JOURNAL OF INTERDISCIPLINARY PERSPECTIVES
PRINT ISSN: 2984-8288 | ONLINE ISSN: 2984-8385
https://doi.org/10.69569/jip

TWR Publishing

Research Article

Energy Use and Economic Growth in the Philippines: Evidence from 1990 to 2024

Almira Thea D. Peñales, Regine I. Bargados, Lorraine Joy S. Jose, Mary Riyuki R. Nicolas, Joaquin Lian E. Pagkatipunan, April Ann P. Reyes, Geneveva T. Dungca

Author Information:

College of Business Education and Accountancy, Bulacan State University, Malolos City, Philippines

Corresponding Author:

Almira Thea D. Peñales
Email: almira.the4@gmail.com

Article History:

Date received: April 23, 2026
Date revised: November 8, 2026
Date accepted: November 19, 2026

Recommended citation:

Peñales, A.T., Bargados, R., Jose, L.J., Nicolas, M.R., Pagkatipunan, J.L., Reyes, A.A., & Dungca, G. (2026). Energy use and economic growth in the Philippines: Evidence from 1990 to 2024. *Journal of Interdisciplinary Perspectives*, 4(12), 282-294. https://doi.org/10.69569/jip.2026.201

Abstract. Energy consumption and economic growth are closely intertwined, yet the nature of this relationship varies across different economies. While existing studies have examined this topic in various countries, empirical evidence specific to the Philippines remains limited, particularly beyond 2010. This study examines the relationship between total energy consumption and economic performance, measured through Gross Domestic Product, in the Philippines from 1990 to 2024. Annual data were sourced from Enerdata and the World Bank. Simple linear regression was initially employed but violated key model assumptions, including independence, linearity, and normality. Several corrective procedures were explored but were each insufficient to fully resolve the violations independently. Generalized Least Squares with a first-order autoregressive correlation structure was subsequently applied and confirmed to satisfy all diagnostic requirements. The results reveal a statistically significant positive relationship between total energy consumption and Gross Domestic Product, with every one-unit increase in total energy consumption associated with an increase of approximately 5,318,836 United States dollars in Gross Domestic Product. The null hypothesis was rejected at the 1% level of significance. These findings suggest that total energy consumption is a statistically significant predictor of economic output in the Philippines, consistent with the Neoclassical Growth Theory. The results underscore the importance of ensuring a stable, efficient, and sustainable energy supply in supporting the country's long-term economic development goals.

Keywords: *Developing economy; Economic growth; Energy consumption; Energy-economy relationship.*

Energy is one of the most essential commodities in any economy. Industries cannot function, products cannot be manufactured, and services cannot be provided without it. It is, in every sense, the foundation upon which economic activity is built. Global economic activity is significantly driven by energy, which serves as an essential component in all stages of production and social consumption (Yan & Bian, 2023). According to the International Energy Agency (2025), global energy demand grew by 2.2% in 2024, notably faster than the annual average of 1.3% between 2013 and 2023. Meanwhile, the global economy expanded by 3.2% in 2024, outpacing energy demand growth and suggesting that the relationship between energy and economic growth, while clearly observable, is complex.

For ordinary Filipinos, energy and economic growth are not abstract concepts—they are felt in daily life. When energy prices rise, or supply becomes unreliable, households pay higher electricity bills, transportation costs increase, and the prices of basic goods go up. At the same time, a growing economy means more jobs, higher incomes, and better access to services such as healthcare, education, and infrastructure. Understanding how

This work is licensed under a Creative Commons Attribution-Noncommercial 4.0 International License (CC BY-NC 4.0)

energy consumption and economic growth are connected therefore matters not just to policymakers and researchers, but to every Filipino whose quality of life depends on a stable and affordable energy supply alongside a thriving economy.

This complexity is well-reflected in existing literature. Most studies indicate that energy consumption and economic growth are related, but the strength and direction of this relationship vary considerably depending on a country's economic structure and stage of development (Wang et al., 2022). Some studies suggest no significant relationship between the two variables, as economic growth in European Transition Economies has become less dependent on high levels of traditional energy consumption (Muço et al., 2021). In contrast, Benhamed and Ramzi (2024) found a significant relationship between energy consumption and economic growth in Saudi Arabia, suggesting that energy is a meaningful predictor of economic output. On a broader scale, Jaiyesimi et al. (2017) found strong evidence of bidirectional causality between total energy consumption and GDP across OECD countries, while Topolewski (2021) found that increased production leads to higher energy consumption in European countries—though in the short run, this did not consistently translate into immediate GDP growth. These mixed findings underscore that the energy-GDP relationship cannot be generalized across all economies, making country-specific investigations particularly important.

This theoretical basis for examining the relationship is grounded in the Neoclassical Growth Theory, specifically the Solow-Swan model, which identifies capital, labor, and technology as the primary drivers of GDP (Popa, 2014). In this framework, energy is treated as a factor of production—an essential input that enables capital and labor to function productively across all sectors of the economy. Furthermore, improvements in energy efficiency represent a form of technological advancement that could sustain GDP growth without proportionally increasing energy demand. This theoretical framework supports the premise that total energy consumption, as a measure of energy input into the production process, should exhibit a significant positive relationship with GDP.

In the Philippine context, the country presents a particularly compelling case for this investigation. According to Enerdata (2024), the Philippines' total energy consumption has been growing steadily, increasing by 4.4% per year since 2009 and reaching 61 Mtoe in 2019, before dropping by 5.6% in 2020 due to the COVID-19 pandemic. It has since recovered, growing by 4.8% per year and reaching 70 Mtoe in 2024. Coal dominates the country's power mix at 62%, and because the Philippines relies heavily on imported fossil fuels, its energy system remains vulnerable to supply chain disruptions, geopolitical instability, and price shocks (OECD, 2026). Meanwhile, the country's GDP has grown by more than 6% annually on average since 2011, excluding the pandemic period, making it one of the region's fastest-growing emerging market economies (OECD, 2026). This rapid expansion, largely fueled by a young, growing population, has intensified domestic economic activity and, in turn, escalated national energy demand.

Understanding how energy consumption relates to this growth is especially critical given the country's long-term development ambitions. AmBisyon Natin 2040, the Philippine government's long-term development vision, aims to roughly triple per capita income from its 2015 levels by 2040, requiring sustained average GDP growth of around 6% per year between 2025 and 2040 (OECD, 2026). With energy demand projected to grow at around 6% per year by 2040 (Enerdata, 2024), whether energy consumption and GDP are significantly related is not merely an academic question—it is a policy imperative. If the two move together, securing adequate energy supply becomes relevant to achieving the country's economic targets. This study is also anchored in the United Nations Sustainable Development Goals, particularly SDG 7 (Affordable and Clean Energy), SDG 8 (Decent Work and Economic Growth), SDG 9 (Industry, Innovation and Infrastructure), and SDG 13 (Climate Action), reflecting the broader relevance of understanding the energy-GDP nexus in a developing economy context. The findings of this study are intended to directly inform energy policy and planning efforts aligned with these goals and with AmBisyon Natin 2040.

