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Exploring How Income Inequality, Education, and Policy Shape Energy Access Disparities in Southeast Asia

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Abstract: The pursuance of Sustainable Development Goal 7, Affordable and Clean Energy, takes center stage in this research in the vibrant geography of Southeast Asia. This investigation centers on the social and economic ramifications of renewable energy policy, examining the various factors that influence energy fairness and justice. The study aims to determine how financial disparity, community participation, education, policy support, and geographical constraints affected energy access discrepancies in a panel of nine selected Southeast Asian countries from 2000 to 2023. The study employed a panel Autoregressive Distributed Lag (ARDL) model and robust least squares regression for estimation. Income inequality negatively and significantly affects energy access disparity (EAD) in the panel ARDL model. Community involvement and education improve energy accessibility. Education raises awareness of sustainable energy practices and technology, which increases energy-efficient solution adoption. Community involvement affects inclusive energy access and environmental sustainability policies, and public opinion. Additionally, geographical obstacles and public support are correlated positively, indicating that practical policy actions and investments can increase energy availability. Centralized infrastructure, technology, and egalitarian energy solutions may overcome geographical obstacles. Finally, policy support has an "inverted U-shaped" pattern, suggesting that it may promote socioeconomic growth and reduce energy access inequities. The study provides deep insights that can influence targeted policy choices and promote a sustainable and inclusive energy future for Southeast Asian countries.

Keywords: Energy Policy, Sustainable Development, Community Participation, Energy Access Disparity, Energy Justice, Southeast Asian Nations

1. Introduction

Southeast Asia contributes 3.5% of the world's GDP, more than US$3.0 trillion in 2022, with a population of over 650 million. Over the last 50 years, the region's GDP has expanded 5% faster than the global average. Even while energy availability has increased from 60% in 2000 to more than 90% in 2018, 45 million people, mainly in Cambodia and Myanmar, lack it (Shyu, 2022). Many factors affect energy availability and economic inequality. A household's capacity to light, cook, and do other productive work is closely tied to its economic progress and ability to overcome poverty (Saddique et al., 2024). Better energy service accessibility may help communities economically and psychologically (Wanof, 2023). Conversely, income gaps affect how socioeconomic groups can afford and receive dependable energy services. Because they cannot afford modern, sustainable energy sources, many low-income households choose antiquated, inefficient methods that hurt people and the environment. This makes energy efficiency and greener options harder for low-income individuals to purchase, perpetuating wealth inequality (Furszyfer Del Rio et al., 2023).

Income disparity affects energy access globally and regionally, especially in Southeast Asia. Wealth disparity exacerbates infrastructure and energy inequity worldwide (Chaurey et al., 2012). Energy poverty may result from economically disadvantaged and disenfranchised people being unable to get affordable and reliable electricity (Asiedu et al., 2023; Jayasinghe et al., 2021). The inequality in energy access in Southeast Asia is worsened by economic inequality. Rapid economic growth in some countries and persistent poverty in others define the region's economy (Balasubramanian et al., 2023). Low-income and rural areas are often cut off from the development of energy infrastructure, while wealthier urban areas have more access (Feng et al., 2023). Economic inequality affects people's willingness to use renewable energy. In Southeast Asia, renewable energy and energy-efficient methods may be accessible to the rich but not to the poor. Educational achievement in high-income nations affects access to energy, particularly electricity. Highly educated people can afford reliable and advanced energy infrastructure. Bachelor's degree holders may have greater work choices in urban or developed locations with widespread electricity. Higher education allows people to use technology in their personal and professional lives and to afford a home with electricity (Sharif & Khan, 2023).

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Southeast Asia has inequalities in energy access due to its diverse geopolitical settings, immense geography, and rapid economic growth (Shyu, 2022). Despite extensive activism, socioeconomic position, government regulations, and geography continue to worsen disparities in clean and affordable energy. Income inequality is particularly relevant in this location, where economic differences typically limit access to basic infrastructure such as power (Hartwig & Nguyen, 2023). In countries with wealth inequality, such as the Philippines and Indonesia, rural and disadvantaged communities face a disproportionate amount of the cost of access to energy (Zhuang, 2023). Educational attainment is vital since rural and urban Southeast Asian literacy rates and awareness of renewable energy technologies vary substantially (Farzana et al., 2023). Countries with greater education utilize renewable energy more. This is particularly true in Thailand and Vietnam, where government energy efficiency projects overlap with educational outreach (Lestari et al., 2024). The Renewable Energy Act in Malaysia and the National Power Development Plans in Vietnam are two of numerous Southeast Asian government initiatives that encourage renewable energy and expand its accessibility (Abd Aziz et al., 2024). Location is especially crucial in this study, since archipelagic Southeast Asian nations such as the Philippines and Indonesia have infrastructure and logistical problems that supply power to rural and island regions (Paché, 2024).

Educational institutions in high-income nations influence energy literacy. Research and academic programmes in energy provide an energy-innovative workforce. These nations are better positioned to lead the development of energy technologies for a more egalitarian and sustainable energy system (Amalu et al., 2023). The complex relationship between education and energy in Southeast Asia has several features. Economic capacity, ecological awareness, and intellectual influence on energy policy and technology are factors. This convoluted interplay promotes educational advancement and personal prosperity, fostering a sustainable and inclusive energy future. The availability of energy worldwide and in Southeast Asia will depend on policy support, notably subsidies and public expenditure. Energy policy affects markets worldwide (Lim et al., 2022). Government programs and subsidies for renewable energy projects make clean energy more affordable. Strong policies in this sector increase energy availability, which fosters sustainable lifestyles (Ofélia de Queiroz et al., 2024). Southeast Asian energy availability depends on policy support. Countries in the area have various renewable energy initiatives. Countries with strict rules have better energy supplies and a greater emphasis on greener solutions. In locations with unequal or no policy support, energy access inequalities persist, and the transformation to more inclusive and sustainable energy systems is slowed. According to Peters et al. (2024), policymakers should collaborate with the Sustainable Development Goals to provide electricity for everyone.

Globally, cities with many individuals and funds have higher power availability due to improved infrastructure and energy investments (Fournier et al., 2023). Rural or remote areas may need help getting sustainable energy due to infrastructural and resource shortages. Southeast Asian energy availability depends on location. Strong energy infrastructure, especially in cities, increases electricity availability. However, resource inequalities and infrastructure restrictions can make it difficult for rural areas, particularly in developing nations, to get clean and reliable electricity (Taghizadeh-Hesary et al., 2022). Geography presents challenges that emphasise the need for targeted policies and investments to reduce the urban–rural divide. Governments and stakeholders should prioritise off-grid alternatives, rural energy infrastructure, and inclusive development (Quirapas & Taeihagh, 2021). Recognising that energy needs vary by location is essential to solving the unique problems of Southeast Asia and the world. Finally, community participation in decision-making about renewable energy projects transforms energy access worldwide and in Southeast Asia. Public participation typically determines the lifetime and effectiveness of energy projects globally. Communities participating in the decision-making of renewable energy projects are more likely to support and accept clean energy solutions. Participation in project development improves community outcomes (McNamara et al., 2020). With its many cultures and socioeconomic conditions, Southeast Asia has remarkable participation in access to energy from the community. Countries that promote public involvement in energy decision-making execute renewable energy projects more readily (Ghorbani et al., 2023). However, low-community participation locations may need help to gain residents' support and provide their energy needs. To increase energy access, governments and stakeholders must emphasize community involvement frameworks. Locals must be involved in energy project design, implementation, and evaluation. Internationally and in Southeast Asia, inclusive and sustainable energy solutions need policies that encourage transparency, public participation, and local perspectives (Aleluia et al., 2022).

