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Policy Instruments Reform for Growth and Renewable Energy Transition in the Southeast Asia Region

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Abstract

One of the strategies used to decrease the production of greenhouse gases is to promote the use of clean, renewable energy. Mitigation initiatives are also part of the action plan to meet the Paris Agreement, which aims to keep global temperature rise below 1.5°C. The growth of the new and renewable energy mix is influenced by a variety of factors, including the economy, technology, energy consumption behavior, financial support, and policy instruments implemented by a country. The novelty of this study lies in examining the effects of five policy tools (i.e., net metering, feed-in tariffs, renewable portfolio standards/quotas, tax incentives, and auctions) on renewable energy growth across Southeast Asian countries grouped by gross domestic product per capita level, which are high (i.e., Singapore, Brunei), upper-middle (i.e., Indonesia, Malaysia, Thailand), and lower-middle (i.e., Cambodia, Myanmar). A fixed-effect model under the Feasible Generalized Least Squares approach was used for panel data estimation with data spanning from 2010 to 2022. It was found that of the 5 policy instruments utilized, net metering, feed-in tariffs, and renewable energy portfolios had a substantial impact on the accelerating renewable energy growth. In comparison, auctions and tax incentives did not. According to the findings, the three types of policy instruments can be strengthened and utilized as recommendations to accelerate the transition to new and renewable energy.

Keywords:

energy policy instrument, fixed-Effect Model, GDP per capita, policy reform, renewable energy growth.

1. Introduction

Climate change, driven by greenhouse gas or carbon emissions, has resulted in extreme weather, rising sea levels, and a 1.43°C increase in global temperatures compared to pre-industrial times (Anderson et al., 2016; Bevacqua et al., 2025; Gao et al., 2017). To combat these effects, the Paris Agreement was established at COP21 in 2015 and has been ratified by 195 countries, including Southeast Asia (SEA) countries. Its primary objective is to limit global warming to below 2°C, while striving to keep it under 1.5°C. Each country contributes to this effort through Nationally Determined Contributions (NDCs), which are reviewed every five years (Siriwardana & Nong, 2021; Umar & Safi, 2023).

The aspect highlighted in the Nationally Determined Contributions (NDC) regarding the reduction of carbon emissions pertains to the energy sector, specifically the electricity subsector, which is considered a key area of ambition. Countries in SEA have expressed their concern over achieving a 23% share of renewable energy (RE) in total primary energy supply and a 35% share of RE in SEA's installed power capacity by 2025 (ACE & IRENA, 2016). The abundance of RE sources in SEA is shown by the highest potential of solar irradiation at around 5.3 kWh/m²/day in Thailand and Lao PDR, 28.9 GW and 75 GW of geothermal and hydropower in Indonesia, and wind speeds of 6-7 m/s in Thailand and the Philippines (Veng et al., 2020).

Renewable energy sources in SEA are underutilized, with reliance on fossil fuels exceeding 70% in 2022. This highlights the need for stronger RE policies to accelerate growth, decarbonization, and energy efficiency (Aleluia et al., 2022; Galeazzi et al., 2024). Nevertheless, RE policy instruments in SEA have evolved significantly over time. Initially, Feed-in Tariffs (FiTs) and tax incentives (TI) were primarily employed to facilitate market entry. As the market matured, net metering (NM) and auctions (AUC) were introduced to enhance competitiveness, while Renewable Portfolio Standards (RPS) concentrated on the long-term integration and stability of RE sources (Sharif et al., 2023; Yan et al., 2023). The implementation of these policies in SEA countries varies according to their specific objectives for achieving RE targets, meeting electricity and energy demand, and attracting financial investment. Notably, a country's gross domestic product (GDP) per capita plays a critical role in shaping the deployment of RE policies.

RE policy instruments, e.g., FiTs involving independent power producers in generating RE and guarantees a fixed price to producers, have accelerated deployment in countries like Thailand and Vietnam, which achieved over 16 GW of solar photovoltaic (PV) capacity by 2020, despite challenges related to fairness and regional disparities. Recently, governments have shifted toward auction (AUC) mechanisms to improve cost efficiency and a real cost analysis approach. For example, Cambodia's reverse auction resulted in record-low solar prices, with similar large-scale tenders initiated in Malaysia and Myanmar (Aleluia et al., 2022; Sreenath et al., 2022). At the distributed scale, NM schemes in Malaysia, Thailand, the Philippines, and Singapore enable rooftop solar producers to offset their electricity bills, promoting household and small-scale adoption (Aleluia et al., 2022; Sreenath et al., 2022). Concurrently, RPS is being implemented to mandate renewable shares in power plants and national grids, supporting ASEAN's target of 23% renewables by 2025, along with national goals like Indonesia's 25.9% by 2025 and the Philippines' 50% by 2030 (Chang & Li, 2015). Lastly, tax incentives (including tax holidays, duty exemptions, value-added tax, and investment benefits) are crucial for reducing project costs and stimulating private investment, which is applied almost in Southeast Asian countries.

Previous research in SEA has established a correlation between RE policies and the RE Growth (REG). Several studies have simulated scenarios for FiT and RPS in Southeast Asian countries (Azhgaliyeva et al., 2024; Sharif et al., 2023). While others have explored tax incentives as a form of fiscal policy (Cansino et al., 2010; Yan et al., 2023). Additionally, other RE policy instruments in Southeast Asia are extensively examined using descriptive methodologies (Erdiwansyah et al., 2019; Sreenath et al., 2022). Roles of hydropower (HP) and solar PV as control variables or alternative energy sources are vital for understanding the potential capacity for RE in Southeast Asia, as underscored in comparable studies conducted in regions outside Southeast Asia (Aguirre & Ibikunle, 2014; Bersalli et al., 2020; Kersey et al., 2021). The analysis of energy economics encompasses energy (ENC) and electricity (ELC) consumption, as well as GDP per capita. Following the findings from Chang & Li (2015) and Erdiwansyah et al. (2019) these variables reflect the energy requirements and economic viability for investing in RE technology. Finally, the carbon emission factor serves as a critical indicator in the advancement of clean and renewable energy, a subject frequently addressed in journals (Aguirre & Ibikunle, 2014; Kersey et al., 2021).