Despite this, evidence on the energy-GDP relationship within the Philippine context remains limited and conflicting. Komarova et al. (2022) found that energy consumption is associated with GDP in non-OECD and Asia-Pacific economies, suggesting an observable relationship may exist in the Philippines. However, Barroga and Tan-Cruz (2017) found no significant causal relationship between total energy consumption and GDP in the Philippines from 1975 to 2010, supporting the neutrality hypothesis. More recently, Chongco et al. (2022) found a significant positive relationship between nonrenewable energy consumption and GDP in the Philippines from

1965 to 2019, though Granger causality from energy to GDP was not established, further underscoring the complexity of the energy-GDP relationship in the Philippine context. Despite these contributions, existing Philippine-specific studies either have data limitations that predate the strong growth period of the 2010s and the post-pandemic recovery, or focus on energy subcategories rather than total energy consumption. Studies that do include the Philippines, such as Ghoshray and Lorusso (2025), treat it as one of several ASEAN countries, limiting the depth of country-specific conclusions that can be drawn.

To address these gaps, this study analyzes the relationship between total energy consumption and economic performance, measured through GDP, in the Philippines from 1990 to 2024. Using Generalized Least Squares with AR(1) correction, this study examines whether total energy consumption is a statistically significant predictor of GDP over the study period. The findings are intended to help policymakers better understand the relationship between energy and economic growth and to inform evidence-based decisions on energy security and development policy in line with the country's long-term goals under AmBisyon Natin 2040.

Methodology

Research Design

This study employs a quantitative correlational research design, utilizing time-series data spanning 1990 to 2024 to examine the relationship between total energy consumption and GDP in the Philippines. A correlational research design examines the connections between two or more variables. This approach identifies how variables move in relation to one another and determines whether their connection is direct, inverse, or nonexistent (Dziak, 2024). This research design aligns with the study, as the data period being tested is not manipulated and is naturally occurring. The study follows a time-series approach, using a 35-year dataset of Total Energy Consumption as the independent variable and GDP as the dependent variable to determine yearly growth from 1990 to 2024. Total Energy Consumption (TEC), measured in kilotonnes of oil equivalent (Ktoe), captures the aggregate energy demand across all sectors of the Philippine economy. GDP, measured in current US dollars, serves as the primary indicator of the country's economic output over the same period. Secondary data were deemed appropriate as the variables of interest are macroeconomic in nature and are systematically recorded by established international institutions.

Data Gathering Procedure

The study used two main secondary datasets to examine the relationship between total energy consumption and Gross Domestic Product (GDP) in the Philippines. GDP in current dollars was obtained from the World Bank's World Development Indicators (WDI) database available through the World Bank's official data portal. This dataset represents the total monetary value of all finished goods and services produced in the Philippines in any given year, expressed in current dollars, and is used as a general measure of the country's overall economic output. The World Bank collects this data from official national account statistics, making it appropriate for comparing countries' economic performance and tracking changes over time.

Total energy consumption data were obtained from Enerdata, a reputable energy analysis company that specializes in providing various research and consultation services. Enerdata aggregates the energy balance data of countries and international organizations to allow for the total calculation of primary energy consumption data in MTOE, as well as overall trends in consumer usage of all primary sources in the Philippines, such as coal, oil, natural gas, and renewables, including total annual per capita energy used. This variable measures the physical amount of energy used to produce, transport, and consume products. Enerdata compiles these statistics from production and delivery data provided by national agencies and international organizations and reconciles the figures by constructing comparative national energy balance sheets to analyze trends across energy sources.

Both datasets are time-based, covering 1990 to 2024. The time frames of the data sets were specifically chosen to capture data on potential relationships of total energy consumption and GDP in the Philippines and some of the most significant economic crises that happened during this time, such as the 1997 Asian Financial Crisis, which disrupted an important development period from 1994 to 1997 during which the Philippines opened to foreign investment and tax reform (Noland, 2000); the 2008 Global Financial Crisis, during which the Philippines performed reasonably well relative to prior crises (Xue & Taylor, 2018); and the COVID-19 pandemic, one of the sharpest single-year declines in Philippine GDP during the study period (World Health Organization, 2020). Including crisis years enables the researcher to determine whether the relationship between total energy

consumption and GDP is stable over time or varies during economic shocks.

Statistical Treatment

The quantitative nature of the research followed a statistical process that measures and interprets the numerical data. This approach involves complex computational procedures that encode baseline data to examine trends and patterns, validate the hypothesis, and identify the relationships between variables (Dziak, 2024). The study used numerical data on total energy consumption and GDP growth in the Philippines from 1990 to 2024. The data were analyzed to identify the relationship between energy demand and the country's economic performance and to assess energy demand's contribution to it. To address the study's general problem, the researchers employed linear regression analysis to examine the relationships between the variables. This statistical instrument tests the basic assumptions and yields significant results that are fundamental to determining whether the variables are related (Laak & Fagerland, 2015). Therefore, it is a competent and most applicable instrument when describing and identifying the relationship between energy consumption and the economic performance of the Philippines.

Simple Linear Regression. During data encoding, Simple Linear Regression was first employed. This statistical tool was deemed appropriate for the study as it estimated the linear relationship between the independent and dependent variables. As shown in Table 1, the OLS regression yielded a statistically significant positive relationship between total energy consumption and GDP ($t = 20.06$, $p < .001$), with an R^2 of 0.92, indicating that approximately 92% of the variation in GDP is explained by total energy consumption. However, as shown in Table 3, the Durbin-Watson test revealed significant autocorrelation in the residuals ($DW = 0.24$, $p < .001$), violating the independence assumption. As shown in Figures 1 and 2, the Residuals vs Fitted plot revealed systematic patterns indicating non-linearity, and the QQ plot confirmed that the residuals deviate from normality. The assumption of homoscedasticity, however, was satisfied as confirmed by the Breusch-Pagan test ($BP = 0.74$, $p = .390$). These assumption violations necessitated corrective action, and data transformations were explored to address them.

Table 1. *OLS Regression Results*

	Coefficient	Std. Error	*t*	*p*
Intercept	-2.631×10^{11}	2.382×10^{10}	-11.05	$p < .001$
Total Energy Consumption	$\mathbf{1.060 \times 10^{7}}$	$\mathbf{5.284 \times 10^{5}}$	**20.06**	***p* < .001**

Table 2. *OLS Model Fit Statistics*

R^2	Adjusted R^2	*F*-statistic	*p*
0.92	0.92	402.40	$p < .001$

Table 3. *OLS Assumption Test*

Test	Statistic	*p*	Result
Durbin-Watson	0.24	$p < .001$	Autocorrelation detected
Breusch-Pagan	0.73	.390	No heteroskedasticity

