The Philippine Electricity Power Market Supply Options: Challenges and Policy Implications for Greening Economic Growth, Climate Resiliency, and Low Carbon Future

Edilberto B. Viray, Jr.
College of Arts and Sciences
San Beda University, Manila, Philippines
eviray@sanbeda.edu.ph

Celedonio B. Mendoza, Jr.[+]
College of Arts and Sciences
San Beda University, Manila, Philippines
cmendoza@sanbeda.edu.ph

Abstract

Over the past few years, energy security and sustainable development have moved up the global agenda. Energy is what makes an economy run. There is a strong correlation between economic development and energy consumption. Energy security plays an important role in all economic sectors in attaining the long-term vision of inclusive economic growth and development of the economy. The attainment of this vision is difficult as it is challenged by the need to build energy infrastructures that are not only responsive to the growing demand but can withstand the maximum credible natural disaster. One of the primary objectives of sustainable development is to make people without access to enough energy be able to meet their needs through the provision of stable, reliable, clean, safe, and affordable energy services. This research will use the Granger Causality test to analyze the causal relationship among the endogenous variables among (1) GNI per capita; (2) GHG Emissions; and (3) Herfindahl-Hirschman Index (HHI) between energy-economic development and the influencing factors of power supply security indicators. In the end, this paper expects to suggest that the paper electric power development plans in the country also have implications for the path that would lead the country to what is known as a green economy. It is in this background that energy security and economic growth development are intertwined by public policy. In a broader development sense, public policy draws in the active involvement of the community in identifying problems. Anchored deeply in the national development agenda, the local community develops its own sets of development goals and pushes itself towards realizing this long-range vision. Hence, the output of public policy supported by strategic planning will require effective monitoring and evaluation of programs. This remains to be both a challenge and priority for both the national and local governments.

Keywords: Gross National Income per capita; Energy Policy; Philippines; Greenhouse Gas Emission; Herfindahl-Hirschman Index

As the world continues to move forward, the countries in it are all dealing with their individual growth and development in all kinds of economic, political, cultural, and technological aspects. The war of economic supremacy continues as all countries are all prepared to have massive productions for domestic prosperity and a higher level of progress. With this, countries are pressured wherein it resulted in a not so favored "trade war" between the two giants, the United States of America (USA) and its close rival, the People's Republic of China. This so-called "trade war" distress its neighbor countries and other industry that upshot to a more unstable and recessionary effect to the industry and economy of both countries. But this narrative was immediately scrapped as the world agonized and endure the effect of the recent global pandemic '2019 novel coronavirus' or '2019-nCoV,' and later on called as COVID-19. The new virus was linked to the same family of viruses as a severe acute respiratory syndrome (SARS) and some types of a common cold that resulted in countries lockdown for months that prohibits 85% to 90% of industries to shut down all their operations. For a while, due to the pandemic, all productions were halted that lowered the Gross Domestic Product (GDP) of top countries and problems with supplies arise. After those "dark period" of pandemic, the world has immediately awakened the power of "digital economy" that provides a number of avenues to continue the operations of various industries following the strict protocols provided by the government to prevent the colossal spread of the said deadly virus.

As the new normal arise in several economies, the reliance and demand for energy in the world was predominantly increases as the optimization of " the digital economy" came early in most of the industries and countries. As economic activity across the nations slowly pick-up after a more relaxed protocols as energy played a vital role in it as its demand increases rapidly over the period. Energy has clearly a significant role in each country's sustainable and economic development that's why campaigns, research and development on energy have heightened to further promote more power accessibility and options to all and policy implications that will provide provisions for stable, reliable, clean, safe, and affordable energy supplies to an entire nation. Moreover, in the Philippines, the government has launched its very own "Energy Agenda" as it embarked on its 2016-2030 sectoral energy roadmaps that will provide guidance and direction to see progress in this particular sector.

In addition, all economies in the world are committed to meet and achieve somehow the "Sustainable Development Goals of 2030" whereas this whole energy research has its own role and contribution on the following chosen SDGs namely, SDG4: Quality Education, SDG8: Decent Work and Economic Growth, SDG10: Reduced Inequalities, SDG13: Climate Action, SDG16: Peace, Justice and Strong Institutions and SDG17: Partnerships for the Goals.

