 and -12.468, respectively.

Table 7: ARDL - Long Run Causality

Variable	Coefficient	Std. Error	t-Statistic	Prob.*
EC	0	0	-1,231	0,223
PEC	-0,054	0,003	-15,591	0
FFC	-0,97	0	-2894,107	0
GDP	-0,001	0,001	-1,287	0,203
GFC	-0,041	0,003	-13,548	0
IVA	-0,001	0,001	-1,19	0,239
LF	-0,033	0,003	-12,468	0
POP	-0,041	0,008	-4,926	0

* significant level at the 0.01 level, ** at 0.05 level

This implies a negative correlation between capital investment, labour force, and the dependent variable. This might indicate an intricate connection between economic development and the use of renewable energy. The variable "Population" (POP) has a strong negative correlation (t-statistic: -4.926), indicating that an increase in population leads to a reduction in the dependent variable. Surprisingly, there is no statistically significant correlation between Energy Consumption (EC), GDP, and Industry Value Added (IVA) with the dependent variable. This is supported by their high p-values (>0.05) and low t-statistics. The findings indicate an intricate interaction between economic variables and the use of renewable energy.

Table 8: ARDL – Short Run Causality

Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.***
REC (-1)	-2,081	0,265	-7,852	0
REC (-2)	-0,771	0,281	-2,747	0,008
REC (-3)	-0,888	0,283	-3,137	0,003
REC (-4)	-0,881	0,173	-5,1	0
EC (-1)	-0,001	0	-1,546	0,127
EC (-2)	0,001	0	1,887	0,064
EC (-3)	-0,001	0	-1,55	0,127
EC (-4)	-0,001	0	-2,039	0,046
PEC (-1)	0,048	0,005	10,357	0
PEC (-2)	0,029	0,007	4,496	0
PEC (-3)	-0,002	0,006	-0,303	0,763
PEC (-4)	0,023	0,005	4,701	0
FFC (-1)	-2,007	0,256	-7,842	0
FFC (-2)	-0,746	0,271	-2,756	0,008
FFC (-3)	-0,856	0,273	-3,134	0,003
FFC (-4)	-0,85	0,167	-5,093	0
GDP(-1)	0,002	0,001	1,415	0,162
GFC (-1)	0,045	0,004	11,875	0
GFC (-2)	0,023	0,007	3,435	0,001
GFC (-3)	0,015	0,006	2,53	0,014
GFC (-4)	0,014	0,005	2,853	0,006
IVA (-1)	0,002	0,001	1,414	0,163
IVA (-2)	-0,001	0	-2,665	0,01
IVA (-3)	0	0	0,901	0,371

IVA (-4)	0,001	0	2,58	0,012
LF (-1)	0,039	0,003	11,819	0
LF (-2)	0,01	0,006	1,7	0,094
LF (-3)	0,015	0,005	3,168	0,002
LF (-4)	0,009	0,004	2,425	0,018
POP (-1)	0,034	0,012	2,911	0,005
POP (-2)	0,019	0,011	1,819	0,074
POP (-3)	0,046	0,011	4,087	0
C	0,678	1,099	0,617	0,539

* significant level at the 0.01 level, ** at 0.05 level

The ECM Model (table 9) showed that the data presented examines the relationship between renewable energy consumption (REC) and several economic indicators. The cointegration equation suggests long-term equilibrium relationships, while the error correction terms indicate short-term dynamics and speed of adjustment to equilibrium. REC (-1) has a coefficient of 1.000 in the cointegration equation, serving as the dependent variable. The error correction term for REC is -97.179, suggesting a relatively rapid speed of adjustment to equilibrium deviations. Energy consumption (EC) shows a positive relationship with REC in the long run (4.893), but its impact appears minimal in the short term (0.001). This might indicate that overall energy use trends are positive, with renewable energy adoption over time. Primary Energy Consumption (PEC) demonstrates a strong negative relationship with REC both in the long (-274.525) and short term (4.038). This inverse relationship suggests that as renewable energy consumption increases, reliance on coal-based electricity decreases significantly. Fossil fuel consumption (FFC) shows a positive long-term relationship (101.588) with REC, which may seem counterintuitive.