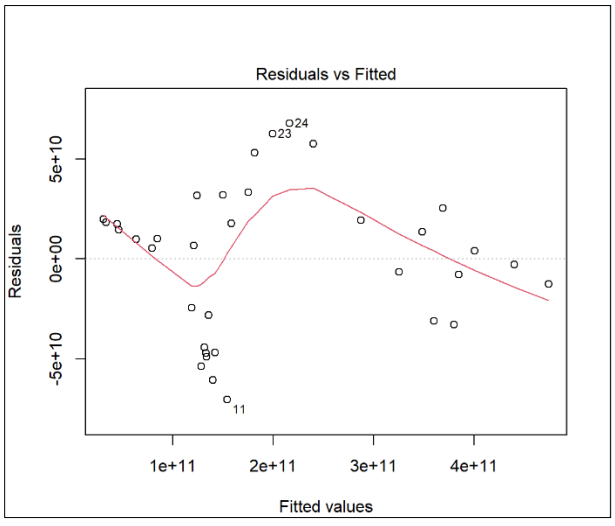


Figure 1. *Residuals vs Fitted Plot (OLS)*

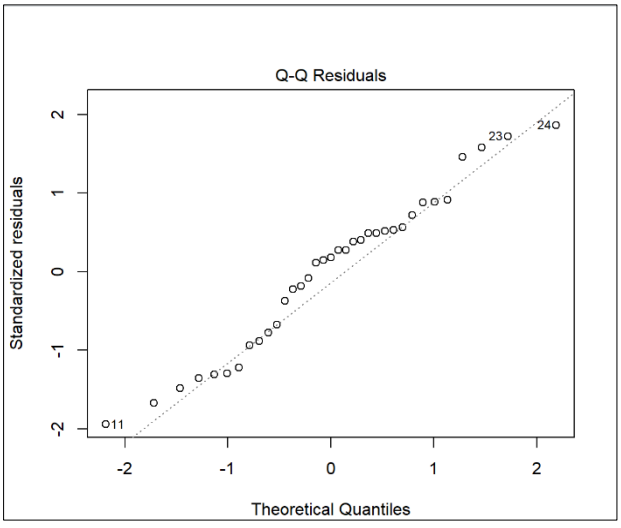


Figure 2. *QQ Plot (OLS)*

Logarithmic Transformation. Logarithmic transformation was applied to address non-linearity and skewness in the data. As shown in Table 4, the log transformation yielded a statistically significant result (t = 15.41, p < .001), with an R^2 of 0.88. However, as presented in Table 6, significant autocorrelation persisted in the residuals (DW = 0.22, p < .001), indicating that the independence assumption remained violated despite the transformation. Homoscedasticity remained satisfied (BP = 0.35, p = .553). As shown in Figures 3 and 4, the Residuals vs Fitted and QQ plots suggest that non-linearity and non-normality were not fully resolved. Since the logarithmic transformation was insufficient to address all assumption violations, further corrective measures were explored.

Table 4. *Logarithmic Transformation Regression Results*

	Coefficient	Std. Error	*t*	*p*
Intercept	-1.34	1.76	-0.76	.453
Total Energy Consumption	**2.55**	**0.17**	**15.41**	***p* < .001**

Table 5. *Logarithmic Transformation Model Fit Statistics*

R^2	Adjusted R^2	*F*-statistic	*p*
0.88	0.87	237.40	p < .001

Table 6. *Logarithmic Transformation Assumption Test*

Test	Statistic	*p*	Result
Durbin-Watson	0.22	p < .001	Autocorrelation detected
Breusch-Pagan	0.35	.553	No heteroskedasticity

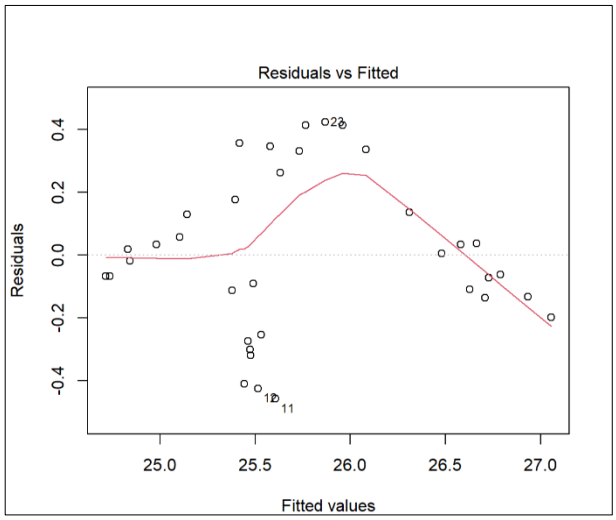


Figure 3. *Residuals vs Fitted Plot (Logarithmic Transformation)*

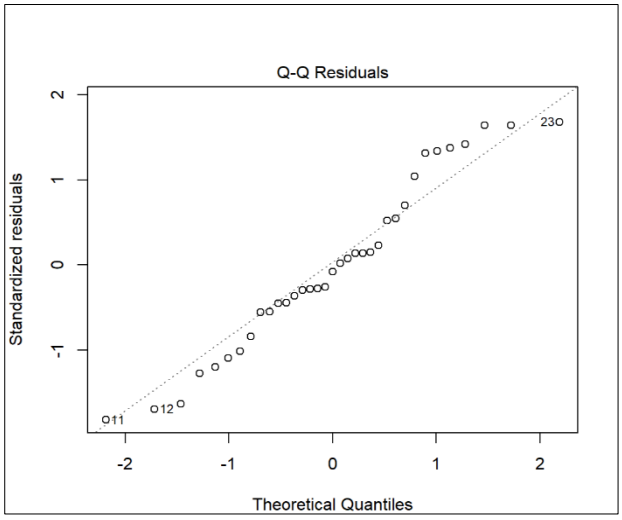


Figure 4. *QQ Plot (Logarithmic Transformation)*

Box-Cox Transformation. Box-Cox transformation was subsequently applied to correct non-normality. The optimal lambda value was λ = 0.95, which was used to transform the dependent variable. As shown in Table 7, the Box-Cox transformation yielded a statistically significant result (t = 19.75, p < .001), with an R^2 of 0.92. However, as presented in Table 9, the Durbin-Watson test still detected significant autocorrelation (DW = 0.24, p < .001), indicating that the independence assumption remained violated. Homoscedasticity was satisfied (BP = 0.65, p = .421). As shown in Figures 5 and 6, the Residuals vs Fitted and QQ plots indicate that assumption violations persisted. Since autocorrelation remained a significant issue, procedures specifically designed to correct for it were explored.

Table 7. *Box-Cox Transformation Regression Results*

	Coefficient	Std. Error	*t*	*p*
Intercept	-6.80×10^{10}	6.48×10^{9}	-10.49	$p < .001$
Total Energy Consumption	$\mathbf{2.84 \times 10^{6}}$	$\mathbf{1.44 \times 10^{5}}$	**19.75**	$\mathbf{p < .001}$

Table 8. *Box-Cox Transformation Model Fit Statistics*

Lambda (λ)	R^2	Adjusted R^2	*F*-statistic	*p*
0.95	0.92	0.92	390.00	$p < .001$

Table 9. *Box-Cox Transformation Assumption Test*

Test	Statistic	*p*	Result
Durbin-Watson	0.24	$p < .001$	Autocorrelation detected
Breusch-Pagan	0.65	.421	No heteroskedasticity