Over the past few years, energy security and sustainable development have moved up the global agenda. Energy is what makes an economy run. There is a strong correlation between economic development and energy consumption. Energy security plays an important role in all economic sectors in attaining the long-term vision of inclusive economic and growth development of the local economy. The attainment of this vision is difficult as it is challenged by the need to build energy infrastructures that are not only responsive to the growing demand but can withstand the maximum credible natural disaster. One of the primary objectives of sustainable development is to make people without access to enough energy be able to meet their needs through the provision of stable, reliable, clean, safe and affordable energy supplies.

Based on relevant data of economic and social development in the Philippines, the authors will analyze the status of the electricity market and determined power supply security indicators (quality, reliability, security and affordability of the supply of electricity) which affect the energy-economic development in the Philippines: energy intensity and efficiency. This paper will emphasize a model to analyze the correlation between energy-economic development and the influencing factors of power supply security indicators. In the end, this paper expects to suggest that the Electric Power Development in the country also has implications for the path that would lead the country to what is known as a green economy.

The diversification of supply is considered as another measure of energy security for a country. The Herfindahl-Hirschman Index (HHI) is used as an indicator to measure the supply diversity index for power generation. HHI is an economic concept applied to assess market share or market concentration. A well-diversified power generation mix means that the country will be more resilient to changes in terms of supply interruption or price escalation as the impact of such would be lessened given the share of each technology or fuel to the mix. The HHI ranges from 0.0 to 1.0 with a higher index means high concentration (or highly not diversified), while a low index translates to low concentration (highly diversified).

The researchers observed that on average, over the last ten years since 2010 based on energy the available data, the profile of the country's total power generation production using all technologies are as approximately as follows: coal (49.8 %), oil-based (4.5%), natural gas (21.7%), hydro (21.7%), geothermal (11.2%) and other renewable energy (3.4% which includes solar, wind and biomass).

Energy economics researchers and experts like Kanchana and Unesaki (2014) used the HHI to describe and measure the degree of diversity of primary energy supply in the study on "ASEAN Energy Security: An Indicator-based Assessment. The study assessed the energy supply security of the ASEAN member states and examined how it evolved over the past decade. Likewise, Tufail, Ibrahim and Melan (2018) affirmed that a commonly used method of measuring the degree of diversification is HHI. On the other hand, the Asia Pacific Energy Research Center (APERC, 2017) also used the HHI as one of the sub-indicators for the development of an overall Energy Security Index. HHI has been widely applied in the electric power industry through the quantification of diversification. The diversity score is defined as a measure of the degree of diversification for a given portfolio.

It is in this background that energy security and economic growth development are intertwined by public policy. In a broader development sense, public policy draws in the active involvement of the community in identifying problems. Anchored deeply in the national development agenda, the local community develops its own sets of development goals and pushes itself towards realizing this long-range vision. Hence, the output of public policy supported by strategic planning will require effective monitoring and evaluation of programs. This remains to be both a challenge and priority for both the national and local governments.

Research Problem

Generally, the researchers sought to answer the question: What is the dynamic relationship of energy-economic development and the influencing factors of power supply security indicator?

Specifically, the researchers aimed to determine the:

1. Performance of the Philippines in terms of Gross National Income (GNI) per capita from the year 1985 to 2019;
2. The situation of the Philippines in terms of Power Supply options;

3. Trend in the Greenhouse Gas (GHG) emission from the electric power industry;
4. Significant causal relationship among the endogenous variables; and
5. Policy implications of the results of the study.

Review of Related Literature

The Philippines energy future and low-carbon development strategies

According to Mondal et.al (2018), the country's essential energy supply comprises 60 percent petroleum derivatives and 40 percent environmentally friendly power. The portion of oil in the complete energy supply-blend is critical, at about 31 percent in the year 2014. The country's independence in essential energy supply has been diminishing lately. The sustainable power share declined from 43 percent in 2012 to 40 percent in 2014. All out essential energy supply and last energy utilization were 36.01 million tons of oil-same (mtoe) and 22.36 mtoe in 2006 and with expansion to 47.5 mtoe and 28.57 mtoe in 2014. On the other hand, all imported energy was 14.26 mtoe in 2006 and has expanded to 20.86 mtoe in 2014; this addresses a portion of 44 percent in the essential energy-blend. About 75 percent of non-renewable energy source request is met through importation. Coal imports also expanded around two-overlay somewhere in the years 2006 and 2014. Fuel utilization by the Philippine power sector also consumes 46 percent of all essential energy. The nation's interest supply viewpoint in the years 2015 and 2030 shows an extra 7-gigawatt (GW) limit needed to satisfy the normal power supply by the year 2030.