Inequitable energy distribution in Southeast Asia causes power interruptions. Core–periphery dynamics occur when certain towns benefit more from energy resources and infrastructure than others. Comprehensive policies that address economic inequity and geographical barriers can ensure an equitable and sustainable energy future for Southeast Asian populations. Thus, the study constructs the research questions in light of economic factors. First, do economic inequality and geographical challenges aggravate Southeast Asian energy access gaps? These concerns cause uneven resource distribution and opportunities, which affect the ability of varied groups to get reliable, inexpensive energy. Second, can education, government backing, and community engagement minimize Southeast Asian energy access gaps? Southeast Asian energy access disparities can be addressed with better education, government support, and community participation. The third and final research question is: Does policy support and energy access inequality in Southeast Asia exhibit an "inverted U-shaped" relationship? Policy support and energy access disparities in Southeast Asia may follow a rise and fall in their relationship. Policy assistance may initially reduce energy access inequities, but later increases may have unforeseen impacts or diminishing returns.

The study has the following research objectives:

I. Examine the impact of increasing income imbalance and geographical challenges on energy access disparities in Southeast Asian nations.
II. To investigate the influence of educational attainment, policy support, and community participation on energy access disparities across countries, and
III. To review an "inverted U-shaped" relationship between policy support and energy access disparities in Southeast Asian nations.

Despite extensive research on sustainable energy transitions, Southeast Asians lack a thorough understanding of the connection between geographical limits, legislative support, renewable energy usage, and environmental equity (Sakti et al., 2023; Rüland, 2023; Bai et al., 2023; Primbetova et al., 2022). Some research has examined policy frameworks, economic inequality, and energy access, but more needs to systematically incorporate these factors into one cohesive framework to investigate energy access differences (Haq et al., 2022; Afridi et al., 2023; Gu et al., 2023; Ul Haq et al., 2022). Energy justice and sustainability research that overlooks these connected aspects is biased and provides isolated outcomes. Forgetting legislative support can obscure policy-driven processes that affect equitable energy distribution, while disregarding geographical limits can underestimate regional energy accessibility. This study fills a significant knowledge gap by employing a panel ARDL model to highlight complicated relationships that other techniques missed and include understudied factors (Khamjalas, 2024; Mahalik et al., 2023). The findings illuminate legislative success by analysing an inverted U-shaped policy support relationship. Including community engagement and education highlights the importance of participatory tactics and knowledge in eliminating energy access disparities, which previous research overlooked (Lei et al., 2023; Dong et al., 2023; Hardi et al., 2024). This comprehensive strategy compares these findings with current research to strengthen the discussion and provide a scientific foundation for targeted policy measures. This multifaceted vision of energy justice and fairness in Southeast Asia may help policymakers and practitioners of Sustainable Development Goal 7 to sustain economic activities and move toward shared prosperity.

The study has the following sections. After the introduction, Section 2 presents the literature review. The methodology is discussed in Section 3. The results are in Section 4. The final section concludes the study with some practical policy recommendations.

2. Literature Review and Hypotheses Development

The literature review provides a sound theoretical framework for the inquiry by reviewing past research. The study divided the literature review section into three sub-sections. The first section evaluates literature on economic inequality and geographical limits on energy availability. The second section illustrates how education, government assistance, and community participation can increase energy availability. The third and final section reviews studies on the dynamic connection between policy support and energy access disparities.

2.1. Wealth Inequality and geographic barriers on Energy Availability

Access to affordable and reliable energy is crucial to reducing economic inequality through the diffusion of education, employment opportunities, and opportunities for mobility. This understanding has, in turn, facilitated an increasing focus on the contribution of SDG-7, which is producing an expanding body of literature that emphasises energy justice and equitable access to energy (Ali et al., 2020; Shahzadi et al., 2022; Lin et al., 2024).

Dong and Hoa (2018) examine the urban–rural income gap and per capita power use in China using provincial data from 1996 to 2013. Lower per capita power consumption in provinces is linked to an increase in urban–rural income disparity in the current economic stage, utilising advanced statistical methods to address problems. Per capita electricity use and GDP per capita have an intriguing inverted U-shaped association, as lower consumption initially rises with economic development but then falls at a certain income level. Higher incomes lead to less energy-dependent economic structures and technologies, as well as early energy-intensive growth. The research found that social and economic factors greatly affect power use in various areas of China.Khan and Heinecker (2018) examine how economic inequality influences energy efficiency using a scaling indicator from ecology and urban studies. The study shows that growing economic disparity affects the efficiency of energy consumption in different urban and national contexts. Despite national energy efficiency advances, cities are growing more unequal and emitting more carbon.

Uzar (2020) investigated income inequality and renewable energy consumption in 43 industrialised and developing countries between 2000 and 2015. Renewable energy consumption increases when the economic difference decreases. Nguyen and Nasir (2021) examined 51 economies from 2002 to 2014 to find evidence of a link between energy poverty and income inequality. The results show that the relationship between income inequality and energy poverty is positive; conversely, lower economic inequality reduces energy poverty.Tan and Uprasen (2021) examined how income inequality influenced ASEAN-5 renewable energy consumption to assess progress toward the UN's Sustainable Development Goals. Using a nonlinear panel ARDL model and four income inequality proxies (1990–2015), the results show that reducing income inequality increases long-term renewable energy consumption. The asymmetry effect indicates that positive shocks (increased inequality) have a greater impact than negative shocks. Renewable energy utilisation and inequality gains have a two-way causation.

Using data from 166 countries between 1990 and 2017, Acheampong et al. (2021) examined how energy accessibility affects income disparity to reduce economic inequality and provide universal access to affordable and reliable energy. The findings show that energy availability is essential to addressing global economic inequality and regional disparities, influencing education and economic progress.Dong et al. (2022) found that China should prioritise energy poverty and economic inequality. Their dynamic panel model, using data from 30 Chinese provinces (2004–2017), shows that energy efficiency minimises both energy poverty and economic inequality. Lower energy costs enable low-income populations to afford essential services and reinvest in health, education, and productivity.Southeast Asia, a significant player in climate change, struggles to switch to greener energy sources while maintaining affordable and reliable power (Mohazzem Hossain et al., 2024).Based on the cited literature, the first hypothesis is as follows:

H1. *Wealth inequality and geographical barriers adversely affect energy availability in Southeast Asia.*

2.2. The Role of Education, Government Support, and Community Engagement in Promoting Energy Access

Education, government aid, and community involvement are helping to reduce energy access disparities. Southeast Asian educational initiatives must promote sustainable practices and renewable energy to promote energy-efficient solutions (Aleluia et al., 2022). Regulatory frameworks and government subsidies have expanded energy infrastructure and ensured affordability. Community involvement encourages participatory methods that integrate local needs with energy policy (Dang et al., 2021).Muhammad et al. (2022) examined renewable energy consumption (REC) in 23 OECD countries regarding carbon emissions, oil prices, income inequality, economic growth, and trade openness. REC is positively correlated with economic growth, oil prices, income inequality, and trade openness using the Augmented Mean Group (AMG) estimator. CO_2 emissions show the opposite trend. Causality tests demonstrate one-way causality from GDP per capita to REC and two-way causality between income inequality and REC.