However, few studies have statistically analyzed the effectiveness of RE policies in relation to GDP per capita. This research aims to address the novelty from this gap by categorizing countries choosen into three income groups based on GDP per capita (High, Upper-Middle, and Lower-Middle) using World Bank data from 2010 to 2022. This timeframe encompasses the initial implementation of RE policies, the release of the Paris Agreement, and the impacts of events such as the COVID-19 pandemic. Table 1 outlines the countries studied, the types of RE policies implemented, and their starting years (ACE & CREEI, 2018; ACE, 2024; IRENA, 2022). Ultimately, this discussion seeks to provide insights for governance, investors, the RE industry, and policymakers, identifying which RE policies are most effective in promoting REG. Furthermore, the findings can inform further analysis by relevant stakeholders to determine the necessary investment levels based on the results.

Table 1. The RE policy applied in South-East Asian countries, and the year it was applied.

	NM	FiTs	RPS	TI	AUC
Indonesia	2013	2012	2017	2010	2013 & 2017
Malaysia	2016	2011	2016	2014	2016, 2017, 2020, & 2021
Singapore	2017	-	-	-	2015
Thailand	2017	2010	2010	2017	2016 & 2017
Brunei	2022	-	-	-	-
Cambodia	-	-	-	2018	2019 & 2021
Myanmar	-	-	-	2016	2020 & 2021

2. Methods and Materials

The study uses panel data from 2010 to 2022, combining time series and cross-sectional data from 7 SEA countries. Data processing is performed with Stata software. The modeling approach is a multiple linear regression model, tested with Hausman and Chow tests to determine the appropriate model between fixed effect, random effects, or common effects (Liu et al., 2019). The fixed effects and common effect model are part of Ordinary Least Squares, but the fixed effect treats the intercept as varying across different cross-sections or time-invariant through the Least Squares dummy variable (Ghoshray & Lurosso, 2025; Hoang & Wooldridge, 2024). Meanwhile, the random effect explains the differential intercept of each cross-sectional data using the error term of each individual.

In panel data analysis, the regression coefficients must satisfy the conditions of the Best Linear Unbiased Estimator to enhance the robustness of the analysis. Consequently, additional testing is often required, commonly referred to as classical assumptions. The initial test assesses the presence of multicollinearity, employing the variance inflation factor (VIF) with a threshold value of 10 (Cheng et al., 2022; Mustafa, 2022). Multicollinearity indicates a strong correlation among the independent variables used in the study (Leiby & Ahner, 2023), which can negatively impact the stability of the regression coefficients. As outlined by Yu et al., (2015), addressing multicollinearity can be (1) increasing the sample size, (2) narrowing the research parameters, (3) omitting certain variables, or (4) transforming variables. In this study, the transformation of data variables into their differentiated form is implemented to mitigate multicollinearity issues (Singh et al., 2023).

Following the resolution of multicollinearity, classical assumption testing proceeds with a heteroscedasticity test. Heteroscedasticity occurs when there is a non-constant variance of the error term after a predictor is included in the regression model. This issue typically arises due to there's an outlier data (Lau et al., 2019). In panel data that successfully passes the classical assumption tests, the data is modeled using a selected model with a feasible generalized least squares (FGLS) estimator method. This estimator is suitable for panel data exhibiting heteroscedasticity (Gnecco et al., 2021; Miller & Startz, 2019), also be applied when the number of time observations exceeds the number of cross-sectional observations, or T > N (Aguirre & Ibikunle, 2014).

Our study uses the model in Equation 1. Y_{it} is the dependent variable that measures the ratio of REG (in terms of electricity) in the country i at year t. The coefficient of the intercept of the regression model when there is no other variable applied in the country i at year t is expressed as $\beta_{0\mathrm{i}}$. Meanwhile, the coefficient of slope for the RE policy is β_D and the β_1 shows the slope for control variables for each country at the year t. The independent variable and control variable are written in the equation as X_{it}. The number of error terms for all countries and all years is denoted as e_{it}.

$$Y_{it} = \beta_{0i} + \sum_{D=1}^{n} \beta_D X_{it} + \sum_{k=1}^{n} \beta_k X_{it} + e_{it} \tag{1}$$

The value of the coefficient before and after FGLS would result from the matrix transformation is shown in Equations 2 and 3. The differences arise from the use of $\widehat{\Omega}^{-1}$. This symbol is derived from the transformation of a nonsingular matrix. The matrix then became an identity matrix, or the heteroscedasticity has been handled, resulting in homoscedasticity. For the independent variable (i.e., RE policy instrument), the variable is presented as a dummy variable so that it is binary. It is coded 1 if the policy instrument is applied to the country in the range of years studied; otherwise, it is coded 0. However, if a country applies more than one type of policy instrument included in this study, then the country will have a multiple value of 1 adjusted for the year of enactment of the regulation.

$$\hat{\beta}_{Before\ FGLS} = \left(\sum_{i=1}^{N} \ddot{X}_i'\ddot{X}_i\right)^{-1}\left(\sum_{i=1}^{N} \ddot{X}_i'\,\ddot{y}_i\right) \tag{2}$$

$$\hat{\beta}_{FGLS} = \left(\sum_{i=1}^{N} \ddot{X}_i'\,\widehat{\Omega}^{-1}\ddot{X}_i\right)^{-1}\left(\sum_{i=1}^{N} \ddot{X}_i'\,\widehat{\Omega}^{-1}\ddot{y}_i\right) \tag{3}$$

Our study employs multiple datasets of SEA countries from 2010 to 2022, encompassing information on energy policy instruments, economic development, energy alternatives, and environmental considerations. All data were sourced from reputable secondary bank sources. The analysis focuses on seven countries categorized by GDP level, which are High-Income Countries (Brunei and Singapore), Upper-Middle-Income Countries (Indonesia, Malaysia, and Thailand), and Lower-Middle-Income Countries (Cambodia and Myanmar). The primary explanatory variables include net metering (NM), Feed-In Tariff (FiT), Renewable Portfolio Standard (RPS) or quota, tax incentives (TI), and auction (AUC). Table 2 offers definitions for the variables utilized in the empirical analysis.

Table 2. Schematic of variables used in the study & hypothesized effects on the dependent variable.