However, this could indicate that countries with higher overall energy consumption invest more in renewables. GDP has a negative long-term coefficient (-117.891) but a minimal short-term effect (-0.119). This might suggest that economic growth does not significantly impact renewable energy adoption in the short run, but there could be a more complex relationship over time. Other factors like gross fixed capital formation (GFC), industry value added (IVA), and labour productivity (L.P.) show varying degrees of influence on REC, highlighting the complex interplay between economic development and renewable energy adoption. The population variable shows a slightly positive long-term relationship (1.922) with REC, suggesting that population growth may contribute to increased renewable energy consumption over time.

Table 9: Error Correction Term Model

CoIntegration Equation	**Renewal Energy Consumption**		
	Coefficient in ICT	**Coefficient of ECT**	**Product-Speed of Adjustment**
REC (-1)	1	-97,179	-97,179
		[-0.71131]	
EC (-1)	0	4,893	0,001
	[2.19191]	[0.06235]	
EPC (-1)	-0,015	-274,525	4,038
	[-21.3682]	[-10.6213] *	

FFC (-1)	0,965	101,588	97,994
	[6988.50]	[0.71969]	
GDP (-1)	0,001	-117,891	-0,119
	[3.13482]	[-1.09036]	
GFC (-1)	-0,021	541,144	-11,45
	[-26.6637]	[11.9367] *	
IVA (-1)	0,001	160,099	0,16
	[3.31782]	[1.43405]	
LP (-1)	-0,016	-339,218	5,35
	[-27.4237]	[-6.14827]	
POP (-1)	-0,028	1,922	-0,053
	[-23.6433]	[0.67307]	
Coefficient	-0,265		

* Accepted Null hypothesis on 0.01 level

DISCUSSION

The ARDL model analysis result found that variable REC has substantial negative coefficients across all four lags, suggesting a robust autoregressive association. This indicates that previous levels of renewable energy consumption significantly influence its present levels, with the most pronounced impact seen in the most recent era (REC (-1) with a coefficient of -2.081). The use of fossil fuels (FFC) has a similar pattern to that of REC, with significant negative coefficients seen at all time delays. There is a clear and significant negative correlation between the use of fossil fuels and the consumption of renewable energy in the near term. This is in line with the assumption that a rise in the adoption of renewable energy results in a reduction in the use of fossil fuels. The link between electricity production and coal is more intricate in the case of Primary Energy Consumption (PEC). The coefficients of the first, second, and fourth lags are statistically significant and positively connected, indicating that short-term increases in coal-based power generation are linked to increases in renewable energy consumption. This paradoxical outcome might be attributed to the general increase in energy demand or implementing policies to achieve energy source equilibrium. The coefficients for both Gross Fixed Capital (GFC) and Labor Force (LF) exhibit primarily positive and statistically significant values over their respective time delays.

This implies that when there is an increase in capital investment and labour force, there is also a short-term rise in renewable energy consumption. This might be due to the general expansion of the economy and the investment in new energy technology. The Energy usage (EC) analysis yields inconclusive findings with little statistical significance, suggesting a tenuous and transient correlation with the usage of renewable energy. The limited substantial connections between GDP and Industry Value Added (IVA) indicate that general economic indicators may have a lesser direct influence on the uptake of renewable energy. The variable "Population" (POP) has substantial and statistically significant coefficients, especially for the first and third-time delays. This suggests that an increase in population is likely linked to a rise in renewable energy consumption shortly. Table 7 shows that the ARDL model uncovers intricate short-term patterns in renewable energy usage. Although there is an evident negative correlation with the use of fossil fuels, other variables, such as the generation of power from coal, financial investment, and population expansion, show positive connections in the immediate timeframe.

The findings emphasize the complex and diverse aspects of the shift towards renewable energy, driven by a combination of economic, demographic, and energy-related variables in the near term.
The research also found there was a strong negative correlation between fossil fuel consumption (FFC) and renewable energy consumption (REC) in the long term (-0.970), which aligns with the findings of [17], who observed a bidirectional causal relationship between renewable energy consumption and fossil fuel use in BRICS countries. This suggests that as renewable energy adoption increases, fossil fuel consumption decreases, supporting the hypothesis that renewable energy can substitute fossil fuels in the long run. Additionally, the rapid adjustment speed of the error correction term for REC (-97.179), as shown in Table 8, indicated that Indonesia could respond dynamically to changes in energy demand, potentially accelerating the transition to renewables in the face of energy scarcity.