Geographic challenges hinder green energy access, contributing to economic inequality. Golubchikov and O'Sullivan (2020) introduced the concept of the *energy periphery* to study low-carbon transitions and uneven geographical development. These communities face compounded energy and place-based vulnerabilities.Murshed (2023) analysed electricity availability in 61 developing nations (2000–2020). Remittance inflows do not directly influence electricity access, but institutional quality and renewable energy adoption do. Income inequality hinders energy access, and institutional quality mediates the relationship.Coleman et al. (2023) evaluated how climate-related hazards in the US energy sector influenced power outages. Due to geography and infrastructure, recovery was poorer in non-coastal and low-income communities. The study emphasizes equality in outage management and emergency planning.

Rontos et al. (2024) examined corruption, competitiveness, human development, and inequality in 110 countries. Competitiveness reduces corruption more in high-human-development countries. Wealth disparity undermines institutions and causes social instability.Liu et al. (2024b) explored economic development, digitalization, and regional inequality in China. Economic inequality decreased, but digital inequality increased, with higher progress southeast of the Hu Huanyong Line. Government investment in education and digital infrastructure in less developed regions is necessary.The second hypothesis of the study is as follows:

H2. *Education, government support, and community involvement favourably affect energy availability in Southeast Asia.*

2.3. Policy Support and Energy Access Disparities

The effectiveness of policy in alleviating energy access disparities is varied and sometimes non-linear (Murshed, 2020). Government subsidies and infrastructure investments considerably improve energy availability in Southeast Asia (Lammers et al., 2020). However, inefficiency, inadequate management, or shifting socioeconomic dynamics can reduce these advantages as systems age.Khan&Heinecker. (2018) investigated energy consumption, sanitation, forest area, financial development, and greenhouse gas emissions in lower-middle-income countries, identifying continent-specific challenges and policy implications. Khan et al. (2022) proposed a disaster resilience index for sustainable development, offering resilience-building measures to mitigate both natural and artificial disasters.

Raza et al. (2021) assessed meteorological factors and COVID-19 in Pakistan, showing that temperature and humidity affected viral spread and indirectly harmed public transit and road safety. Wang et al. (2024) found that environmental degradation and inadequate healthcare systems significantly worsened road accident mortality in highly polluted countries.In Yalova metropolitan, Turkey, Bilgiç and Şahin (2021) surveyed 214 households and found that income inequality and low education levels hinder access to modern energy systems, increasing reliance on fossil fuels. Improving income and education boosts renewable energy adoption.Hassan et al. (2022) examined BRICS countries (1989–2016) and found that economic progress, income disparity, and energy poverty increase environmental stress. Education investment yields environmental benefits.

Apergis et al. (2022) examined education and energy poverty in 30 developing countries (2001–2016), finding that education consistently reduces energy poverty. Bishoge et al. (2020) stressed the importance of community involvement in Tanzania's renewable energy landscape, noting insufficient awareness and weak regulatory structures. Coy et al. (2021) emphasised community empowerment in energy transitions for sustainable development. Hussain et al. (2022) showed that government sponsorship and organisational innovation strongly affect community participation in renewable projects, which moderates project success.Mia et al. (2022) argued that long-term community development requires community engagement and planning, providing social and financial support without harming the environment. Streimikiene and Kyriakopoulos (2023) highlighted that energy poverty is multifaceted and linked to low-carbon transitions. Lee and Yuan (2024) found that urbanisation mitigates the negative effects of energy poverty on public health in 185 countries.The third hypothesis of the study is as follows:

H3: *Southeast Asia's policy support and energy access disparities follow an"inverted U-shaped" curve.*

Energy conservation is crucial to achieving a long-term balance between nature and energy. This study emphasizes the need for education as a long-term investment in energy conservation, removing barriers, and changing people's energy usage habits. Government expenditure and tailored subsidies can cut renewable energy costs and make them more accessible to underprivileged communities.

3. Methodology

Table 1 shows the list of variables used in the study, which is taken from the World Bank (2024). The nine Southeast Asian nations for the years 2000 to 2023 have been selected based on the availability of data, namely, Cambodia, Indonesia, Malaysia, Lao PDR, Myanmar, Philippines, Thailand, Viet Nam, and Timor-Leste.

Table 1: *Variables List*

Variable Type	Variable Name	Measurement/Indicator	Description	Formula (if applicable)
Dependent Variable	Energy Access Disparities (EAD)	Access to electricity (% of population)	Measures the degree to which marginalised communities have access to clean energy technologies.	N/A
Independent Variables	Income Inequality (II)	GINI index (%)	Measures income disparities within a country.	N/A
	Educational Attainment (EA)	Government expenditure on education, total (% of GDP)	Assesses the level of educational attainment based on government spending on education.	N/A

Variable Type	Variable Name	Measurement/Indicator	Description	Formula (if applicable)
	Policy Support (PS)	Subsidies and other transfers (% of expense)	Evaluates the level of policy support for renewable energy.	N/A
	Geographical Location (GL)	Geographical Location Index (GLI)	Represents the geographical distribution of communities.	GLI = 0.4 × (Urban Population) + 0.3 × (Rural Population) + 0.2 × (Energy Use) + 0.1 × (Economic Growth)
	Community Participation (CP)	Voice and Accountability estimate	Measures the extent to which citizens can participate in governance and express their opinions.	N/A
Potential Additional Variables	Square Term for Policy Support (SQPS)	PS^2	Captures the potential inverted U-shaped relationship between policy support and energy justice.	PS^2
	Interaction Term between Income Inequality and Policy Support (II×PS)	IIPS	Explore whether the impact of policy support on energy justice is moderated by income inequality.	II × PS

Source: By the Author

3.1 Source: World Bank (2024).

The study developed the Geographical Location Index (GLI) to assess the regional disparities in Southeast Asian energy availability. The impact of each component on the topography and infrastructure of the region determined its weight. Urban people are given the most weight (0.4) as they are more dependent on centralised energy infrastructure and services. Rural populations (0.3) show energy access disparities in sparsely populated and underdeveloped areas. The energy consumption trend (0.2) indicates the accessibility of supply and demand, and the economic growth trend (0.1) demonstrates its influence on regional energy planning and investment. This approach gives a consistent and policy-relevant assessment of geography's influence on energy access disparities.

The World Development Indicators (WDI. The database provides comprehensive and consistent data across countries, while some limitations include insufficient sector-specific granularity, missing value interpolation, and data availability delays when using the WDI. Data consistency was first ensured by excluding years with several missing or imputed values and using globally defined criteria. Second, the study cross-validated key measures using other international datasets to ensure their strength. Finally, the study recognises that disaggregated sub-national data is a restriction that cannot be fully addressed. Future studies might integrate satellite energy access measurements, household survey data, or WDI with regional institution records for a more thorough and regionally focused analysis.