Furthermore, the country's power sector depends generally on fossil-fuels by 77 percent and is required to expand its utilization of coal-based plants to fulfill future energy needs, which would adversely influence the environment. Coal utilization in the power sector also expanded from 7 million tons (mt) in 2006 to 15.5 mt in 2014. As dependence on coal-based power generation continues to expand, greenhouse gases (GHG) were also expected to rise eventually. Carbon dioxide (CO2) emissions from coal power plants added up to 26 mt and are projected to increment to 92 mt of CO2 each year if all arranged coal plants will be done on time.

The nation has been enduring power blackouts or deficiencies, especially throughout the summer season since the 1990s. Power request during those periods was about 25.6 GWh in 1991 and expanded to 53 GWh in 2003 and 77.3 GWh in 2014. Demand for energy supply in the country is expected to double in the coming years. That is why energy shortage adversely affects the economic stand of the country. Energy flow difficulties in the power sector in the Philippines incorporate an inventory request hole described by neglected interest, high power cost; under-investment; decreased independence; and expected high development of GHG emissions levels. A national renewable energy program was embraced to drastically expand (three-overlay) the life of sustainable power advances expected by the year 2030; this development will considerably relieve GHG emissions from the power sector.

Moreover, to assist with the diminishing worldwide environmental change (Climate Change), the public authority of the Philippines has made a promise to restrict the future development of GHG emissions by carrying out the elective arrangement choices, for example, carbon charges, improvement of energy proficiency in both age and utilization, broadening of the energy supply-blend, and sped up the advancements of sustainable power. The nation plans to diminish emissions by about 70 percent from various areas, like energy, transport, waste, ranger service, and industry by 2030, contrasted with the same old thing situation of emission levels in between 2000 and 2030.

The possible approaches to address these difficulties are to incorporate broadening of the energy supply-mix and consideration of climate change moderation technique in energy advancement and foundation support. These endeavors should uphold the national economic progress through job creation, expanded food security and lower poverty. On the other hand, the renewable energy capability of the Philippines is somewhat high and could add to the inventory of current dependable energy benefits and further developed overall energy security. The government's energy reform agenda features the significance of access to a more dependable energy supply, utilizing native energy assets while limiting imported petroleum products in an ideal and practical manner. The government's energy reform agenda highlights the following: (1) ensuring energy security, (2) achieving optimal energy pricing, (3) diversifying sources of fuel, and (4) developing a sustainable energy system.

Greening Economic Growth

According to Astana (United Nations, 2011), the term "green economy" can be characterized and perceived diversely and inside various settings. In their Green Economy Drive, the United Nations Environment Program (UNEP) characterized the term within a "broad economic, social and environmental agenda": a green economy is "one that results in improved human well-being and social equity, while significantly reducing environmental risks and ecological scarcities." Others, for example, the United Nations Economic and Social Commission for Asia and the Pacific (ESCAP) defined green economy as a policy that centers "environmentally sustainable economic progress to foster low-carbon, socially inclusive development." On the other hand, Organization for Economic Cooperation and Development (OECD) characterized "green growth" as "fostering economic growth and development, while ensuring that natural assets continue to provide the resources and environmental services on which well-being relies." These definitions are viable with the view progressively upheld by the United Nations framework that "greening the economy" can be an apparatus to achieve sustainable development and possible reduce the problem of poverty. In this specific situation, green economy supposedly is at the heart of reestablished endeavors to consider environmental and social contemplations within the standard of economic decision-making as discussed in the United Nations Conference on Sustainable Development in Rio and beyond.

In addition, according to Soderholm (2020), the "green economy" is another vision for development and advancement; one that can produce economic turn of events and enhancements in individual's lives in a manner that is reliable with progress together with economic and social prosperity. Another important part of a green economy methodology is to support progress and the possible integration of sustainable technologies. As we pursue this goal (sustainable technology for green economy) for a country and the world, challenges will be expected to rise eventually, and these will be lessening with the presence of proper policies and understanding and cooperation of all leaders in the world regarding the importance of green economy. On the other hand, the extension and the nature, the cultural difficulties that emerge as an outcome of the climate and environmental dangers are uncertain and diverse as the main authors focus on its five important challenges to sustainable technological change: (1) dealing with diffuse – and ever more global – environmental risks; (2) achieving radical – and not just incremental – sustainable technological change; (3) the advent of green capitalism: the uncertain business-as-usual scenario; (4) the role of the state: designing appropriate policy mixes and (5) dealing with distributional concerns and impacts.