Variables	Hypothesized Effects on the Dependent Variable	Data Source
Dependent Variable		
REG in % of electricity supply		(IRENA, 2025)
Independent Variables		
NM FiT RPS TI AUC	(+) Countries that implement RE policies have the potential to have a higher amount of REG growth.	(ACE & CREEI, 2018; ACE, 2024; Ghazanchyan et al, 2018; IRENA, 2022)
Control Variables: Energy Substitute variables		
Hydropower (HP) in GWh	(+) Countries with a high hydropower or low-carbon energy mix have high REG.	(IRENA, 2025)
Solar PV (PV) in GWh	(+) Countries with a high Solar PV or low-carbon energy mix have high REG.	(IRENA, 2025)
Control Variables: Energy Economic Variable		
Energy Consumption (ENC) in TWh	(+) Countries with high energy consumption require large energy supplies, including from REG.	(IEA, 2022)
Electricity consumption (ELC) in TWh	(+) Countries with high electricity consumption require a large supply of electricity, including from the REG.	(IEA, 2022)
GDP per Capita (GDP) in current USD	(+) Countries with high GDP per capita are more likely to invest in technologies that support REG.	(World Bank Data, 2025)
Control Variables: Environmental variable		

Variables	Hypothesized Effects on the Dependent Variable	Data Source
CO_2 Emission (CO_2) in ton CO_2 per capita	(-) REG will increase clean energy, which reduces carbon emissions.	(IEA, 2022)

3. Results and Discussions

3.1 Simulation Result from Statistical Modeling

The study utilizes strongly balanced panel data for each identity, encompassing an equal number of research years. A total of 91 observations were generated, with the descriptive statistical values presented in Table 3. The analysis indicates that all data exhibit a positive mean value. Furthermore, the standard deviation for all variables exceeds the mean, suggesting variability among the data items. Regarding the independent variables of the policy instrument, the minimum value is 0.00, and the maximum value is 1.00, as these variables are binary dummy variables.

Table 3. Descriptive statistics and the results of multicolinearity test

Variables	Mean	St. Dev	Min	Max	VIF value	VIF value after differentiation
RE	0.22	0.23	$2x10^{-4}$	0.77		
NM	0.44	0.5	0	1	18.72	5.60
FIT	0.35	0.48	0	1	10.69	6.61
RPS	0.21	0.41	0	1	17.22	3.26
TI	0.44	0.5	0	1	8.25	5.49
AUC	0.21	0.41	0	1	1.84	1.77
HP	8.09	8.55	0	27.3	49.83	8.82
PV	0.54	1.26	$6x10^{-4}$	5.14	16.06	4.24
ENC	580.47	600.29	13.77	2040.47	583.56	2.20[1]
ELC	90.56	90.67	2.27	350.55	259.87	3.03[1]
GDP	1.71	2.19	0.09	8.84	37.11	7.42
CO_2	5.5	5.62	0.16	21.3	90.75	4.20

[1] Notation for variables that performed data differentiation

To determine the appropriate linear regression model for the research panel data, the Hausman and Chow tests were conducted. The Hausman test, assessing the Fixed-Effect versus Random-Effect models, yielded a p-value of 0.0012 (Table 4). Since this p-value is less than 0.05, weleading to rejection of the null hypothesis (H_0) and accept the alternative hypothesis (H_1), indicating that the Fixed-Effect model is significant. The Chow test, evaluating the Fixed-Effect versus Common-Effect models, produced a p-value of 0.004, also lower than 0.05, confirming the significance of the Fixed-Effect model. The Lagrange Multiplier Test, which distinguishes between the Random-Effect and Common-Effect models, was not conducted, as both preceding tests indicated significance for the Fixed-Effect model.

Table 4. Modeling test.

Modeling test	p-value
Hausman	0.0012
Chow	0.0004

Classical assumption tests, including the multicollinearity test, are interpreted based on the VIF values. Table 3 shows that multicollinearity is present in nearly all variables (VIF > 10). Therefore, one-stage data differentiation was performed on the ENC and ELC variables, resulting in VIF values less than 10 for all variables.

Additionally, the classical assumption tests for homoscedasticity and autocorrelation were conducted using the Modified Wald method and the Breusch-Godfrey LM Serial Correlation test, respectively. Table 5 indicates that the p-value of the Modified Wald Test is 0.0000, less than the alpha value of 0.05, suggesting the panel data exhibit heteroscedasticity. In contrast, the Breusch-Pagan Test yielded a p-value of 0.5259, greater than 0.05, indicating no autocorrelation issues in the model.

Table 5. Homocedastic & autocorrelation test.

Modeling test	p-value
Modified Wald Test	0.0000
Breusch-Godfrey Serial Correlation LM	0.5259

The results of the Fixed-Effect modeling using FGLS are presented in Table 6. The modeling outcomes indicate that the F-test yielded a value of 31.72, with a significance level ("prob > F") of 0.000, which is lower than the 0.05 threshold. This suggests acceptance of the null hypothesis (H_1), indicating that all variables collectively influence REG.

Table 6. Fixed-effect FGLS result.

Y = REG	Coefficient	Standard Error	Significance	Significance Level
NM	-0.12442	0.0252	(-)S	***
FIT	-0.26168	0.0422	(-)S	***
RPS	-0.148589	0.0400	(-)S	***
TI	0 .02038	0.0413	(+)NS	
AUC	-0.00377	0.0152	(-)NS	
HP	0.01098	0.0027	(+)S	***
PV	0.06601	0.0139	(+)S	***
dENC	0.00002	0.0002	(+)NS	
dELC	0.00021	0.0018	(+)NS	
GDP	-0.01601	0.0065	(-)S	**
CO_2	-0.01971	0.0021	(-)S	***
Constanta	0.39388	0.0279	(+)S	***
R^2	0.8289			
Prob > F	0.0000			

Notes: (S): Statistically significant, (NS): Non-significant; Significance Levels: *(10%) **(5%) ***(1%)

Additionally, the t-test results are detailed in the significance column. The independent variables, particularly the energy policy instruments, that exhibit a significant impact on REG include NM, FiT, and RPS, all with a significance level of 1%. Furthermore, the control variables that significantly affect REG include HP energy use, PV, GDP per capita, and CO_2 emissions. Statistically significant energy policy instruments like NM, FiT, and RPS tend to have lower coefficient values. These RE policy instruments significantly affect RE generation as they provide clear regulations, predictable returns, and attract institutional investors through mature technologies (Polzin et al., 2015; Tabatabaei et al., 2017; Watts et al., 2015). However, current regulations are inadequate to effectively enhance investment in RE technology. By contrast, TI and AUC show little impact. TI is weakened by administrative and institutional barriers in emerging economies, while Auctions face challenges of limited capacity, restrictive terms, and regulatory instability (Yang et al., 2019).