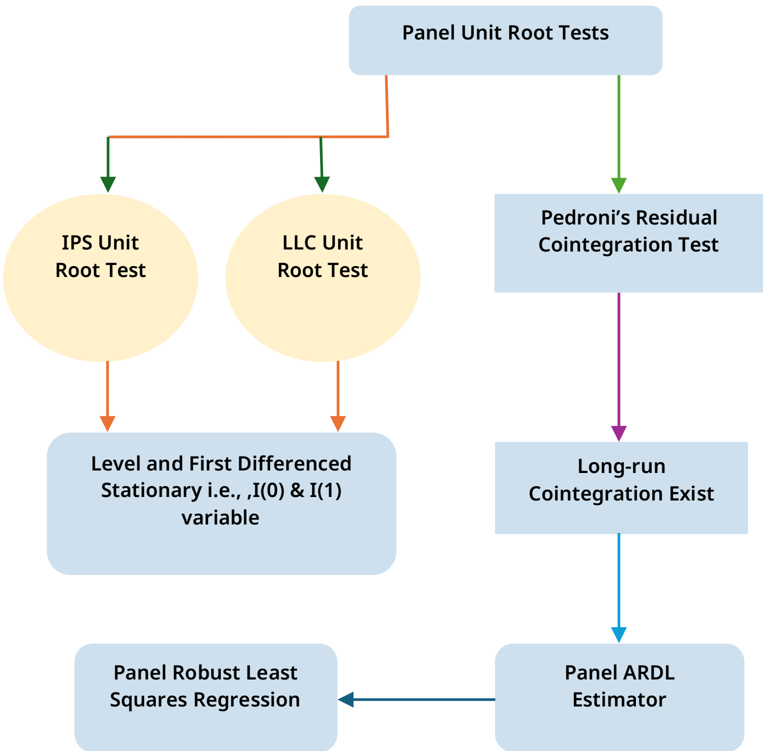

Figure 1: Research Framework of the Study. Source: Author's own work.

All statistical analyses and estimations were performed using EViews 9. The study used this application for data purification, unit root testing (IPS and LLC), Pedroni cointegration tests, Panel ARDL computations, and robustness checks. EViews software was chosen for its reliability in handling complex panel data types and its widespread use in empirical economic research. Figure 1 shows the research framework of the study.

3.2. Panel Unit Root Tests

The econometric results are obtained from the primary panel unit root test, followed by panel cointegration, which shows a long-run association among the considered variables. The panel unit root test is used to test a stationary panel data set. The study used many panel unit root tests, including the Im, Pearan and Shin (IPS) test, which is more flexible for heterogeneous panels because it allows individual unit root processes, unlike the Levin, Lin, and Chu (LLC) test, which assumes a standard unit root process across cross-sectional units (Im et al., 2003; Levin et al., 2022). Fisher-type tests are also used to create a total test statistic from unit root test p-values for each cross-section to account for variability and cross-sectional dependence. Autoregressive lag lengths and cross-sectional dependence may affect test findings. The null hypothesis generally states that all panel series have a unit root (non-stationarity), while the alternative hypothesis varies with each test. While the IPS and Fisher-type tests allow a series subset to be stationary, the LLC test assumes all series are stationary. Thus, the panel unit root tests give valuable insights into data series. Traditional econometric approaches assume stationarity, which is maintained when the null hypothesis of a unit root is rejected or the series is stationary. If the null hypothesis cannot be rejected, a unit root must be present, and data differencing or cointegration must be employed. Panel data analysis requires these tests because they can handle large datasets and adapt to changing requirements.

3.3. Panel Cointegration Tests

Long-term variable interdependencies were explored using Pedroni's panel cointegration test. Pedroni's test determines whether non-stationary variables in panel data are cointegrated. Pedroni's panel cointegration test requires estimating the cointegration linkages between each panelist and then calculating the test statistics to summarize these connections and draw panelist conclusions (Pedroni, 1999; Pedroni, 2013). Pedroni uses seven statistical tests to examine the two hypotheses: cointegration or not. Panel tests and group tests use within-dimension and between-dimension statistics. Within-dimension tests use a similar autoregressive coefficient under the null hypothesis, whereas between-dimension tests allow distinct coefficients. This dual strategy improves test robustness by enabling panel dynamics and cross-sectional dependencies to change. Group tests include rho, Phillips-Perron (PP), and Augmented Dickey-Fuller (ADF) statistics, whereas panel tests include v, rho, PP, and ADF data (Pedroni, 2004). Before utilizing Pedroni's test, the study employed panel unit root tests to ensure all variables were integrated in the same order, generally I(1). After calculating the test statistics, we examined their significance to reject the null hypothesis of no cointegration. Pedroni's panel cointegration test showed that the variables move together over the long term despite short-term fluctuations. This revelation that varied interactions are stable and enduring is crucial to the study's theoretical basis.

3.4. Panel ARDL Estimator

Based on the mix results of the panel unit root test (mix cointegration, i.e., I(1) and I(0)), then Panel ARDL is applied as it is beneficial because it simultaneously estimates short- and long-run dynamics; it accommodates different orders of integration namely, I(0), I(1) or a or mixture of I(0) and I(1) variables as long as none of the variables are I(2); and it also provide different number of lags on each variable (Pesaran et al., 2001). To ensure consistent empirical modeling of the panel ARDL technique, similar methodological adjustments have been utilized in a recent study (Raihan et al., 2024), which examined how the digital economy influenced nations' environmental sustainability. The Panel ARDL model shows long-run and short-run coefficients in Equation (1), i.e.,

$$\begin{aligned}\Delta \ln(EAD)_{i,t} &= \beta_0 + \sum_{i=1}^{p} \beta_1 \Delta \ln(EAD)_{t-1} + \sum_{i=0}^{q} \beta_2 \Delta \ln(II)_{i,t-1} + \sum_{i=0}^{r} \beta_3 \Delta \ln(EA)_{i,t-1} + \sum_{i=0}^{t} \beta_4 \Delta \ln(PS)_{i,t-1} \\ &+ \sum_{i=0}^{u} \beta_5 \Delta \ln(SQPS)_{i,t-1} + \sum_{i=0}^{w} \beta_6 \Delta \ln(GL)_{i,t-1} + \sum_{i=0}^{x} \beta_7 \ln(CP)_{i,t-1} + \sum_{i=0}^{y} \beta_8 \ln(IIPS)_{i,t-1} + \delta_1 \ln(II)_{i,t-1} \\ &+ \delta_2 \ln(EA)_{i,t-1} + \delta_3 \ln(PS)_{i,t-1} + \delta_4 \ln(SQPS)_{i,t-1} + \delta_5 \ln(GL)_{i,t-1} + \delta_6 \ln(CP)_{i,t-1} + \delta_7 \ln(IIPS)_{i,t-1} + \varepsilon_{i,t} \end{aligned} \quad (1)$$

Where,

EAD shows energy access disparity

II shows income inequality

EA shows educational attainment

PS shows policy support

GL shows the geographical location

SQPS shows the square term of policy support

CP shows community participation

IIPS shows the interaction term of income inequality and policy support

Δ shows the first difference

'i' shows cross-sections

't' shows the time period and

Ɛ shows the error term

The research uses a comprehensive econometric framework and the panel ARDL model for analysis. This model was chosen because it can capture both short-term dynamics and long-term correlations across variables in the panel dataset and examine energy access disparities over time. The panel ARDL technique is best for studying the complex interplay of social, economic, and geographical aspects since it is resistant to non-stationary variables and compensates for parameter estimate variability between countries. The panel ARDL model can handle stationary and non-stationary variables, making it useful for Southeast Asian studies with diverse socio-economic settings.