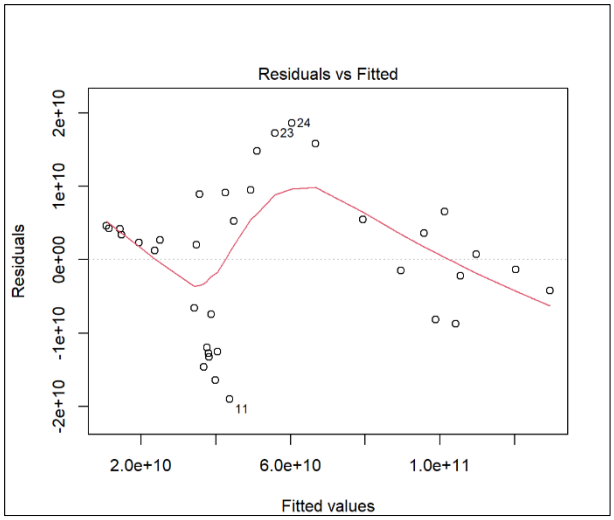


Figure 5. *Residuals vs Fitted Plot (Box-Cox Transformation)*

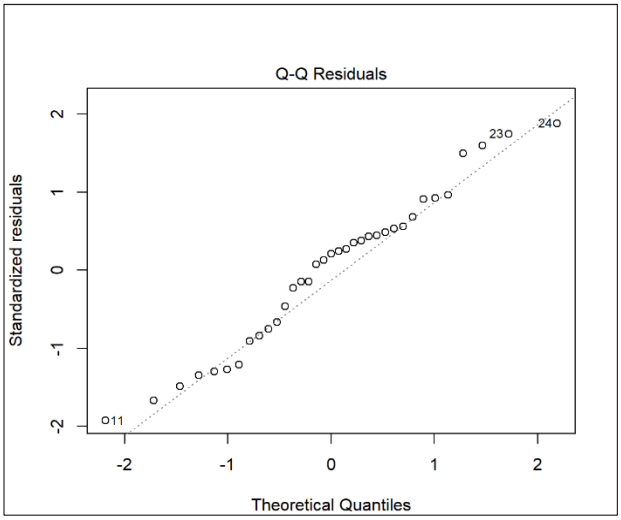


Figure 6. *QQ Plot (Box-Cox Transformation)*

Cochrane-Orcutt Procedure. The Cochrane-Orcutt procedure was applied to correct autocorrelation in the Box-Cox transformed model. The procedure did not converge under default settings; convergence was achieved only after applying a stricter tolerance of 1×10^{-6}. Both the non-converged and converged results are reported in Table 12 below for transparency. The non-converged model is presented solely to document the iterative process and should not be used for inference; the converged model constitutes the valid output.

Table 10. *Cochrane-Orcutt Regression Results*

	Coefficient	Std. Error	*t*	*p*
Intercept	-2.24×10^{10}	1.73×10^{10}	-1.30	.205
Total Energy Consumption	$\mathbf{1.94 \times 10^{6}}$	$\mathbf{3.06 \times 10^{5}}$	**6.34**	$\mathbf{p < .001}$

Table 11. *Cochrane-Orcutt Model Fit Statistics*

R^2	Adjusted R^2	*F*-statistic	*p*
0.56	0.54	40.10	$p < .001$

Table 12. *Cochrane-Orcutt Assumption Tests*

Model	Test	Statistic	*p*	Result
Cochrane-Orcutt (non-converged)	Durbin-Watson	1.58	.092	No autocorrelation
Cochrane-Orcutt (non-converged)	Breusch-Pagan	0.08	.781	No heteroskedasticity
Cochrane-Orcutt (converged)	Durbin-Watson (original)	0.24	$p < .001$	Autocorrelation detected
Cochrane-Orcutt (converged)	Durbin-Watson (transformed)	0.95	$p < .001$	Autocorrelation detected
Cochrane-Orcutt (converged)	Breusch-Pagan	0.01	.934	No heteroskedasticity

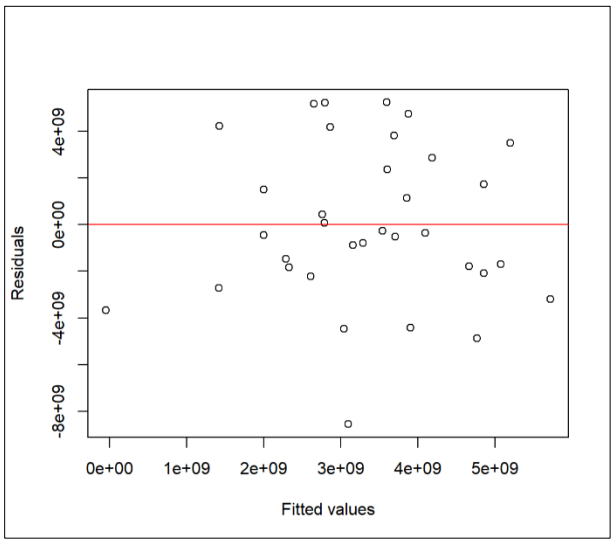


Figure 7. *Residuals vs Fitted Plot (Cochrane-Orcutt)*

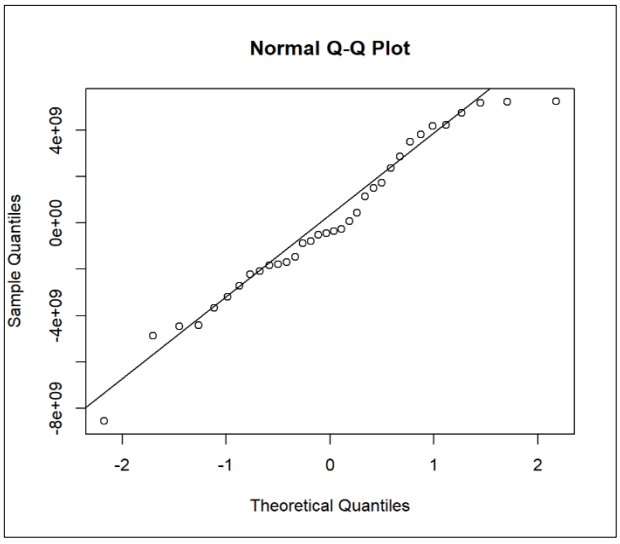


Figure 8. *QQ Plot (Cochrane-Orcutt)*

The Cochrane-Orcutt procedure was initially run under default settings; however, the model did not converge, as indicated by the warning generated in the output. A second model was run with a stricter convergence tolerance of 1×10^{-6}, which converged. As shown in Table 10, the converged Cochrane-Orcutt model yielded a statistically significant result for total energy consumption (t = 6.34, p < .001), with an R^2 of 0.56. The substantial drop in R^2 from the OLS result (0.92) to 0.56 is expected: correcting for autocorrelation removes the artificially inflated explanatory power typical of time-series OLS regressions. As presented in Table 12, however, the non-converged model showed no significant autocorrelation (DW = 1.58, p = .092) and no heteroskedasticity (BP = 0.08, p = .781). Despite this, the converged model still showed significant autocorrelation in both the original (DW = 0.24, p < .001) and transformed residuals (DW = 0.95, p < .001), indicating that the procedure did not fully resolve the autocorrelation issue. The converged model satisfied homoscedasticity (BP = 0.01, p = .934). As shown in Figures 7 and 8, assumption violations remained present. Given these persistent violations, the Prais-Winsten procedure was subsequently explored as an alternative.