Soderholm (2020) also concludes that in socio-technical transitions, multi-disciplinary research is must to further understand sustainable technology to promote green economy. Thus, it is important to make more collaborations between natural scientist and engineers together with other social sciences disciplines like economics, management, political science and support more research on sustainable entrepreneurs and transition studies. In addition, the study also suggests that the public sector should make a bigger role in "green innovation." As the government together with private sector has all the power to craft and implement policies that will make way to promote "green innovation" through technology-specific sustainability policies or green industrial policies. And finally, Soderholm suggested to conduct follow up research and impact assessments that will entail all possible theories and strategies that might help to create more policies to achieve the "green economy."

Climate Resiliency

According to Miola, et. al (2015), the term "resilience" was basically given as flexible, sturdy and pliant but applicable to the concept of natural, environmental and social capital. As a natural sciences term, according to Holling (1973), ecological resilience was conceptualized first that involves persistence, resistance, and transformation. Resilience in biological terms is characterized as the greatness of unsettling influence that can be retained before the framework changes its construction by changing the factors and cycles that control behavior. It contends that a specific level of variance in a framework may really work on the framework's capacity to face with change.

Resilience's point of view has been integrated with economics as it counts generic shocks and extreme events that might affect the whole economy. So basically, economic resilience is identified as capability of the economy to manager, expand and rebuild given all the macroeconomic shocks; and it also considers microeconomic effects on the welfare of household and issues of the firms. Moreover, another thing to integrate is the level of community, as it results in the concept of social resilience as it characterized the ability of the communities to survive all the possible shocks to their social infrastructure. A system with resilience provides the community pride, dependence, comfort and security as it easily manages the possible problems that might arise and will surely survive the test of time. That's why climate resiliency has the same impact as social and economics, as a nation or country survives the test of weather and climate changes. A lot of shocks might happen during climate change as it affects production, livelihood and food supply & security of a certain nation. That's why, the presence of sustainable development programs will help craft policies and regulations in order to cope up, survive and handle climate change and make a nation a climate resilient country.

Green House Gas effect

According to University Corporation for Atmospheric Research (UCAR) is that energy from the sun that advances toward the earth can experience some difficulty bouncing it back to space. The "greenhouse effect" impacted these energies waylaid in the environment, assimilated, and delivered by greenhouse gases. These greenhouse gas helps the earth to keep its warm temperature and make sure it is livable for every humankind; but, too much of it is bad as it made the earth warmer and can create a lot of natural disaster like typhoon, drought and more that may kill a lot of every living kind on earth.

Moreover, the greenhouse effect showed that solar energy assimilated at earth's surface is emanated once again into the air as warmth. As the warmth clears its path through the atmosphere and back out to space, greenhouses gases assimilate a lot of it. For what reason do greenhouse gases still absorb heat? Greenhouse gases are more unpredictable than different gas particles in the environment, with a structure that can assimilate heat. They emanate the warmth back to the world's surface, to another greenhouse gas or outside the space.