3.5. Robust Least Squares Regression

Further, the study notes that findings from one econometric model may need to be more accurate. Thus, Robust Least Squares (RLS) regression was used to corroborate estimates and assess the consistency. The RLS approach offers a novel perspective by ensuring estimate consistency across specifications and eliminating outliers (Huber, 1992). These methods have pros and cons. Since it assumes a linear adjustment mechanism, the panel ARDL model may simplify real-world interactions. If not adjusted, Lag selection may introduce biases, requiring a vast time range to offer solid long-term estimations. The RLS method reduces outliers but ignores endogeneity, which may make causal linkages challenging to comprehend.

4. Results

Table 2 shows the descriptive statistics of the variables. The mean value of energy access disparity shows 78.97 percent of electricity provision, and the minimum to maximum value is 9.52 to 101.37. Income inequality ranges from 9.7 to 47.82, with the maximum value to minimum range in the selected Southeast Asian nations. Similarly, educational attainment has a mean value of 3.56 as a percentage of government expenditures. The minimum to maximum value ranges from 0.85 to 12.90. Moreover, policy support as a subsidy and transfer payment has a mean value of 27.32 and a maximum range of 68.44. The geographical challenges have an average index of 2312 and a maximum range of 9944. Finally, community participation ranges from -2.33 to 0.55 maximum value. The energy access disparity, income equality, and community participation are negatively skewed, while the rest variables are positively skewed.

Table 2:*Descriptive Statistics*

Methods	EAD	II	EA	PS	GL	CP
Mean	78.792	34.319	3.569	27.320	23126	-0.714
Maximum	101.377	47.822	12.90	68.442	99447	0.553
Minimum	9.528	9.733	0.8503	0.0279	284833.5	-2.338
Std. Dev.	24.72	9.485	2.0131	14.058	25540	0.761
Skewness	-1.092	-0.871	2.1206	1.0754	1.656	-0.255
Kurtosis	2.989	2.778	8.6203	3.694	4.995	1.782

Source: Author's estimate.

Table 3 shows the panel unit root estimates and finds that, except for educational attainment, geographical location, and policy support, which show the level stationary variables, the order of integration is zero, i.e., I(0) variables. The remaining variables are first differenced and stationary, and follow the random walk hypothesis. The order of integration of the variables is one, i.e., I(1) variable series. Thus, the mixture of the order of integration needs confirmation of whether the studied variables are cointegrated. Thus, the study used Pedroni's cointegration technique to confirm it.

Table 3:*Panel Unit Root Test Summary*

Variables	Methods	Level		First Difference		Results
		Statistics	Prob.	Statistics	Prob.	
EAD	Levin, Lin & Chu t	-0.7227	0.2349	-7.0325	0.0000	
	Im, Pesaran and Shin W-stat	2.0433	0.9791	-8.5632	0.0000	I(1)
	ADF - Fisher Chi-square	10.006	0.9317	100.805	0.0000	
	PP - Fisher Chi-square	25.285	0.1171	463.808	0.0000	
II	Levin, Lin & Chu t	0.7077	0.7604	-10.819	0.0000	I(1)
	Im, Pesaran and Shin W-stat	1.5236	0.9362	-9.5322	0.0000	
	ADF - Fisher Chi-square	15.779	0.6079	141.385	0.0000	
	PP - Fisher Chi-square	16.633	0.5484	405.999	0.0000	
EA	Levin, Lin & Chu t	-0.8621	0.194	-6.129	0.0000	I(0)
	Im, Pesaran and Shin W-stat	-1.661	0.0438	-7.6604	0.0000	
	ADF - Fisher Chi-square	27.538	0.0692	89.382	0.0000	
	PP - Fisher Chi-square	27.298	0.0736	176.258	0.0000	
PS	Levin, Lin & Chu t	-1.3391	0.0913	-40.074	0.0000	I(1)
	Im, Pesaran and Shin W-stat	-0.3015	0.3815	-21.6121	0.0000	
	ADF - Fisher Chi-square	25.562	0.1102	341.589	0.0000	
	PP - Fisher Chi-square	16.0197	0.5912	395.647	0.0000	
GL	Levin, Lin & Chu t	-1.5124	0.0652	0.0023	0.0000	I(0)
	Im, Pesaran and Shin W-stat	2.4193	0.992	1.2987	0.0000	
	ADF - Fisher Chi-square	15.711	06127	15.105	0.0000	
	PP - Fisher Chi-square	75.883	0.000	9.9122	0.0000	
CP	Levin, Lin & Chu t	-2.4276	0.0076	-10.2418	0.0000	I(0)
	Im, Pesaran and Shin W-stat	-2.2425	0.0125	-8.0143	0.0000	
	ADF - Fisher Chi-square	39.048	0.0028	99.090	0.0000	
	PP - Fisher Chi-square	33.292	0.0154	102.905	0.0000	

Source: Author's estimate.

Table 4 shows that panel PP and ADF statistics are significant in Pedroni's cointegration test. Further, the same result is confirmed by the group statistics, which exhibit that the variables are contrasted. Now, the estimations obtain the variable's short- and long-term coefficient values by the pooled ARDL technique. However, before estimating, the lag length selection criterion was deemed necessary to find the optimal lag length for the ARDL estimation procedure for the variables.

***Table 4:**Pedroni Residual Cointegration Test Estimates*

Methods	Statistic	Prob.	Weighted Statistic	Prob.
Panel v-Statistic	-0.927930	0.0233	-1.435033	0.0244
Panel rho-Statistic	0.070819	0.5282	-0.105264	0.4581
Panel PP-Statistic	-4.484695	0.0000	-5.430105	0.0000
Panel ADF-Statistic	1.376227	0.0156	-0.945619	0.0722
Alternative hypothesis: individual AR coefs. (between-dimension)				
Methods	**Statistic**	**Prob.**		
Group rho-Statistic	0.604753	0.7273		
Group PP-Statistic	-8.935272	0.0000		
Group ADF-Statistic	-0.190124	0.0246		

Source: Author's estimate.

Table 5 shows the lag length selection criterion and found that, except for the AIC value, the remaining lag length criterion suggests that the optimal lag length of the variables should be 2, while the AIC criterion shows its value to take the lag length up to 8. Thus, the study used a second lag length criterion for estimation.

***Table 5:**VAR Lag Order Selection Criteria*

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-6404.012	NA	2.30e+29	90.31003	90.47655	90.37770
1	-4544.331	3483.627	2.39e+18	65.01875	66.51748	65.62778
2	-4227.707	557.4378	6.86e+16*	61.46066	64.29159*	62.61104*
3	-4185.699	69.22359	9.54e+16	61.77041	65.93355	63.46214
4	-4106.356	121.8087	8.00e+16	61.55431	67.04965	63.78739
5	-4041.456	92.32192	8.44e+16	61.54164	68.36918	64.31608
6	-3985.244	73.63087	1.04e+17	61.65132	69.81107	64.96711
7	-3913.804	85.52578	1.09e+17	61.54654	71.03849	65.40369
8	-3835.801	84.59567*	1.09e+17	61.34931*	72.17346	65.74780

* indicates lag order selected by the criterion

Source: Author's estimate.

The study performed a cross-sectional dependence (CD) test using Pesaran's CD statistic to ensure the reliability of panel data estimations. This test seeks to identify latent commonalities or spillover effects among panel countries. Table 6 demonstrates a strong cross-sectional dependence between variables, including energy access disparity (EAD), income inequality (II), policy support (PS), its square term (SQPS), and the interaction term (IIPS) ($p < 0.05$). Southeast Asian countries appear to have a significant impact on one another in terms of energy and economic development. Thus, the study supported the use of the Panel ARDL estimator that accounts for cross-sectional dependence.