Prais-Winsten Procedure. The Prais-Winsten procedure was applied as an alternative to the Cochrane-Orcutt method to correct for autocorrelation. The estimation converged after 8 iterations with a final AR(1) coefficient (rho) of 0.99. As shown in Table 13, the Prais-Winsten procedure yielded a statistically significant result for total energy consumption (t = 4.88, p < .001). However, as presented in Table 15, while the transformed Durbin-Watson statistic improved from 0.24 to 1.15, indicating that autocorrelation was substantially reduced but not fully eliminated, the original Durbin-Watson test still detected significant autocorrelation (DW = 0.24, p < .001), confirming that the Prais-Winsten procedure alone was insufficient to fully resolve the issue. Homoscedasticity was satisfied (BP = 0.74, p = .390). As shown in Figures 9 and 10, violations of this assumption persisted.

Table 13. *Prais-Winsten Regression Results*

	Coefficient	Std. Error	*t*	*p*
Intercept	-2.77×10^{10}	9.56×10^{10}	-0.29	.774
Total Energy Consumption	**5.72×10^{6}**	**1.17×10^{6}**	**4.88**	***p* < .001**

Table 14. *Prais-Winsten Model Fit Statistics*

Rho (ρ)	DW Original	DW Transformed
0.99	0.24	1.15

Table 15. *Prais-Winsten Assumption Tests*

Test	Statistic	*p*	Result
Durbin-Watson	0.24	*p* < .001	Autocorrelation
Breusch-Pagan	0.74	.390	No heteroskedasticity

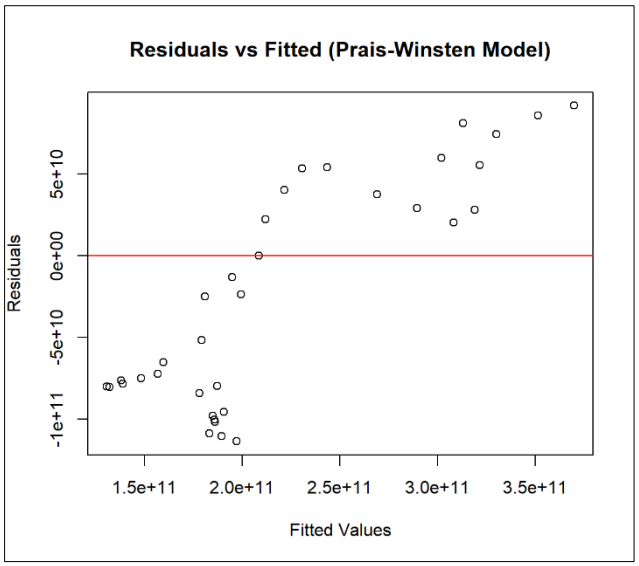


Figure 9. *Residuals vs Fitted Plot (Prais-Winsten)*

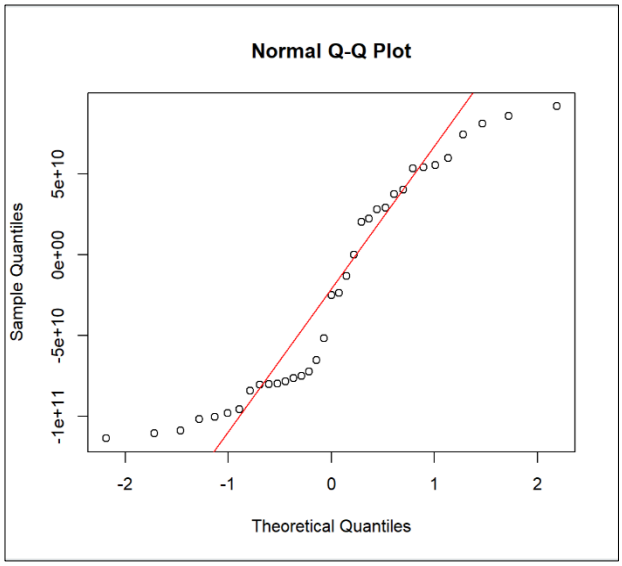


Figure 10. *QQ Plot (Prais-Winsten)*

Generalized Least Squares (GLS). After exhausting standard transformation and correction procedures, Generalized Least Squares (GLS) was applied as the final and most appropriate remedy within this study's methodological framework. Taboga (2021) describes this as a sophisticated procedure designed to identify and rectify unknown parameters for more accurate results. This method is used in econometric models to improve estimate efficiency when data exhibit heteroskedasticity or autocorrelation. By mathematically adjusting the data, the procedure yields more precise and objective parameter estimates than ordinary least squares (OLS), which assumes constant variance and no error correlation. Ultimately, this approach is more efficient for time-series and panel data models where autocorrelation is prevalent, providing a more reliable basis for statistical inference (Dinas-Morales & Burbano-Vallejo, 2024; Taboga, 2021).

Beyond its general suitability for correcting autocorrelation, the choice of GLS-AR(1) over the Autoregressive Distributed Lag (ARDL) bounds testing approach warrants further justification. While ARDL offers a comprehensive framework for jointly estimating short-run dynamics and long-run cointegrating relationships, its application requires that the order of integration of all variables first be established through unit root testing, as the bounds test procedure is valid only when variables are integrated of order zero or one (Pesaran, Shin, & Smith, 2001). This precondition falls outside the scope of the present study's objectives, which centered on establishing whether a statistically significant association exists between total energy consumption and GDP rather than modeling long-run equilibrium relationships. Given these considerations, GLS-AR(1) was retained as the estimation method most directly suited to correcting the autocorrelation identified in the initial OLS diagnostics, while non-stationarity concerns are transparently disclosed rather than left unaddressed, as discussed further in the study's limitations.

By utilizing GLS-AR(1), the study produced reliable results that satisfied all model assumptions. As shown in Table 17, the model was tested for autocorrelation using the Ljung-Box test (p = .055), heteroskedasticity using the ARCH test (p = .160), and normality using the Jarque-Bera test (p = .841). The Ljung-Box p-value, while marginally above the .05 threshold, is considered acceptable and indicates no significant autocorrelation in the residuals. All three post-estimation tests passed, confirming the validity and reliability of the GLS-AR(1) model for inference. It should also be noted that the intercept in this model returned a t-value of approximately zero (t = −0.000011, p = 1.000), indicating it carries no meaningful explanatory weight. This is not uncommon in GLS models with strong autocorrelation correction and does not affect the validity of the slope coefficient, which remains the focus of inference.

All statistical analyses in this study were performed using R (version 4.4.2), an open-source programming language and environment for statistical computing (R Core Team, 2024).