In Indonesia, the decline in net metering is linked to regulatory changes regarding rooftop solar installations. Initially, consumer generators could export electricity to the grid under a 1:1 net metering scheme, with installed capacity up to 100% (Kementerian ESDM, 2021). In 2022, the state-owned utility eliminated the ability to inject electricity into the grid and restricted installed capacity to only 10-15% of the total power required. This shift discouraged installers. The number of rooftop solar power customers reflected this trend, growing from 609 in 2018 to 1787 in 2021, but then declining to 1667 in 2022. In Brunei, net metering was set to begin in 2020 but was postponed until 2022 as the country focused on an electric vehicle pilot project until 2021(Brunei Government, 2022).

This condition resembles the FiT policy, as the transition from Feed-in Premium to FiT in Thailand (despite some regions still using the premium scheme) has demotivated Independent Power Producers. This is mainly due to fixed-price offers over long periods that do not align with market price fluctuations. A similar scheme is in place in Malaysia. In contrast, Indonesia has adopted a local production cost-based system, benefiting the state-owned utility, but power producers risk reduced profits, as RE technologies like solar, wind, biomass, and tidal energy receive only 85% of the proposed cost as incentives (ACE & CREEI, 2018; Mentari, 2021). Additionally, the lower coefficients in the Renewable Portfolio Standards (RPS) policy suggest that the regulatory designs in Indonesia, Malaysia, and Thailand are less strong than those in European countries. European nations often integrate their policies with the Tradable Green Certificate system, which includes penalty payments if the expected renewable electricity is not generated (Zhou et al., 2022).

In Southeast Asia, hydropower and solar PV show significantly higher values for RE. ACE & IRENA (2016) state that countries in the region aim to increase RE generation from 9% in 2014 to 23% by 2025, primarily through hydropower and solar PV (Ahmed et al., 2017; Sakti et al., 2023). Hydropower is not viable in Singapore due to a lack of rapid-flowing rivers, prompting a focus on solar PV, which reached 0.74 GW/hour by 2022. Similarly, hydropower is absent in Brunei Darussalam due to its reliance on oil and gas, with 77% of its energy supply sourced from gas as of 2022.

Our estimation shows an insignificant relationship between ENC and ELC, contradicting the hypothesis of a significant correlation. This differs from the findings of Aguirre & Ibikunle (2014) and Bersalli et al. (2020), which reports lower significance. In Southeast Asia, increases in ENC and ELC do not significantly impact REG, despite a direct proportionality. For instance, Indonesia and Thailand, which have the highest growth in energy and electricity consumption and comprehensive renewable policy implementations, show lower REG. In 2022, Indonesia and Thailand recorded 350 and 205 TWh of electricity consumption as the highest among the sample, but REG only reached 19.6% and 19.9%, respectively. Meanwhile, Cambodia had an ELC of only 13.9 TWh but a REG of about 65%. This also shows that less energy is required to fulfill RE technology in their electricity supply.

Regarding the economic variable GDP per capita, Table 6 shows a significantly negative value, slightly deviating from the hypothesis. However, a high GDP per capita correlates with increased energy demand, aligning with Azam et al. (2015) and Tran et al. (2024). In developed countries like those in Europe, GDP per capita typically has a significantly positive impact, as noted by Anton & Afloarei Nucu (2020). Unfortunately, in Southeast Asia, countries with the highest GDP (i,e., Singapore and Brunei Darussalam) exhibit lower REG values compared to those with middle or lower economies. This is due to fewer sources of RE in Singapore and being highly dependent on fossil fuel subsidies in Brunei. Table 7 categorizes each country by GDP per capita into REG. Using Indonesia as the baseline, the intercept shows that upper-middle-income countries have similar average REG characteristics, while high-income countries exhibit the lowest average REG. Conversely, lower-income countries display the highest average REG.

Table 7. Intercept of each country

Country-Income Group	Country	Differential Intercept[1]	Intercept[2]	Remark
Upper-Middle Income	Indonesia	0.39388	0.39388	Baseline
	Malaysia	-0.07566	0.31822	Close to the baseline
	Thailand	-0.08005	0.31383	
High Income	Singapore	-0.14317	0.25071	Lower than the baseline

Country-Income Group	Country	Differential Intercept[1]	Intercept[2]	Remark
	Brunei	-0.15686	0.23702	
Lower-Middle Income	Cambodia	0.34945	0.74333	Higher than the baseline
	Myanmar	0.37359	0.76747	

[1] The differential intercept is derived from a further regression model analysis of fixed effects utilizing the Least Squares Dummy Variable method to understand the average of REG

[2] The intercept consists of the baseline differential intercept plus the differential intercept of a specific country

REG on carbon emissions is hypothesized to be significantly negative. That is, lower carbon emissions are found in countries with higher REG. This statement is in accordance with the results of research conducted in Southeast Asian countries by Tran et al. (2024) and Rahman et al. (2024) and Kilinc-Ata & Proskuryakova (2024) in Asia-Pacific countries.

3.2 Discussion

Our study has used a fixed-effect model to determine the relationship of RE policy implemented in SEA countries to the growth of the RE mix. In addition, a spider chart is developed to classify GDP per Capita related to the policy instrument applied. REG in high-income countries is notably low, as can be seen in Figure 1, particularly in Brunei Darussalam, where REG is close to 0%. The country primarily relies on fossil energy sources, such as coal, gas, and oil, due to its abundant oil reserves. In 2010, Brunei exported 160,000 barrels of oil, although this export volume has been declining (CEIC, 2021). As of 2022, Brunei has begun implementing an NM policy for residential and commercial grid-tied systems with capacities ranging from 1 to 1,000 kWh. Factors contributing to low REG in Brunei include reliance on electricity subsidies and limited land for solar PV installations (Merdekawati et al., 2024).

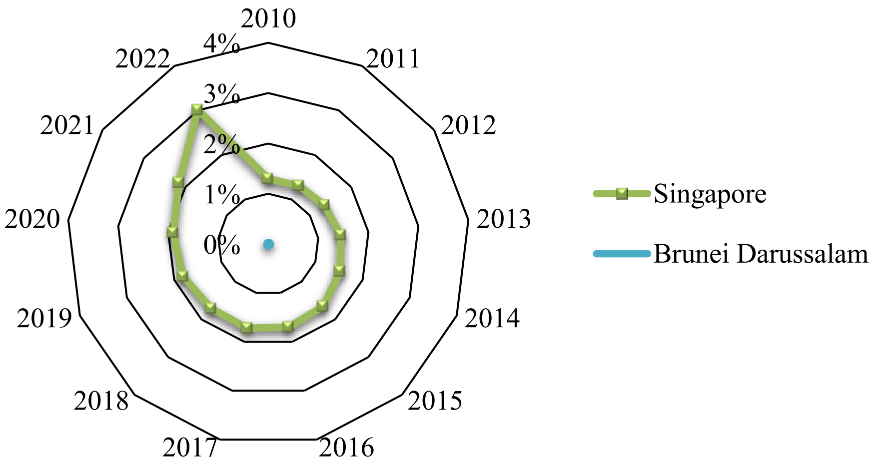

Figure 1. REG (%) in Southeast Asia of high-income countries.