***Table 6:** Cross-Sectional Dependence Test Results (Pesaran CD Test)*

Variables	Pesaran CD Statistic	p-value	Cross-Section Dependence
EAD	3.21	0.001	Yes
II	2.78	0.005	Yes
EA	0.65	0.513	No
PS	2.45	0.014	Yes
GL	1.87	0.061	Yes
SQPS	2.39	0.017	Yes
CP	1.12	0.261	No
IIPS	2.96	0.003	Yes

Source: Author's estimate.

Table 7 shows the ARDL estimates and found that income inequality (II) is positively and significantly related to energy access disparity (EAD) in the short run, while negatively and significantly associated in the long run. This suggests that fundamental utilities like electricity may be favorably distributed to those with higher incomes in countries with significant levels of income inequality. This inequality might be worsened when low-income families do not have access to inexpensive energy choices, which is in line with the findings of previous studies (Wang et al., 2020; Seyedrezaei et al., 2024). Also, the higher initial expenses of technology like solar panels or energy-efficient appliances can make them out of reach for lower-income families regarding clean and sustainable energy sources. Therefore, these homes may depend more on expensive conventional energy sources, widening the energy access gap (Amankwah et al., 2024).

The long-term relationship between income inequality and energy access discrepancy may become harmful since economic growth and development can gradually decrease income inequality, and a more fair distribution of income results from the tendency for income levels to converge as economies evolve. When low-income families can invest in cleaner, more efficient energy solutions, their access to energy improves (Nia et al., 2024). Also, technological developments and governmental initiatives could be game-changers in the fight against economic inequality in energy access in the future. Governments and policymakers may use tools to increase low-income people's access to energy, including subsidies, incentives, and targeted initiatives (Azimiet al., 2024). Clean energy may become more accessible and cheaper for people of all income levels due to technological breakthroughs like the declining cost of renewable energy technology. This will further help to reduce the discrepancy in energy access. Economic development, governmental interventions, and technical improvements might help decrease energy access discrepancies in the long run, even while wealth disparity may initially contribute to them in the short term (Yan et al., 2024).

Table 7:Panel ARDL Estimates

Dependent Variable: Δln(EAD)

Model Selected: ARDL(2, 1, 1, 1, 1)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Long Run Elasticities				
ln(II)	-0.185	0.048	-3.854	0.000
ln(EA)	1.642	0.537	3.058	0.002
ln(PS)	4.385	1.215	3.609	0.001
ln(GL)	0.524	0.083	6.313	0.000
ln(CP)	-1.932	0.994	-1.944	0.052
ln(SQPS)	-0.089	0.027	-3.296	0.003
ln(IIPS)	-0.017	0.005	-3.4	0.001
Short Run Elasticities				
Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
ECT(-1)	-0.312	0.119	-2.622	0.010
Δln(II)	1.925	0.743	2.591	0.011
Δln(EA)	0.324	0.552	0.587	0.558
Δln(PS)	0.158	0.184	0.859	0.391
Δln(GL)	-0.006	0.029	-0.207	0.837
Δln(CP)	2.651	1.072	2.472	0.015
Δln(SQPS)	0.001	0.001	1.073	0.285
Δln(IIPS)	-0.086	0.043	-2	0.048
C	0.938	3.128	0.3	0.764

Source: Author's estimate.

There is a positive relationship between energy access disparity (EAD) and educational attainment (EA) in the long run. The result implies that higher levels of knowledge lead to better energy availability in the near run. The findings align with the research conducted by Dias et al. (2004) and Crawfurd et al. (2024). The effects of education on energy access are subtle and take some time to become apparent; it affects income levels, career prospects, and knowledge of energy-efficient techniques. However, higher levels of education are likely to be significantly associated with EAD. People with more education tend to have more disposable money and job prospects, which might increase their ability to purchase and use renewable energy sources. People are more likely to embrace energy-efficient solutions when educated on the significance of sustainable energy practices and technology (Li et al., 2024a). Energy availability and environmental sustainability are two areas where public opinion and policy may be influenced by education (Li et al., 2024b). According to Peters et al. (2024), people with greater knowledge could be more inclined to support renewable energy projects and lobby for legislation that makes energy more accessible to everyone. This might lead to a gradual narrowing of energy access gaps. Although there may not be much of an immediate correlation between levels of education and access to energy, it is likely to have a positive and substantial effect in the long term. In order to reduce energy access discrepancies in the long run, education is necessary since it shapes people's knowledge, lobbying activities, and economic prospects.

A positive relationship exists between political stability and energy access disparity in the long run. Well-crafted policies facilitate investments in energy infrastructure, encourage the use of renewable energy sources, boost efficiency, and, in the end, increase access to energy. In addition, according to Vazquez et al. (2024), energy access and inequities may be reduced and improved over the long term by consistent and stable policies that support investment and planning in the energy sector. Education and wealth are other factors that impact energy availability; however, policy backing may also alter these variables. For instance, renewable energy policies have the potential to raise incomes and education levels, which in turn may lead to a decrease in EAD since they provide new employment possibilities and boost economic development. By improving the energy access landscape and fostering an atmosphere conducive to sustainable energy development, effective policy interventions may be pivotal in reducing energy access inequities (Zou& Wang, 2024).

Further, a positive relationship exists between geographical location and energy access disparity in the long run. Energy accessibility may be affected by geographical variables, including the distribution of populations, the development of infrastructure, and the availability of natural resources (Zhang et al., 2024). Bouzarovski and Herrero (2015) and Cao et al. (2024) find the same implications. Gobelet al. (2024) found that regions with complex topography, including isolated or mountainous places, could have to pay more to build and maintain their energy infrastructure. Consequently, people in these areas may face higher energy costs and less access to contemporary energy services, exacerbating energy access inequities. There is a strong correlation between economic development, income levels, and energy availability, but one's physical location may have an even greater impact. Disparities in energy access may be worsened when economically disadvantaged regions also have lower incomes and slower economic development. To overcome geographical constraints and enhance energy availability in underserved or rural locations, investments in infrastructure, technological developments, and better legislative frameworks may assist in the long run (Edsand&Bangens, 2024). In addition, as economies expand, there may be an increased push to ensure that all areas have access to energy. This would result in a fairer allocation of energy resources and less inequality. The advantages of renewable energy sources in tackling geographical obstacles may account for the substantial positive association in the long term. Reduce dependence on centralized infrastructure and increase energy availability via renewable energy technologies like solar and wind power, which may be more readily implemented in distant places than conventional energy sources (Lawal et al., 2024). To promote sustainable energy development and achieve an equal distribution of energy resources, investments in infrastructure, technological breakthroughs, and enabling regulatory frameworks may assist in overcoming geographical constraints and improving energy access (Dong et al., 2024).