Results and Discussion

Trend of Total Energy Consumption in the Philippines, 1990–2024

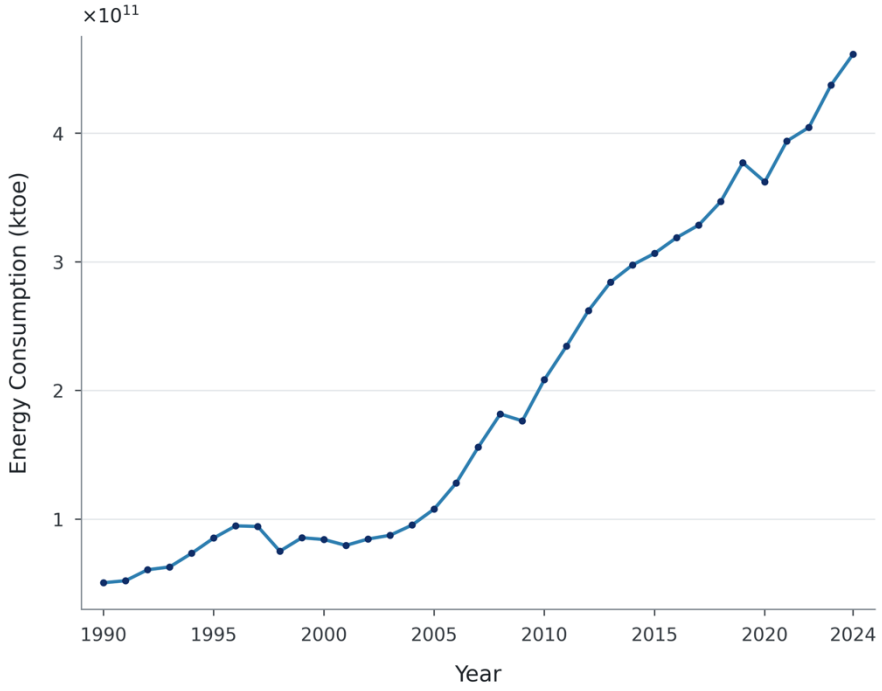


Figure 11. *TEC Line Graph: Total Energy Consumption in the Philippines 1990-2024*

As shown in Figure 11, total energy consumption in the Philippines grew steadily from 1990 to 2024, driven by transportation expansion, industrialization, and population growth (Huang et al., 2008). Growth was gradual through 2000, followed by a marginal decline from 2001 to 2003 attributed to industrial shifts and economic uncertainty (Barroga & Tan-Cruz, 2017), and brief fluctuations from 2004 to 2006. From 2007 to 2019, consumption grew steadily and rapidly, consistent with economic expansion observed in developing Asia-Pacific economies (Komarova et al., 2022). A notable decline in 2020 corresponded with the broad economic restrictions of the COVID-19 pandemic (Dinas-Morales & Burbano-Vallejo, 2024), after which consumption recovered strongly, reaching 69,558 Ktoe by 2024 (Enerdata, 2024).

Trend of the Philippines' Gross Domestic Product, 1990–2024

The Philippines' GDP recorded substantial long-term growth from 1990 to 2024, as shown in Figure 12, though major external shocks interrupted its path. Starting at approximately 50.5 billion USD in 1990, growth was steady until the Asian Financial Crisis caused a sharp decline to 74.5 billion USD in 1998 from a peak of 94.6 billion USD in 1996, before the economy gradually recovered into the 2000s, supported by macroeconomic stabilization and trade liberalization (Xue & Taylor, 2018). A brief slowdown in 2009 due to the Global Financial Crisis had a mild impact given the Philippines' limited financial market exposure (Xue & Taylor, 2018), and recovery was swift. The 2010s marked the most stable growth period, with GDP rising from 208.4 billion USD in 2010 to 376.8 billion USD in 2019, driven by services sector expansion, remittance inflows, and domestic consumption (OECD, 2026). The COVID-19 pandemic caused GDP to fall to 361.7 billion USD in 2020 (World Health Organization, 2020), before rebounding to about 461.6 billion USD by 2024, though real economic activity gradually moderated as post-pandemic inflation rose (FocusEconomics, 2025). From 1990 to 2024, the Philippines' GDP grew nearly ninefold, reflecting the economy's resilience and capacity for sustained long-term development.

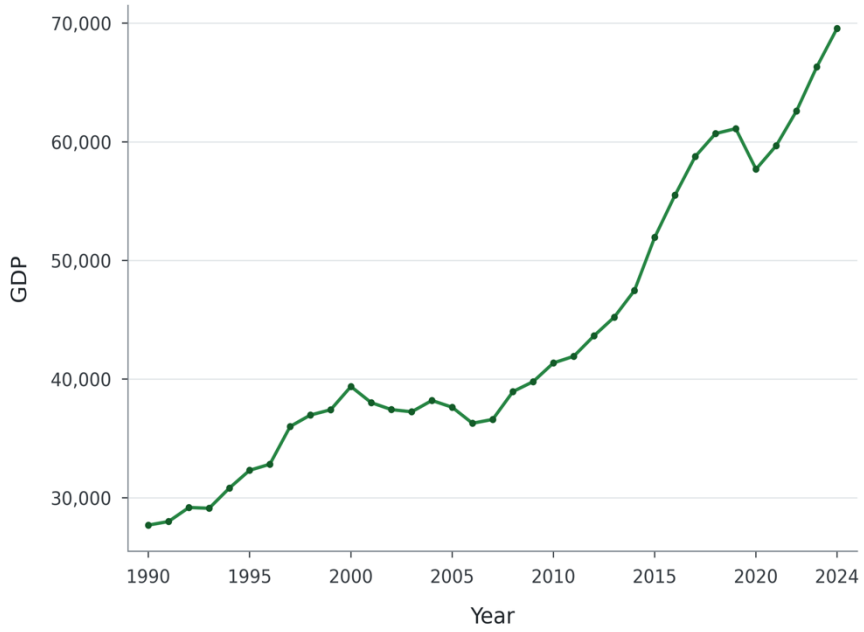


Figure 12. *GDP Line Graph: GDP in the Philippines, 1990-2024*

Together, total energy consumption and GDP in the Philippines followed broadly similar upward trajectories over the study period, with both variables experiencing notable declines during the same major economic disruptions—particularly the Asian Financial Crisis of 1998, the Global Financial Crisis of 2009, and the COVID-19 pandemic of 2020. This parallel movement suggests a possible positive relationship between the two variables, which is formally examined through the GLS regression analysis presented in the succeeding discussion.

Relationship Between Total Energy Consumption and GDP

Table 16. *GLS-AR(1) Regression Results*

	Coefficient	Std. Error	*t*	*p*
Intercept	-2,616,041,542	2.42×10^{14}	-0.00	1.000
Total Energy Consumption	**5,318,836**	**1,200,826**	**4.43resi**	***p* < .001**

Table 17. GLS-AR(1) Diagnostic Test Results

Test	Statistic	df	*p*	Result
Ljung-box	3.70	1	.055	No autocorrelation
ARCH LM	1.98	1	.160	No heteroskedasticity
Jarque-Bera	0.35	2	.841	Residuals are normal

As presented in Table 16, the Generalized Least Squares (GLS) estimation with an AR(1) correlation structure reveals a statistically significant positive relationship between total energy consumption and GDP in the Philippines from 1990 to 2024. The coefficient on total energy consumption was estimated at 5,318,836 and is statistically significant ($t = 4.43$, $p < .001$), as shown in Table 16. Since $p < .001$ and is substantially lower than the 0.05 level of significance, the null hypothesis—that there is no significant relationship between total energy consumption and GDP in the Philippines—is rejected. Consequently, the alternative hypothesis, which states that there is a significant positive relationship between the two variables, is accepted. This indicates that for every one-unit increase in total energy consumption (in Ktoe), GDP is associated with an increase of approximately 5,318,836 USD, holding other factors constant. This positive association suggests that energy consumption is meaningfully linked to sustaining economic output in the Philippines, aligning with the broader energy-growth literature.

Komarova et al. (2022) similarly found that the association between energy consumption and GDP tends to be stronger in non-OECD and developing economies, particularly in the Asia-Pacific region, consistent with this study's findings. Jaiyesimi et al. (2017) also found strong evidence of a relationship between total energy consumption and GDP across OECD countries, further supporting the notion that energy and economic output are deeply intertwined regardless of development context.