Similarly, Singapore has a stagnant REG from 2010 to 2020, despite implementing an NM scheme in 2017. During this period, Singapore depended heavily on fossil fuels, particularly imported gas. REG in Singapore began to show a slight increase post-2020. By the NM scheme, participants are required to register with the Energy Market Company to sell electricity as wholesale market participants. An auction process in 2015 allocated 405 MWp of solar rooftop capacity over seven rounds, resulting in a total awarded capacity of 366 MWp. According to Our World in Data, electricity generation from solar power in Singapore rose from 0.3 TWh to 0.7 TWh between 2020 and 2022. Despite growing interest in solar PV, Singapore faces significant challenges related to land availability, prompting the exploration of floating solar PV solutions (Vakulchuk et al., 2023).

In middle-income countries, as seen in Figure 2, REG from 2017 to 2022 has shown similar trends due to comparable policy approaches. In Indonesia, the Ministry of Energy and Mineral Resources sets a solar PV target of 3.6 GW; however, only 574 MW has been installed. The NM scheme initially allowed 65% of electricity exports, expanded to 100% in 2021, but was revised in 2022 to restrict rooftop exports to 15%, undermining progress (Kuneman et al., 2024). The FiT system ties tariffs to local production costs relative to the national average, offering up to 85% cost incentives for solar PV, wind, and bioenergy projects, while hydropower, waste-to-energy, and geothermal projects may achieve full recovery (ACE & CREEI, 2018; Kumar Dalapati et al., 2023). This structure reduces incentives for Independent Power Producers, especially in high-cost regions outside of Java.

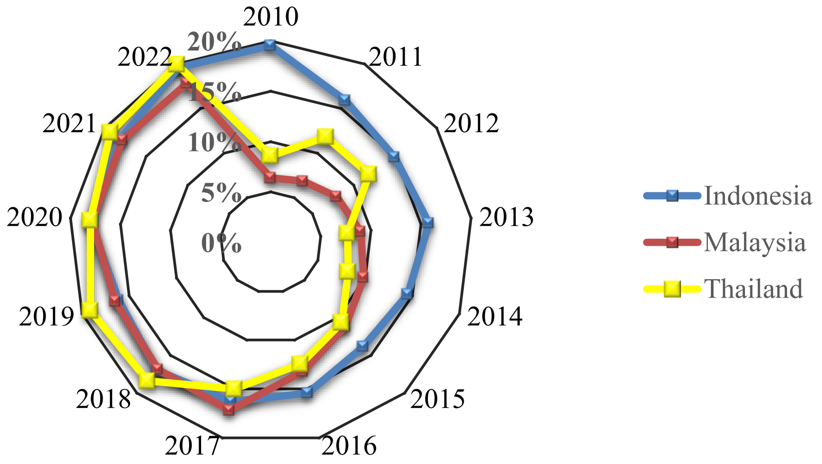

Figure 2. REG (%) in Southeast Asia, middle-upper income countries.

The Indonesia's RPS, implemented by grid zone instead of tradable certificates, establishes negotiable targets but suffers from weak enforcement. Auctions in Indonesia have been ineffective; since 2013, seven solar PV auctions have resulted in only 15 MW due to regulatory uncertainty, grid capacity concerns by the state-owned utility, and inadequate bidding preparation. Geothermal auctions attracted few participants, awarding contracts for only 3 out of 15 offered sites, attributed to a lack of regulatory clarity on tariffs and their impact on investor confidence (IRENA, 2022). Other challenges include high exploration costs and local community opposition. Additionally, TI has generated about USD 1 billion annually, but below the USD 4 billion needed to meet RE investment requirements.

Thailand has emerged as a regional leader in solar PV, generating 5.03 TWh by 2022. The NM scheme applies to households with capacities up to 10 kWh under a 90 MW quota, while FiT has evolved from a premium system to bankable fixed-price schemes. FiTs also support Small and Very Small Power Producers, enabling hybrid renewable generation from sources such as biogas, biomass, solar PV, wind, and hydropower. The RPS further mandated that power plants add at least 5% renewable capacity annually during 2010–2015, with penalties directed to the Renewable Development Fund (Chaowiang & Leeprechanon, 2020). Thailand's auction framework has focused on biogas but initially suffered from low participation due to strict technical requirements. A later hybrid auction successfully awarded 17 projects for 300 MW, with biomass dominating capacity allocation. Fiscal incentives remain modest, including VAT deductions up to 50% and personal income tax deductions of up to THB 200,000 for rooftop solar installations. While limited, these measures provide incremental support for RE deployment (Han et al., 2018).

Malaysia has exhibited a robust interest in NM and solar PV technology, as evidenced by three regulatory phases: 500 MW export quotas established in 2016 and 2019, and a significant 2,400 MW allocation for the period of 2021–2025. The FiT is structured around the levelized cost of electricity, featuring long-term fixed prices and additional incentives for specific renewable sources, such as sewage gas and solid waste. The RPS applied a zonal-based approach in conjunction with Large-Scale

Solar (LSS) planning, in line with the government's objective of achieving a 20% renewable capacity target by 2025. This target is implemented through annual solar PV expansion forecasts as outlined in Malaysia's generation development plan. Malaysia's auction processes frequently attract bids that exceed four times the targeted capacity; however, awards are limited to the planned levels. In a manner similar to Thailand, biomass auctions remain relatively modest, typically around 10 MW, while long-term fixed-price contracts, often exceeding 10 years, tend to deter broader participation (Alcorta et al., 2024; Haufe et al., 2018).

As illustrated in Figure 3, lower-income countries like Cambodia and Myanmar show the highest REG within the sample. In Cambodia, REG grew significantly post-2013 due to hydropower development along the Mekong River, despite a lack of formal RE policies. Auction in Cambodia, including solar PV of 60 MW in 2019 and 40 MW in 2021, facilitated by the Asian Development Bank. While competitive bidding led to low tariffs for consumers, concerns about project viability arose. The existing tax incentives are broad, aligned with general fiscal policies rather than specifically for RE (Song et al., 2020; Yan et al., 2023).