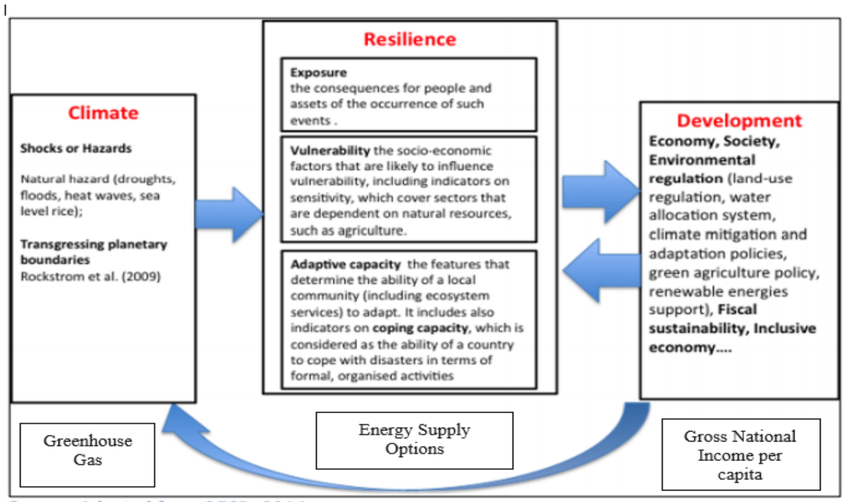
Furthermore, there are several types of greenhouse gases given the major ones, carbon dioxide, water vapor, methane, and nitrous oxide. These gas particles are made of at least three atoms. The particles are held together freely enough that they vibrate when they ingest heat. Ultimately, the vibrating atoms discharge the radiation, which will probably be consumed by another greenhouse gas. This cycle keeps heat close/trapped to the world's surface. The vast majority of the gas in the climate is nitrogen and oxygen, which can's assimilate warmth and add to greenhouse effect.

Although there is only little amount of greenhouse gases has seen on earth, but it has a significant effect when it comes to the climate. At some point during this century, the measure of greenhouse gas carbon dioxide in the environment is now twofold. Other greenhouse gases like methane and nitrous oxide are also expanding. Moreover, the amount of greenhouse gas suddenly expands as petroleum derivatives are scorched, followed by other pollutants that continue to poison the environment. Given the various sources of gases (for instance, livestock discharge methane gas as they processed food and concrete is produced using limestone-it significantly discharges carbon dioxide), it shows an impactful increase of greenhouse gas on earth.

Conceptual and Theoretical Framework

Figure 1.

The Conceptual and Theoretical Framework of the study



Source: Adapted from OECD, 2014.

The diagram in Figure 1 shows the building blocks from which the study is founded. In the study we used (1) GNI per capita to represent income; (2) GHG Emissions to relate to climate change; and (3) Herfindahl-Hirschman Index (HHI) to represent the resiliency of power supply options. Edomah (2018) supports this framework as it gives some insights into key aspects of energy supply economics (HHI). It also provides some insights on the business and regulatory dynamics in the energy sector, as well as their impact on energy supply; the economic and financial analysis of energy projects, as well as how they influence investment decisions. That over the medium and long term, the effects of power supply options (HHI) will improve income (GNPPC) and will reduce GHG emissions significantly.

Environmental Kuznets' Curve

According to Stern (Encyclopedia of Energy, 2004) EKC is named for Simon Kuznets, who "hypothesized that income disparities will increase and decrease as economic growth and development happens." The presence of several pollutants, like carbon dioxide, sulfur, and nitrogen oxides, are firmly coupled to the utilization of energy. Thus, the EKC is a "model of the relationship among energy utilization, economic growth and the climate."

The EKC is an important "empirical phenomenon" stresses by Stern but, struggles in statistics as shown in most of EKC literature. The history of EKC epitomized what can go wrong given the presence of a bad econometrics, done easy way. The EKC's diagnostic statistics was being panned by many, as it was not being given proper attention and interpretation. Other statistical properties have been utilized in analyzing EKC with the likes of serial dependence, and random walk trends in time series, and few tests of model adequacy together with econometrics, wherein its main goal is to examine relationships of variables and their correlations. For instance, applying econometrics plus supporting evidence, the result shows an alarming issue of pollution being addressed and making some solutions by developing economies.

The environment Kuznets curve (EKC) is a "hypothesized relationship between various indicators of environmental degradation and per capita income," according to Stern. This shows an expectation that continued economic growth will cause an increase in pollution emissions and decline in the quality of environment, but examining the other indicators of per capita income this trend reverses in which it considers that economic growth might lead to an environmental improvement instead. As it clearly related to the study wherein the authors used the following variables with GNI per capita to represent income, GHG emissions to relate it to climate change and HHI Herfindahl-Hirschman Index that will represent the resiliency of power supply options.

Methodology

In this study, the Granger Causality Test is used to analyze the interaction of the three selected endogenous variables of the study. This specifically includes the following steps: (1) Conduct of the unit root test for all the variables; (2) describe the selection of lag order, model construct and the robustness test; (3) measure the granger causality of the specified variables.