It should be noted, however, that while the results establish a statistically significant association between TEC and GDP, this study does not formally test the direction of causality between the two variables. The finding indicates that energy consumption and economic output move together, but whether energy consumption is associated with GDP growth, whether GDP growth is associated with energy demand, or both cannot be determined from the current model alone. This distinction matters, as establishing association is not equivalent to establishing causation, and future studies using Granger causality testing or vector autoregression would be better positioned to address this question.

This finding, however, contrasts with the earlier Philippine-specific study of Barroga and Tan-Cruz (2017), which found no significant relationship between total energy consumption and GDP in the Philippines from 1975 to 2010. This divergence may be due to the longer study period in the present study, which covers 1990 to 2024 and captures major structural shifts in the Philippine economy. Although both studies examine a similar research question, the time periods covered differ substantially. The present study begins in 1990, a period marked by rapid industrialization and transportation expansion in the Philippines, and extends through the strong growth of the 2010s, continued industrialization, and the post-pandemic economic recovery. From 1990 to 2024, the Philippine economy expanded significantly, driven by sustained capital formation and increased investment in business operations, which contributed to considerable employment and output growth (World Bank Group, 2025). As economic activity intensified over this period, energy demand correspondingly increased, which may have strengthened the energy-GDP association over time and made it more observable in a longer dataset. Therefore, the significant association found in the present study may reflect the cumulative effect of these structural economic developments, which were not fully captured in the earlier, shorter dataset of Barroga and Tan-Cruz (2017).

The reliability of these findings is further supported by the diagnostic tests presented in Table 17. The Ljung-Box test yielded p = .055, indicating no significant autocorrelation in the residuals—meaning the residuals are independent of one another and do not influence the outcome variable. This is critical, as addressing residual correlation helps prevent inefficient estimates and misleading results (Taboga, 2021). The ARCH test returned p = .160, indicating no evidence of heteroskedasticity. In simpler terms, this means the spread of errors remains consistent across all values of the independent variable, satisfying the homoscedasticity assumption. Finally, the Jarque-Bera test produced p = .841, suggesting that the residuals follow a normal, bell-shaped distribution. This condition is a key requirement for ensuring that the model's statistical inferences are reliable and valid (Dziak, 2024). Taken together, all three diagnostic tests passed, confirming that the GLS-AR(1) model is statistically well-specified and appropriate for drawing conclusions about the Philippine economy (Dinas-Morales & Burbano-Vallejo, 2024). This final validation ensures that the observed association between energy consumption and GDP is not a statistical fluke, but a robust reflection of the country's economic structure.

Conclusion

The results of this study align with the Neoclassical Growth Theory of Solow-Swan, which argues that the availability and productive use of factor inputs are associated with economic output (Popa, 2014). While the model traditionally highlights capital, labor, and technology, energy is increasingly recognized as a foundational input that enables all other factors. In this sense, the significant positive association between total energy consumption and GDP found in this study reflects something deeper than a statistical pattern. It reflects the reality that economic activity in the Philippines remains strongly tied to energy availability. Equally important is the model's emphasis on technological progress as a long-term driver of growth. This suggests that as the Philippines advances technologically, the focus should shift not just toward consuming more energy but toward consuming it more efficiently, generating greater economic output per unit of energy used. In this light, how the Philippines uses its energy matters as much as how much it consumes, consistent with Neoclassical Growth Theory's emphasis that the efficient use of factor inputs, not just their quantity, sustains long-term economic growth.

This study adds to the small number of Philippine-specific studies on the energy-GDP relationship by covering a

longer, more recent period through 2024, allowing it to capture the rapid growth of the 2010s and the post-pandemic recovery that earlier studies could not observe because of their more limited data. Beyond the statistical results, this study can give policymakers and energy planners a better understanding of how sustained economic growth will impact energy demand, enabling them to plan energy infrastructure in advance rather than reacting to shortages. These results matter for the Philippines' long-term development goals under AmBisyon Natin 2040, which calls for sustained average GDP growth of around six percent per year to triple per capita income by 2040. The results indicate that energy consumption is closely tied to economic growth, not just a side effect, highlighting how important energy security and availability are to achieving the nation's development goals. As the population keeps growing and cities continue to expand, energy demand will only increase, and how the country manages that demand will play a big role in shaping how fast and how sustainably its economy can grow.

This study acknowledges several limitations. The analysis is limited to two variables—total energy consumption and GDP—and does not account for other factors that may influence economic growth such as population, inflation, trade, and investment. Additionally, the AR(1) coefficient (rho) obtained from the GLS estimation was approximately 0.99, suggesting a near-unit root or non-stationarity in the data. This is a known limitation of the GLS-AR(1) approach: while the model satisfied all required post-estimation diagnostic tests within the scope of this study's methodological framework, more advanced techniques such as unit root testing and cointegration analysis would be better suited to formally address non-stationarity concerns. Applying such methods was outside the scope of the present study but is strongly recommended for future research. These limitations open avenues for further research that could build on and refine this study's findings.

Based on the findings of this study, the following recommendations are proposed:

For Policymakers and Energy Planners. The government is encouraged to prioritize investment in energy infrastructure and develop indigenous and renewable energy sources to ensure a stable, affordable, and sustainable energy supply. Since energy consumption is strongly associated with GDP, expanding energy capacity is essential to sustaining long-term economic growth. Furthermore, given that the energy-GDP relationship is vulnerable to major economic disruptions such as the Asian Financial Crisis, the Global Financial Crisis, and the COVID-19 pandemic, energy planning should be integrated into a broader economic resilience framework to mitigate the impact of future shocks.

For Energy Policy and Security. The government should pursue policies that reduce the country's heavy dependence on imported fossil fuels, particularly coal, by accelerating the transition toward renewable energy sources. This would strengthen energy security and reduce the economy's exposure to global price volatility and supply chain disruptions. Aligning energy policy with the country's long-term development goals under AmBisyon Natin 2040 would ensure that energy supply keeps pace with the sustained GDP growth required to achieve the vision's targets.

For Future Researchers. Future researchers are encouraged to go beyond total energy consumption and examine the specific economic effects of different energy sources, such as renewable versus fossil fuel-based energy, and compare these findings with other developing countries that similarly depend on energy imports. Incorporating additional macroeconomic variables such as population growth, inflation, trade openness, and investment would also provide a more complete picture of what drives economic output in the Philippines, addressing the current study's two-variable limitation. Additionally, replicating this study over the next three to five years would allow researchers to detect structural changes and determine whether the significant positive relationship between energy consumption and GDP persists as energy policies and economic conditions evolve. More advanced econometric methods such as cointegration analysis or vector autoregression (VAR) are also recommended to better capture the dynamic nature of the energy-GDP relationship and address the non-stationarity concerns identified in this study.

For the Private Sector. Businesses are encouraged to treat energy investment not just as an operational necessity but as closely tied to economic output. Given that every unit increase in total energy consumption is associated with an estimated 5,318,836 USD increase in GDP, the private sector's role in energy investment and efficiency carries measurable economic weight. Companies that invest in energy capacity and adopt efficient energy practices not only reduce their own costs—they contribute to the broader economic expansion that the country

needs to sustain. Active private sector participation in energy development would complement government efforts and help close the gap between rising energy demand and the sustained growth required under AmBisyon Natin 2040.