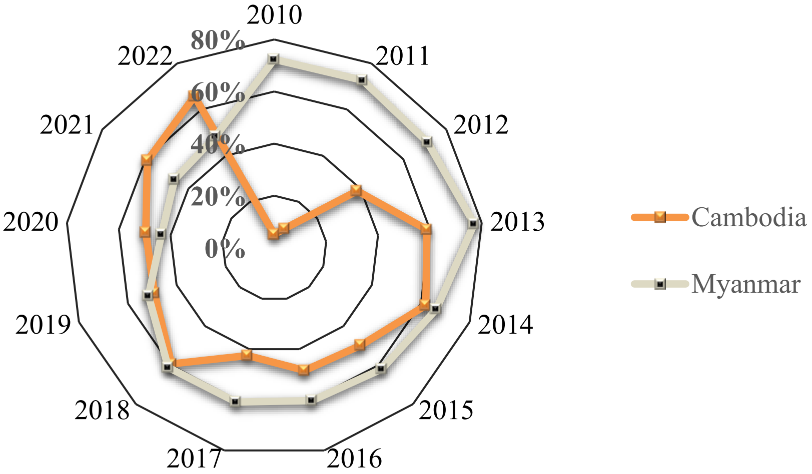

Figure 3. REG (%) in Southeast Asia of lower-upper income countries.

Myanmar follows a similar trend, with hydropower as the main RE source, supplemented by natural gas. Although REG is relatively high, it has stagnated despite TI and auctions implemented in 2016 and 2020. Recent auctions done about 1.06 GW in 2020 and 480 MW in 2021 were mainly led by Chinese investors (IRENA, 2022). The available tax incentives are not directly initiated by the government but stem from investment provisions, including import tax exemptions under ASEAN and Chinese trade agreements.

4. Conclusion

This study applied a multiple linear regression fixed-effect model under the Feasible Generalized Least Squares (FGLS) approach to assess the impact of RE policy instruments on REG in Southeast Asia. The novelty of this research lies in its comparative analysis across countries grouped by GDP per capita. It is found that most effectively supported by net metering (NM), feed-in tariffs (FiTs), and renewable portfolio standards (RPS), while auctions and tax incentives have shown weaker outcomes.

Policy reform should therefore prioritize strengthening NM by extending its scope beyond households to industrial and commercial sectors, designing FiTs that balance investment security with market flexibility, and enhancing RPS with stricter enforcement mechanisms such as penalties for non-compliance. Meanwhile, auctions and tax incentives can be improved through greater administrative transparency, streamlined procedures, and timely payments to developers.

Tailoring these reforms to country income levels is essential: high-income countries should focus on innovative solutions such as floating solar and regional power trade, middle-income countries must improve regulatory consistency and grid reliability, and lower-income countries should emphasize solar auctions and investor confidence alongside hydropower reliance. Strengthening these instruments will provide clearer regulatory signals, attract investment, and accelerate the region's RE transition.

This study has several limitations that can be further developed by subsequent researchers. These limitations include political factors and the lack of information on countries with low GDP per capita of REG through secondary data search. The influence of other regulations, such as education, training, and RE research and development, on REG in the Southeast Asian region can be suggested as topics for further research.

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References

ACE. (2024). *ASEAN Energy Investment 2024, 11*(1). ASEAN Centre for Energy (ACE). Jakarta, Indonesia. https://aseanenergy.org/wp-content/uploads/2024/09/ASEAN-Energy-Investment-2024.pdf

ACE & CREEI. (2018). *ASEAN Feed-In-Tariff (FIT) Mechanism Report - A joint publication of ACE and CREEI*. ASEAN Centre for Energy (ACE) and China Renewable Energy Engineering Institute (CREEI). Jakarta, Indonesia. https://aseanenergy.org/publications/asean-feed-in-tariff-mechanism-report/

ACE & IRENA. (2016). *Renewable Energy Outlook for ASEAN*. ASEAN Centre for Energy (ACE) & International Renewable Energy Agency (IRENA). (2016). Jakarta, Indonesia. https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2022/Sep/IRENA_Renewable_energy_outlook_ASEAN_2022.pdf

Aguirre, M. & Ibikunle, G. (2014). Determinants of renewable energy growth: A global sample analysis. *Energy Policy*, *69*, 374–384. https://doi.org/10.1016/j.enpol.2014.02.036

Ahmed, T., Mekhilef, S., Shah, R., Mithulananthan, N., Seyedmahmoudian, M. & Horan, B. (2017). ASEAN power grid: A secure transmission infrastructure for clean and sustainable energy for South-East Asia. *Renewable and Sustainable Energy Reviews*, *67*, 1420–1435. https://doi.org/10.1016/j.rser.2016.09.055

Alcorta, P., Espinosa, M. P. & Pizarro-Irizar, C. (2024). Right and Duty: Investment Risk Under Different Renewable Energy Support Policies. *Environmental and Resource Economics*, *87*(12). Springer Netherlands. https://doi.org/10.1007/s10640-024-00909-3

Aleluia, J., Tharakan, P., Chikkatur, A. P., Shrimali, G. & Chen, X. (2022). Accelerating a clean energy transition in Southeast Asia: Role of governments and public policy. *Renewable and Sustainable Energy Reviews*, *159*, 112226. https://doi.org/10.1016/j.rser.2022.112226

Anderson, T. R., Hawkins, E. & Jones, P. D. (2016). CO2, the greenhouse effect and global warming: from the pioneering work of Arrhenius and Callendar to today's Earth System Models. *Endeavour*, *40*(3), 178–187. https://doi.org/10.1016/j.endeavour.2016.07.002

Anton, S. G. & Afloarei Nucu, A. E. (2020). The effect of financial development on renewable energy consumption. A panel data approach. *Renewable Energy*, *147*, 330–338. https://doi.org/10.1016/j.renene.2019.09.005

Azam, M., Khan, A. Q., Bakhtyar, B. & Emirullah, C. (2015). The causal relationship between energy consumption and economic growth in the ASEAN-5 countries. *Renewable and Sustainable Energy Reviews*, *47*, 732–745. https://doi.org/10.1016/j.rser.2015.03.023

Azhgaliyeva, D., Le, H., Olivares, R. O. & Tian, S. (2024). Renewable energy investments and feed-in tariffs: Firm-level evidence from Southeast Asia. *Applied Energy*, *374*(November). https://doi.org/10.1016/j.apenergy.2024.123986