Energy access differential positively correlates with community participation (CP) in the short term and negatively correlates in the long run. It is possible that the early difficulties and expenses of community-led energy efforts are to blame for the short-term positive and substantial relationship between CP and EAD. As a result of limited resources, knowledge, or backing from higher-ups, grassroots initiatives to increase the adoption of sustainable energy practices sometimes need more support from within the community (Gajdzik et al., 2024). Disparities in energy availability may emerge from these obstacles, especially in areas with a high concentration of CP and few resources. Consistent with the research of Abulibdeh et al. (2024), CP's long-term promotion of sustainable energy solutions and community empowerment may lead to a strong negative correlation with EAD. Energy access gaps may be narrowed via community-led efforts that raise awareness, strengthen community networks, and enhance access to finance and technology. Participatory energy decision-making increases the likelihood that communities will prioritize energy access, which in turn increases the likelihood that solutions will be developed that are both locally relevant and effective in addressing the root causes of inequity (Sharif et al., 2024). Additionally, CP may considerably impact socio-economic growth, which is strongly related to energy accessibility. Economic possibilities, healthcare, and education may all increase for communities that participate in energy projects (Russell-Bennett et al., 2024), and those communities may also see an overall rise in living standards. These enhancements can foster more equitable and environmentally friendly development by lowering energy access inequities. Finally, according to Cheng et al. (2024), encouraging community involvement in energy projects can help reduce energy access disparities and promote sustainable energy development, even though CP may have a positive and significant impact on EAD in the short term due to initial challenges.

Policy support squared (SQPS) exhibits a strong negative correlation in the long run, confirming an "inverted U-shaped" pattern. The short-run positive but statistically insignificant relationship between policy support squared (SQPS) and energy access disparity (EAD) raises the possibility that policy support has a declining influence on lowering EAD. Subsidies and incentives for renewable energy projects can help reduce energy access gaps in the short term if governmental backing grows (Gobelet al., 2024). Ultimately, the negative correlation between PS2 and EAD suggests a threshold beyond which policy assistance begins to have a more noticeable effect on narrowing energy access gaps. Substantial advances in energy access may be achieved over time if policies are strengthened and made more effective. Increased investment in renewable energy infrastructure, better regulatory frameworks, and higher institutional capacity might be the outcome of long-term policy initiatives. Consistent with the research of Liu et al. (2024a).

The long-term negative relationship may reflect how governmental assistance may spur broader socio-economic development, which helps reduce energy access inequities. New economic possibilities, improved living standards, and enhanced overall energy access for communities may be achieved by policies that encourage deploying renewable energy, energy efficiency, and access to contemporary energy services (Katoch et al., 2024; Adom et al., 2021). Although policy assistance may have little effect on energy access inequities, the results show that long-term gains in access may be achieved via effective and persistent policy actions. It is crucial to maintain governmental backing and investment in renewable energy to combat energy access inequities and advance sustainable development.

The short-term and long-term effects of the interaction between income inequality and policy support (II*PS) on energy access disparity (EAD) are negative and statistically significant at the 1% level. This could be because policy support acts as a moderator between income inequality and energy access. Higher policy support may assist in reducing the impact of income disparity on energy access gaps in the near term, according to this negative link. This may result from policies aimed at providing low-income areas and disadvantaged groups with access to inexpensive and dependable energy services (Burgess et al., 2024). Over time, the moderated impact of policy assistance on income inequality becomes more apparent due to the considerable negative association between IIPS and EAD. This, in turn, leads to a fairer allocation of energy access. The significance of policy support in tackling energy access disparities, especially regarding income inequality, is underscored by the negative and significant relationship between IIPS and EAD. Sustained and effective policy interventions can aid in addressing the underlying causes of energy access disparities, such as income inequality (Li et al., 2024b). Politicians may promote sustainable development and alleviate poverty by enacting targeted policies and initiatives that provide cheap, dependable, and environmentally friendly energy services to all parts of society. In conclusion, the short-term data reveal a negative and statistically significant correlation between the error correction term (ECT) and the rate of convergence from disequilibrium to equilibrium, which is 26.2%. Figure 2 shows the crucial linkages affecting energy access disparity in Southeast Asia.

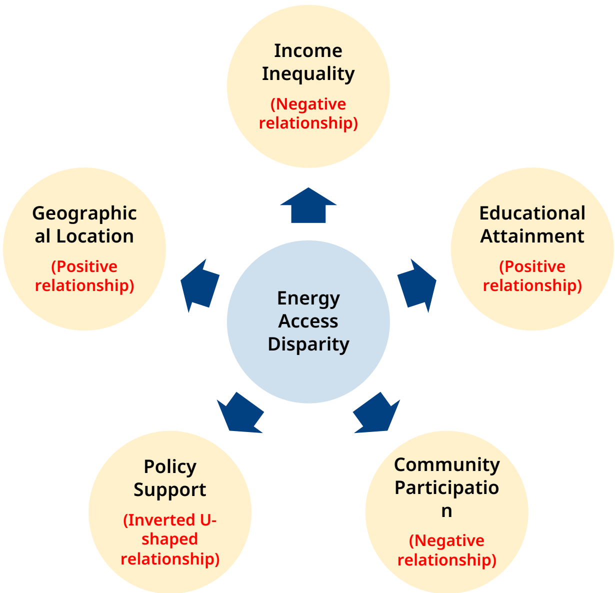

Figure 2: Framework Depicting the Relationship between Inequality, Geographical Location, and Energy Access Disparity. Source: Author’s own work.

5. Discussion

The study employed the Robust Least Squares (RLS) estimator to validate the earlier received estimates from the panel ARDL model. The findings are compatible; the RLS estimates align closely with the panel ARDL findings (see Table 8).

Table 8: *Panel Robust Least Squares Estimates. Dependent Variable: ln(EAD)*

Variables	Coefficient	Std. Error	z-Statistic	Prob.
ln(II)	-0.421	0.097	-4.34	0.000
ln(EA)	0.267	0.128	2.086	0.037
ln(PS)	0.472	0.086	5.488	0.000
ln(SQPS)	-0.009	0.001	-7.205	0.000
ln(GL)	0.305	0.072	4.236	0.000
ln(CP)	-3.218	0.41	-7.849	0.000
ln(IIPS)	-0.002	0.009	-0.222	0.824
C	3.265	1.948	1.676	0.094
Robust Statistics				
Rw^2	0.693	Rn^2	311.204	
Scale	11.842	Prob(Rn^2)	0.000	

Source: Author's estimate.

The results show that income difference and community participation reduce energy access inequalities. Given the negative association between income inequality and the energy access gap, a more equitable wealth distribution would likely boost accessibility due to better resource allocation and cheaper pricing. Community engagement strengthens communities, increases energy decision-making inclusiveness, and ensures equitable energy resource distribution, reducing inequality. Energy access discrepancies worsen when academic achievement, government assistance, and geography are included. Unequal access to educational resources and technology, which may benefit urban or affluent areas over rural or impoverished ones, may explain how education ameliorates inequalities, and the inverted U-shaped relationship between policy support and energy access gaps. Due to regional policy implementation or resource allocation asymmetries, greater policy interventions may initially aggravate inequalities. However, better policies reduce inequality and promote energy justice. Because generating and distributing energy supplies in rural or neglected regions is challenging, geographical location has become crucial in explaining discrepancies. Robust regression illuminates the complex interplay of socio-economic, policy-driven, and geographical factors in Southeast Asian energy access inequalities. This supports the study's empirical base and provides policymakers with practical insights into energy imbalances by validating hypothesized links and demonstrating these elements' complicated consequences. Table 9 shows the comparative analysis of energy access disparity across countries.