Contributions of Authors

Almira Thea D. Peñales: Conceptualized the research framework, introduction, synthesis, data collection, statistical data analysis, results interpretation and discussion, manuscript editing and final review.
Regine I. Bargados: Literature review, research design, and research recommendations.
Lorraine Joy S. Jose: Literature review, statistical data analysis, results interpretation and discussion.
Mary Riyuki R. Nicolas: Introduction, literature review, results interpretation and discussion.
Joaquin Lian E. Pagkatipunan: Literature review, statistical data analysis, data encoding, results interpretation and discussion.
April Ann P. Reyes: Literature review, population and sample, and research recommendations.
Geneveva T. Dungca: Research review, validation, and supervision.

Funding

This research was not funded by any external financing organization. The study was carried out by utilizing personal resources.

Conflict of Interests

The authors declare no financial, personal, or professional interests that may have influenced the execution, analysis, or publication of the research. All authors confirm that the research was conducted with due academic integrity and objectivity.

Acknowledgment

The researchers wish to express their sincere gratitude to everyone who contributed to the completion of this study. First, to our research adviser, Mrs. Geneveva T. Dungca, for her patient guidance, helpful feedback, and constant support throughout the research process. To our defense panelists, for their valuable comments and suggestions that helped improve this paper. To our friends and classmates, who shared their time and insights during our mock defense and helped us prepare for the final defense. Finally, the researchers extend their heartfelt appreciation to everyone who supported this study in any way.

References

Barroga, K., & Tan-Cruz, A. (2017). Energy consumption and gross domestic product in the Philippines: An application of maximum entropy bootstrap framework. Advances in Research Journal of Banking, Economics and Finance, 5(1), 1–17. https://tinyurl.com/2dw8vy7y
Benhamed, A., & Ramzi, K. (2024). The relationship between energy consumption and GDP: Saudi Arabia case study. Pakistan Journal of Life and Social Sciences, 22(2), 21165–21172. https://doi.org/10.57239/PJLSS-2024-22.2.000210
Chongco, S.M.R., Dumlao, N.M., Co, K.J., & Cabauatan, R. (2022). The causal relationship of renewable energy and non-renewable energy consumption to the economic growth of the Philippines. Journal of Economics, Finance and Accounting Studies, 4(1), 340–358. https://doi.org/10.32996/jefas.2022.4.1.22
Dinas-Morales, A., & Burbano-Vallejo, E.L. (2024). Energy use and economic growth: An empirical study of short-run and long-run dynamics for Colombia between 1990 and 2021. SAGE Open. https://doi.org/10.1177/21582440241279682
Dziak, M. (2024). Correlational research. Research Starters: Mathematics. EBSCO. https://tinyurl.com/2p9njcm7
Enerdata. (2024). Philippines energy market report. https://www.enerdata.net/estore/energy-market/philippines/
FocusEconomics. (2025). Philippines economic outlook. FocusEconomics Consensus Forecast. https://tinyurl.com/4syybpmj
Ghoshray, A., & Lorusso, M. (2025). Energy consumption, CO2 emissions and economic growth in selected ASEAN countries. Letters in Spatial and Resource Sciences, 18(1). https://doi.org/10.1007/s12076-025-00398-y
Huang, B.-N., Hwang, M.-J., & Yang, C.-W. (2008). Causal relationship between energy consumption and GDP growth revisited: A dynamic panel data approach. Ecological Economics, 67(1), 41–54. https://doi.org/10.1016/j.ecolecon.2007.11.006
International Energy Agency. (2025). Economic growth. https://www.iea.org/reports/economic-growth
Jaiyesimi, M.T., Osinubi, T.S., & Amaghionyeodiwe, L.A. (2017). Energy consumption and GDP in the OECD countries: A causality analysis. Review of Economic and Business Studies, 10(1), 55–74.
Komarova, A.V., Filimonova, I.V., & Kartashevich, A.A. (2022). Energy consumption of the countries in the context of economic development and energy transition. Energy Reports, 8(3), 683–690. https://doi.org/10.1016/j.egyr.2022.07.039
Laake, P., & Fagerland, M.W. (2015). Chapter 11 – Statistical inference. In Research in Medical and Biological Sciences. Academic Press. https://doi.org/10.1016/B978-0-12-799943-2.00011-2
Muço, K., Valentini, E., & Lucarelli, S. (2021). The relationships between GDP growth, energy consumption, renewable energy production and CO2 emissions in European transition economies. International Journal of Energy Economics and Policy, 11(4), 362–373. https://doi.org/10.32479/ijeep.11275
National Economic and Development Authority. (n.d.). About AmBisyon Natin 2040. https://2040.neda.gov.ph/about-ambisyon-natin-2040/
Noland, M. (2000). The Philippines in the Asian financial crisis: How the sick man avoided pneumonia. Asian Survey, 40(3), 401–412. https://doi.org/10.2307/3021153
OECD. (2026). OECD economic surveys: Philippines 2026. OECD Publishing. https://doi.org/10.1787/f0e0c581-en
Pesaran, M. H., Shin, Y., & Smith, R. (2001). Bounds testing approaches to the analysis of level relationships. Journal of Applied Econometrics, 16(3), 289–326. https://doi.org/10.1002/jae.616
Popa, F. (2014). Elements of the neoclassical growth theory. Studies and Scientific Researches. Economics Edition, 20. https://tinyurl.com/rkfdfkef
R Core Team. (2024). R: A language and environment for statistical computing. R Foundation for Statistical Computing. https://www.R-project.org/
Taboga, M. (2021). Generalized least squares. In Lectures on Probability Theory and Mathematical Statistics. Kindle Direct Publishing. https://tinyurl.com/y2rzmsa7
Topolewski, L. (2021). Relationship between energy consumption and economic growth in European countries: Evidence from dynamic panel data analysis. Energies, 14(12), 3565. https://doi.org/10.3390/en14123565
Wang, J., Hassan, M.S., Alharthi, M., Arshed, N., Hanif, I., & Saeed, M.I. (2022). Inspecting non-linear behavior of aggregated and disaggregated renewable and non-renewable energy consumption on GDP per capita in Pakistan. Energy Strategy Reviews, 39, 100772. https://doi.org/10.1016/j.esr.2021.100772
World Bank. (n.d.). GDP growth (annual %) – Philippines. World Bank Open Data. https://tinyurl.com/ms8w6cbw
World Bank Group. (2025). Running uphill: Growth, jobs, and the quest for productivity. Philippines Country Growth and Jobs Report 2025. https://tinyurl.com/5n6e2v4u
World Health Organization. (2020). COVID-19 pandemic declaration. https://tinyurl.com/2t65mdwf
Xue, W., & Taylor, J. (2018). Recovery from the Asian financial crisis: The importance of non-monetary financial factors. Asian Pacific Economic Literature. https://tinyurl.com/2w75xh8r
Yan, G., & Bian, W. (2023). The impact of relative energy prices on industrial energy consumption in China: A consideration of inflation costs. Economic Research-Ekonomska Istraživanja, 36(1). https://doi.org/10.1080/1331677X.2022.2154238