Bersalli, G., Menanteau, P. & El-Methni, J. (2020). Renewable energy policy effectiveness: A panel data analysis across Europe and Latin America. *Renewable and Sustainable Energy Reviews*, *133*. https://doi.org/10.1016/j.rser.2020.110351

Bevacqua, E., Schleussner, C. F. & Zscheischler, J. (2025). A year above 1.5 °C signals that Earth is most probably within the 20-year period that will reach the Paris Agreement limit. *Nature Climate Change*, *15*. https://doi.org/10.1038/s41558-025-02246-9

Brunei Goverment. (2022). *Net Metering Programme*. https://www.energy.gov.bn/SitePages/Pages/NetMetering Programme.aspx

Cansino, J. M., Pablo-Romero, M. del P., Román, R. & Yñiguez, R. (2010). Tax incentives to promote green electricity: An overview of EU-27 countries. *Energy Policy*, *38*(10), 6000–6008. https://doi.org/10.1016/j.enpol.2010.05.055

CEIC Data. (2021). *Brunei Crude Oil: Exports*. https://www.ceicdata.com/en/indicator/brunei/crude-oil-exports

Chang, Y. & Li, Y. (2015). Renewable energy and policy options in an integrated ASEAN electricity market: Quantitative assessments and policy implications. *Energy Policy*, *85*, 39–49. https://doi.org/10.1016/j.enpol.2015.05.011

Chaowiang, S. & Leeprechanon, N. (2020). Demand-side renewable portfolio standard: A case of Thailand. *International Transaction Journal of Engineering, Management, & Applied Sciences & Technologies*, *11*(13), 1–9. https://doi.org/10.14456/ITJEMAST.2020.260

Cheng, J., Sun, J., Yao, K., Xu, M. & Cao, Y. (2022). A variable selection method based on mutual information and variance inflation factor. *Spectrochimica Acta - Part A: Molecular and Biomolecular Spectroscopy*, *268*, 120652. https://doi.org/10.1016/j.saa.2021.120652

Erdiwansyah, Mamat, R., Sani, M. S. M. & Sudhakar, K. (2019). Renewable energy in Southeast Asia: Policies and recommendations. *Science of the Total Environment*, *670*, 1095–1102. https://doi.org/10.1016/j.scitotenv.2019.03.273

Galeazzi, C., Steinbuks, J. & Anadon, L. D. (2024). Assessing the impact of renewable energy policies on decarbonization in developing countries. *Renewable and Sustainable Energy Reviews*, *199*. https://doi.org/10.1016/j.rser.2024.114444

Ghazanchyan, M., Klemm, A. D., Zhou, Y. S. (2018). *Tax Incentives in Cambodia* (IMF Working Paper No. 18/1). International Monetary Fund (IMF) Working Papers. https://doi.org/10.5089/9781484347522.001.

Ghoshray, A. & Lurosso, M. (2025). Energy Consumption, CO2 Emissions and Economic Growth in selected ASEAN Countries. *Letters in Spatial and Resource Sciences*, *18*(2), 1–14. https://doi.org/10.1007/s12076-025-00398-y

Gnecco, G., Nutarelli, F. & Selvi, D. (2021). Optimal data collection design in machine learning: the case of the fixed effects generalized least squares panel data model. In *Machine Learning* (Vol. 110, Issue 7). Springer US. https://doi.org/10.1007/s10994-021-05976-x

Han, P., Kimura, S., Andurrahman, S., Sirikum, J., Manaligod, L. R. & Zulkifli, Z. (2018). *Distributed energy system in Southeast Asia*. https://www.eria.org/uploads/media/Distributed_Energy_System_in_Southeast_Asia_book.pdf

Haufe, M. C., Ehrhart, K. M., Haufe, M. C. & Ehrhart, K. M. (2018). Auctions for renewable energy support – Suitability, design, and first lessons learned. *Energy Policy*, *121*, 217–224. https://doi.org/10.1016/j.enpol.2018.06.027

Hoang, T. & Wooldridge, J. M. (2024). Consistency of the fixed effects Poisson estimator with multiplicative measurement error and unbalanced panels. *Economics Letters*, *234*, 111436. https://doi.org/10.1016/j.econlet.2023.111436

IEA. (2022). *World Energy Balance*. International Energy Agency (IEA). Paris, France. https://www.iea.org/data-and-statistics/data-product/world-energy-balances.

IRENA. (2022). *Renewable energy auctions: Southeast Asia*. International Renewable Energy Agency (IRENA). Abu Dhabi, UAE. https://www.irena.org//media/Files/IRENA/Agency/Publication/2022/Dec/IRENA_RE_Auctions_SEA_2022.pdf

IRENA. (2025). International Renewable Energy Agency (IRENA). Abu Dhabi, UAE.

https://www.irena.org/

Kementerian ESDM. (2021). *Ministerial Regulation No. 26 of 2021.* Kementerian Energi dan Sumber Daya Mineral Republik Indonesia (ESDM). Jakarta, Indonesia. https://jdih.esdm.go.id/

Kersey, J., Blechinger, P. & Shirley, R. (2021). A panel data analysis of policy effectiveness for renewable energy expansion on Caribbean islands. *Energy Policy*, *155*(July 2020), 112340. https://doi.org/10.1016/j.enpol.2021.112340

Kilinc-Ata, N. & Proskuryakova, L. N. (2024). The contribution of energy policies to green energy transition in the Asia-Pacific region. *Renewable Energy*, *237*, 121797. https://doi.org/10.1016/j.renene.2024.121797

Kumar Dalapati, G., Ghosh, S., Sherin P A, T., Ramasubramanian, B., Samanta, A., Rathour, A., Kin Shun Wong, T., Chakrabortty, S., Ramakrishna, S. & Kumar, A. (2023). Maximizing solar energy production in ASEAN region: Opportunity and challenges. *Results in Engineering*, *20*. https://doi.org/10.1016/j.rineng.2023.101525

Kuneman, E., Vivero, G. De, Kokchang, P. & Juta, C. (2024). *Electricity market designs in Southeast Asia*. https://caseforsea.org/id/post_knowledge/electricity-market-designs-in-southeast-asia/

Lau, L. S., Ng, C. F., Cheah, S. P. & Choong, C. K. (2019). panel data analysis (stationarity, cointegration, and causality). In *Environmental Kuznets Curve (EKC): A Manual*. Elsevier. https://doi.org/10.1016/B978-0-12-816797-7.00009-6

Leiby, B. D. & Ahner, D. K. (2023). Multicollinearity applied stepwise stochastic imputation: a large dataset imputation through correlation-based regression. *Journal of Big Data*, *10*(1). https://doi.org/10.1186/s40537-023-00698-4