Table 9: *Comparative Analysis of Energy Access Disparity in Southeast Asian Countries*

Country	II	EA	PS	SQPS	GL	CP	IIPS	C	R^2
Cambodia	3.902**	7.329***	-0.029	0.054	6.35E-05***	13.314**	-0.228	-305.717***	0.715
Indonesia	-1.844*	-1.010	-1.670***	0.0009	2.51E-07*	7.622	0.039***	79.158	0.644
Malaysia	-0.254**	0.113***	-0.263**	0.0004	4.13E-07***	-0.059	0.005**	106.011***	0.879
Lao PDR	2.142**	-0.629	5.111***	0.002	8.78E-05***	0.608	-0.141***	-187.960***	0.721
Myanmar	-0.228***	-1.599***	0.466***	-0.014***	1.00E-05***	0.342	0.001	-102.628***	0.825
Philippines	-2.054	-2.113	2.419***	0.036***	1.27E-06**	-23.300	-0.029*	137.403***	0.728
Thailand	-5.789***	0.032	-7.898*	0.028	4.82E-06***	-4.319***	0.165**	341.167***	0.882
Viet Nam	-7.111	0.540	540.925***	-14.690***	4.17E-06***	4.602	0.404	-5011.134**	0.657
Timor-Leste	3.902**	-0.080	6.607*	-0.030**	0.0005***	13.354**	-0.179*	-270.810***	0.845

*Source: Author's estimate. Note: *, **, and *** indicates 10%, 5%, and 1% significance level.*

The results show that income inequality affects energy access disparity differently in different nations, demonstrating the complexity of socioeconomic systems. Wealth inequality affects energy access disparities in Timor-Leste, Cambodia, and Laos. This is likely due to long-standing socioeconomic disparities that limit energy availability for underprivileged communities. However, economic inequality reduces energy access disparity in Thailand, Indonesia, Malaysia, and Myanmar. Localized energy projects or targeted redistributive strategies that better address inequality in certain countries may explain this startling conclusion. Educational success is also complex. Educational attainments are linked to a greater energy access difference in Cambodia and Malaysia, demonstrating that uneven educational attainment maintains inequities. Higher education in Myanmar is connected with little energy access discrepancies, suggesting that education improves inclusion by increasing awareness and supporting equitable energy distribution. In the region, policy support serves two purposes. It reduces energy access gaps in Thailand, Indonesia, and Malaysia, likely due to infrastructural improvements and energy equity regulations. Government support worsens inequality in Laos, Timor-Leste, Vietnam, the Philippines, and Myanmar. This may be due to resource allocation issues or energy plans for cities that ignore rural needs. Early policy efforts may widen disparities before maturing and reaching ignored populations in Timor-Leste, Vietnam, and Myanmar because policy support and energy access disparity have an inverted U-shaped relationship. Geographic location strongly correlates with energy disparity in all nine nations. This indicates that physical topography, infrastructural constraints, and regional disparities affect energy supply. Even with legislation, remote or distant areas need equal access owing to higher pricing and practical obstacles. The impacts of community engagement vary widely. Timor-Leste and Cambodia saw increased community engagement in energy access gaps, showing marginalized groups are underrepresented or underrepresented in community-driven initiatives. Community participation in Thailand reduces inequality, showing that inclusive local engagement may promote equitable energy access.

Income inequality and governmental assistance complicate matters. This interaction exacerbates energy access disparities in Thailand, Indonesia, and Malaysia due to inequality and weak policy. In contrast, this interaction lowers inequality in the Lao People's Democratic Republic, the Philippines, and Timor-Leste, suggesting that policy interventions and income redistribution may reduce inequality.

6. Conclusions

Contemporary energy sources are needed to promote health, education, information access, and agricultural productivity. Despite these benefits, many emerging countries struggle to fulfil expanding energy requirements, ensure accessibility, and provide equitable access to everyone. This study highlights the social issues created by a shortage of modern energy, the importance of accomplishing this objective, the fundamental requirements for modern energy, and its value for families.

This research investigates energy access discrepancies in nine Southeast Asian countries from 2000 to 2023 using income disparity, education, government assistance, geographical obstacles, and community participation. The results show that income inequality increases socioeconomic disparities and reduces energy availability. Government subsidies, community input, and accountability positively affect energy access disparities. With increasing government investment in green energy projects, technology, and community decision-making over renewable energy resources, socioeconomic disparities will shrink, and electricity access will improve. The substantial positive association between geographical issues and community participation suggests that greater geographical obstacles contribute to more pronounced disparities and diversified energy access patterns.

The study adds to the growing body of knowledge on energy policy and sustainable development by clarifying Southeast Asia’s interconnected social and economic dynamics. It reveals that energy access gaps are multifaceted, influenced by financial inequality, education, community involvement, government support, and geographical factors. The identification of an inverted U-shaped link between policy support and energy access disparities offers a unique perspective on how governance can initially reduce, but later unintentionally widen, inequalities. Overall, this research strengthens the ongoing conversation on equitable energy transitions and aligns with the broader objectives of sustainable development.

7. Implications

Short-term government action is essential to reduce inequality. Southeast Asian countries require inclusive energy policies that prioritise disadvantaged communities, incorporate economic disparity, and promote renewable energy. Targeted subsidies or income assistance can address immediate energy access needs for low-income households. Educational initiatives, such as outreach, seminars, and awareness campaigns, should promote energy conservation and renewable energy adoption. Additionally, geographic mapping of energy access disparities can help identify local barriers and guide more tailored interventions. Governments should also publicise existing renewable energy programs and incentives through workshops and community engagement.

Medium-term strategies should include progressive taxation and broader social support systems that increase low-income households’ purchasing power and energy access. Improving educational opportunities, especially in rural and underserved regions, can enhance sustainable energy use. Governments should prioritise areas with the most severe energy access gaps, collaborating with private stakeholders and local communities to design regional solutions. Strengthening renewable energy policies, including carbon pricing, feed-in tariffs, and subsidies, is essential. Increased public participation can support both policy implementation and renewable energy adoption.

Long-term policy goals include reducing income inequality through investments in education and skill development. Expanding renewable energy infrastructure can lower energy costs and enhance access over time. Integrating energy and environmental education across all levels of schooling, combined with vocational and higher education programs in renewable energy, will accelerate the transition to sustainable energy systems. Governments should adopt comprehensive regional energy plans that incorporate sustainability goals and consider geographic constraints. Empowering communities through capacity-building can encourage local control of energy resources. Broad renewable energy strategies should include incentives for private investment and ensure equitable, affordable energy access.

The findings emphasise the need for sustained, inclusive, and adaptable policy interventions that balance economic development with environmental sustainability. Community-led renewable energy projects and decentralised energy networks can further promote equitable access across Southeast Asia.

8. Limitations and Future Research

Although this study highlights important insights into Southeast Asian energy access inequalities, several limitations must be acknowledged. The region’s cultural, socioeconomic, and political diversity may restrict the generalisability of the findings. Despite using robust econometric techniques, inconsistencies in data availability and quality may have influenced results for certain countries. Differences in infrastructure development and urbanisation may also limit direct applications to other regions. While the study incorporates income inequality, policy support, and geographical factors, it does not examine political stability, governance quality, or technological advancement, all of which may significantly affect energy access disparities.

Future research could broaden this work by using a larger dataset, extending the study period, or including more Southeast Asian countries to capture temporal and regional variations. Qualitative methods, such as case studies or stakeholder interviews, could complement the quantitative analysis and provide deeper context. Further exploration of the intersection between energy access disparities, climate adaptability, and renewable energy consumption is recommended. Finally, cross-regional comparative studies could reveal broader patterns and enhance the generalisability of the findings beyond Southeast Asia.

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