However, the positive long-term relationship between FFC and REC (coefficient of 101.588) suggests fossil fuels may still stabilise Indonesia's energy mix, particularly during geopolitical instability or energy scarcity. This finding is consistent with [18], who argue that renewable energy growth often supplements rather than replaces fossil fuel use, a phenomenon they term "energy addition." This implies that simply increasing renewable energy capacity may not be sufficient to completely transition away from fossil fuels, especially in developing economies like Indonesia, where energy security concerns prioritise short-term fossil fuel use over long-term sustainability goals.

The positive correlations between Gross Fixed Capital (GFC), the labour force (LF), and REC suggest that economic growth and investment are critical enablers of renewable energy adoption. This is supported by [19], who found that capital formation and labour force characteristics significantly influence emission patterns and energy transitions. In Indonesia, increased capital investment in renewable energy technologies and a growing labour force could drive the energy transition, particularly in the short term. Furthermore, [20] highlight that renewable energy consumption can have positive economic effects, especially in countries where renewable energy penetration is below a certain threshold. This suggests that with its relatively low current levels of renewable energy adoption, Indonesia could benefit economically from increased investment in renewables. However, the negative long-term coefficient for GDP (-117.891) indicates that economic growth alone may not be sufficient to drive renewable energy adoption. This aligns with [21], who found that the relationship between economic growth and energy consumption is highly context-dependent and often nonlinear. In Indonesia, the pursuit of rapid economic growth may initially lead to increased reliance on fossil fuels, particularly in energy-intensive industries. This creates a tension between short-term economic objectives and long-term sustainability goals, as highlighted by [22] in their study of China's energy transition. Policymakers must, therefore, design strategies that balance immediate economic needs with long-term investments in renewable energy infrastructure.

The positive long-term relationship between population POP and REC (coefficient of 1.922) suggests that population growth may contribute to increased renewable energy consumption over time. This is supported by (Bilan et al., 2019), who found that population dynamics significantly influence renewable energy adoption, particularly in countries with more significant populations. In Indonesia, a growing population could drive demand for cleaner energy sources, particularly as urbanisation increases and energy needs expand. This demographic shift could create opportunities for scaling up renewable energy infrastructure, particularly in urban areas where energy demand is concentrated. However, the short-term negative correlation between population growth and REC (t-statistic: -4.926) indicates that immediate increases in population may strain existing energy systems, leading to greater reliance on fossil fuels. This is consistent with [24], who found that urbanisation initially increases CO_2 emissions, as expanding urban populations require more energy, often met through conventional sources. In Indonesia, rapid urbanisation and population growth pose challenges for the energy transition [25], mainly if renewable energy infrastructure is not developed with demographic changes.

Our findings support both hypothesised responses to geopolitical risks and energy scarcity in Indonesia. The short-term increase in fossil fuel consumption (H1) and long-term acceleration of renewable energy investments (H2). The research reveals a dual impact of energy scarcity risks on Indonesia's energy transition. Short-term geopolitical uncertainties increase fossil fuel reliance, while long-term risks accelerate renewable energy investments. [26] support this complex relationship, finding that energy security concerns can simultaneously serve as both barriers and drivers of renewable energy transitions, creating multifaceted policy challenges. In Indonesia, geopolitical risks could incentivise long-term investments in renewable energy to achieve greater energy independence and reduce vulnerability to external supply shocks. Nonetheless, the temporary rise in dependence on fossil fuels amid geopolitical tensions underscores the difficulties in reconciling urgent energy security requirements with enduring sustainability objectives. This tension holds significant importance for emerging economies such as Indonesia, where the risks associated with energy scarcity are frequently more pronounced than in developed countries. [1] highlights that nations with emerging economies encounter distinct obstacles in navigating these trade-offs, as they must tackle urgent energy security issues alongside long-term goals for environmental sustainability. Consequently, Indonesian policymakers must formulate thorough strategies that cater to immediate energy requirements while considering long-term transition objectives. This could involve the development of diversified energy portfolios that incorporate both renewable and transitional energy sources, such as natural gas.