Liu, W., Zhang, X. & Feng, S. (2019). Does renewable energy policy work? Evidence from a panel data analysis. *Renewable Energy*, *135*, 635–642. https://doi.org/10.1016/j.renene.2018.12.037

Mentari. (2021). *Guidelines for a Renewable Energy Quota System for Indonesia*. https://castlerockasia.com/wp-content/uploads/2022/03/250122_RE_Quota_New.pdf

Merdekawati, M., Suryadi, B. & Pangestika, V. A. (2024). Brunei Darussalam's REC market assessment and opportunities for regional integration. *ASEAN Centre for Energy*, *5*, 1–5. https://aseanenergy.org/wp-content/uploads/2024/09/Policy-Brief-Brunei-Darussalams-REC-Market-Assessment.pdf

Miller, S. & Startz, R. (2019). Feasible generalized least squares using support vector regression. *Economics Letters*, *175*, 28–31. https://doi.org/10.1016/j.econlet.2018.12.001

Mustafa, A. (2022). Examining correlates of life satisfaction among Indian older adults using household fixed-effect approach. *Discover Social Science and Health*, *2*(1). https://doi.org/10.1007/s44155-022-00028-8

Polzin, F., Migendt, M., Täube, F. A. & von Flotow, P. (2015). Public policy influence on renewable energy investments-A panel data study across OECD countries. *Energy Policy*, *80*, 98–111. https://doi.org/10.1016/j.enpol.2015.01.026

Rahman, A., Murad, S. M. W., Mohsin, A. K. M. & Wang, X. (2024). Does renewable energy proactively contribute to mitigating carbon emissions in major fossil fuels consuming countries? *Journal of Cleaner Production*, *452*, 142113. https://doi.org/10.1016/j.jclepro.2024.142113

Sakti, A. D., Rohayani, P., Izzah, N. A., Toya, N. A., Hadi, P. O., Octavianti, T., Harjupa, W., Caraka, R. E., Kim, Y., Avtar, R., Puttanapong, N., Lin, C. H. & Wikantika, K. (2023). Spatial integration framework of solar, wind, and hydropower energy potential in Southeast Asia. *Scientific Reports*, *13*(1), 1–18. https://doi.org/10.1038/s41598-022-25570-y

Sharif, A., Kocak, S., Khan, H. H. A., Uzuner, G. & Tiwari, S. (2023). Demystifying the links between green technology innovation, economic growth, and environmental tax in ASEAN-6 countries: The dynamic role of green energy and green investment. *Gondwana Research*, *115*, 98–106. https://doi.org/10.1016/j.gr.2022.11.010

Singh, P., Singh, S. & Paprzycki, M. (2023). Detection and elimination of multicollinearity in regression analysis. *International Journal of Knowledge-Based and Intelligent Engineering Systems*, *27*(1), 105–111. https://doi.org/10.3233/KES-221622

Siriwardana, M. & Nong, D. (2021). Nationally Determined Contributions (NDCs) to decarbonise the world: A transitional impact evaluation. *Energy Economics*, *97*, 105184. https://doi.org/10.1016/j.eneco.2021.105184

Song, M., Wang, S. & Zhang, H. (2020). Could environmental regulation and R&D tax incentives affect green product innovation? *Journal of Cleaner Production*, *258*, 120849. https://doi.org/10.1016/j.jclepro.2020.120849

Sreenath, S., Azmi, A. M., Dahlan, N. Y. & Sudhakar, K. (2022). A decade of solar PV deployment in ASEAN: Policy landscape and recommendations. *Energy Reports*, *8*, 460–469. https://doi.org/10.1016/j.egyr.2022.05.219

Tabatabaei, S. M., Hadian, E., Marzban, H. & Zibaei, M. (2017). Economic, welfare and environmental impact of feed-in tariff policy: A case study in Iran. *Energy Policy*, *102*, 164–169. https://doi.org/10.1016/j.enpol.2016.12.028

Tran, T., Bui, H., Vo, A. T. & Vo, D. H. (2024). The role of renewable energy in the energy–growth–emission nexus in the ASEAN region. *Energy, Sustainability and Society*, *14*(1), 1–13. https://doi.org/10.1186/s13705-024-00446-3

Umar, M. & Safi, A. (2023). Do green finance and innovation matter for environmental protection? A case of OECD economies. *Energy Economics*, *119*, 106560. https://doi.org/10.1016/j.eneco.2023.106560

Vakulchuk, R., Overland, I. & Suryadi, B. (2023). ASEAN's energy transition: how to attract more investment in renewable energy. *Energy, Ecology and Environment*, *8*(1), 1–16. https://doi.org/10.1007/s40974-022-00261-6

Veng, V., Suryadi, B., Pranadi, A. D. & Shani, N. (2020). A review of renewable energy development and its policy under nationally determined contributions in ASEAN. *International Journal of Smart Grid and Clean Energy*, *July*, 149–161. https://doi.org/10.12720/sgce.9.1.149-161

Watts, D., Valdés, M. F., Jara, D. & Watson, A. (2015). Potential residential PV development in Chile: The effect of Net Metering and Net Billing schemes for grid-connected PV systems. *Renewable and Sustainable Energy Reviews*, *41*, 1037–1051. https://doi.org/10.1016/j.rser.2014.07.201

World Bank. (2025). *World Bank Data*. https://databank.worldbank.org

Yan, H., Qamruzzaman, M. & Kor, S. (2023). Nexus between Green Investment, Fiscal Policy, Environmental Tax, Energy Price, Natural Resources, and Clean Energy—A Step towards Sustainable Development by Fostering Clean Energy Inclusion. *Sustainability*, *15*(18), 13591. https://doi.org/10.3390/su151813591

Yang, X., He, L., Xia, Y. & Chen, Y. (2019). Effect of government subsidies on renewable energy investments: The threshold effect. *Energy Policy*, *132*, 156–166. https://doi.org/10.1016/j.enpol.2019.05.039

Yu, H., Jiang, S. & Land, K. C. (2015). Multicollinearity in hierarchical linear models. *Social Science Research*, *53*, 118–136. https://doi.org/10.1016/j.ssresearch.2015.04.008

Zhou, D., Hu, F., Zhu, Q. & Wang, Q. (2022). Regional allocation of renewable energy quota in China under the policy of renewable portfolio standards. *Resources, Conservation and Recycling*, *176*, 105904. https://doi.org/10.1016/j.resconrec.2021.105904