The results highlight the importance of a well-rounded strategy for Indonesia's energy transition, focusing on immediate energy security issues while considering long-term sustainability objectives. Initially, Indonesia should broaden its energy portfolio by integrating renewable energy sources alongside transitional fuels such as natural gas. This approach is backed by the findings of [17], which indicate that natural gas can effectively function as a "bridge fuel" in the transition to renewable energy, offering stability as renewable capacity is developed. Second, increasing renewable energy capacity may prove insufficient to achieve a complete transition away from fossil fuels. [18] emphasise the need for direct policies targeting fossil fuel reduction, such as carbon pricing mechanisms or planned phasedown schedules for coal and oil. Without such targeted measures, renewable energy growth may simply supplement rather than replace fossil fuel consumption.

Third, economic growth and capital investment represent critical enablers of renewable energy adoption. [19], highlight the importance of capital formation in driving energy transitions, suggesting that Indonesia should prioritise investments in renewable energy infrastructure, particularly in urban areas experiencing high energy demand growth. Such investments could create positive feedback loops between economic development and sustainable energy adoption. Fourth, population growth and urbanisation present opportunities and challenges for Indonesia's energy transition. Policymakers should develop proactive strategies to manage the energy demands of a growing population while simultaneously scaling up renewable energy infrastructure in rapidly urbanising areas. This requires integrated planning approaches that consider demographic projections alongside energy system development.

Finally, policy consistency emerges as a crucial factor in successful energy transitions. [26] found that regulatory stability significantly influences renewable energy investment decisions. Indonesia should, therefore, establish stable, long-term renewable energy policies to provide certainty for investors and stakeholders, creating an environment conducive to sustained renewable energy development despite short-term economic or political pressures. By implementing these recommendations, Indonesia can navigate the complex challenges of its energy transition, balancing immediate energy security needs with long-term sustainability goals while leveraging the potential economic and environmental benefits of renewable energy adoption.

CONCLUSION

This study examined the dual impact of energy scarcity risks and geopolitical uncertainties on Indonesia's transition to renewable energy, focusing on understanding how these factors influence both short-term energy security needs and long-term sustainability goals. By employing the Autoregressive Distributed Lag (ARDL) model and analysing time-series data from 1990 to 2017, the research aimed to provide insights into the complex dynamics of energy transitions in a developing economy. The findings reveal a dual impact of energy scarcity risks on Indonesia's energy transition. In the short term, geopolitical uncertainties and immediate energy security concerns lead to increased reliance on fossil fuels, as evidenced by the positive relationship between fossil fuel consumption (FFC) and renewable energy consumption (REC) in the long run (coefficient of 101.588). The result suggests that fossil fuels play a stabilising role in addressing immediate energy needs during geopolitical instability. However, in the long term, these same risks accelerate investments in renewable energy, as indicated by the rapid adjustment speed of the error correction term for REC (-97.179). The result highlights the dynamic response of energy policy to changing geopolitical conditions and the pursuit of energy independence.

The study also underscores the importance of economic variables such as Gross Fixed Capital (GFC) and labour force (LF) in driving renewable energy adoption. The positive correlations between these variables and REC suggest that economic growth and investment are critical enablers of the energy transition. However, the findings also reveal that economic factors do not solely drive the transition to renewable energy but are significantly influenced by geopolitical risks and energy scarcity. From these results, several key conclusions can be drawn. First, the transition to renewable energy in Indonesia is a complex process that requires balancing short-term energy security needs with long-term sustainability goals. Policymakers must recognise the dual impact of geopolitical risks and design strategies that address immediate energy demands while fostering long-term investments in renewable energy. Second, economic growth and investment are crucial in facilitating the energy transition, but their effectiveness depends on coordinated policies and stakeholder collaboration. Finally, the study highlights the importance of understanding the unique challenges faced by developing countries like Indonesia, where both domestic and global factors influence energy transitions.

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