The researchers utilized Ordinary Least Squares (OLS) method or Maximum Likelihoods. Based on the objectives of the study, the econometric model of the study can be expressed as:

Eq1: $GNIPC = \beta_0 + \beta_1(GNIPC_{T-1}) + \beta_2(HHI_{T-1}) + \beta_3(GHG_{T-1}) + e$

Eq2: $HHI = \beta_0 + \beta_1(GNIPC_{T-1}) + \beta_2(HHI_{T-1}) + \beta_3(GHG_{T-1}) + e$

Eq3: $GHG = \beta_0 + \beta_1(GNIPC_{T-1}) + \beta_2(HHI_{T-1}) + \beta_3(GHG_{T-1}) + e$

Where:

GNIPC = Gross National Income per capita

HHI = Herfindahl-Hirschman Index

GHG = Greenhouse Gas emissions

t-1 = Single Year Lag

B_0 = Constant term (intercept)

B_1, B_2, B_3 = Partial regression coefficient; each regression coefficient represents the amount of deviation of the group identified in the dummy variable from the mean of the reference category

Granger Causality

The study used Granger Causality Test to examine the causal relationships among the given variables like GNI per capita to represent income, GHG emissions to represent climate change and HHI Herfindahl-Hirschman Index to represent resiliency of power supply options. Under this system, an endogenous variable can be treated as exogenous. In addition, performing the Granger Causality testing in this study to explore the direction of causality among the variables from GNPIC, GHG to HHI (Granger, 1969). It is a technique for determining whether one time series is useful in forecasting another. For instance, if a variable X is found to be helpful for predicting another variable say, Y, then X is said to Granger cause.

Impulse Response Function

In order to probe the dynamic relationship between variables gross national income per capita (GNIPC), greenhouse gas emission (GHG) and Herfindahl-Hirschman Index (HHI) in the estimated model, impulse response functions are employed in this section. An impulse response function also shows the dynamic impact of the endogenous variables to standard deviation shock.

Unit Root Test

The results of ADF and DFGLS test provide sufficient reason to accept the conclusion that the level series is a non-stationary sequence. The test results will suggest if that null hypothesis of a unit root in first-order difference can be rejected for all variables at the 1%, 5% or 10% significance level.

Determining the Lag Order for the Vector Autoregression Model

In order to construct the VAR model, the optimum number of lags is needed. The optimum lag length can be determined either by using the Akaike Information Criteria (AIC), the Schwartz Information Criteria (SC), Final Prediction Error (FPE), and Likelihood Ration (LR) or by the Hannan-Quin Information Criterion (HQ). A * sign, located on the upper right of the value, will indicate the lag order selected by the criterion.

Results and Discussion

The Causal Relationship between GHG Emissions, GNI per capita and HHI of power supply options

Table 1.

Variables of the study

Indicators	1985	2000	2010	2019	1985-2019*	1985-2000
GNI per Capita[1]	520.0	1,150.0	2,370.0	3,850.0	6.1%	5.4%
HHI of power supply options[2]	0.28	0.27	0.25	0.36	0.7%	-0.2%
GHG[3] from Power Systems	6.3	21.4	31.3	61.4	6.9%	8.6%

Sources: Philippines Department of Energy; World bank open data portal
*/*Annual average growth rate*

[1] The GNI per capita is the dollar value of a country's final income in a year, divided by its population. It should be reflecting the average before tax income of a country's citizens. Source: World bank open data

[2] Herfindahl-Hirschman Index is calculated by squaring the share of each technology/fuel to total power generation, and then add each share to get the total. For energy security indicator purposes, the HHI is modified such that the range of high concentration (highly not diversified) was adjusted from its original of >0.25 to 1.00. A higher HHI means a high concentration in one or few sources. HHI of below 0.10 is considered low concentration (highly diversified), 0.10-0.19 is moderately diversified, 0.20-0.49 is somewhat diversified, 0.50-0.99 is highly not diversified (dominant fuel in the mix), and 1.0 is not diversified.

[3] Greenhouse gas emission. The unit of measure used in a GHG inventory is Million tonnes of carbon dioxide equivalent.

Table 1 illustrates the development of the three variables from 1985-2019 for the research: Gross National Income (GNI) per capita which are as follows: From the year 1985 GNI per capita is USD 520.0, it has improved 35 years later to USD 3,850 in 2019 which is an equivalent of 6.1% growth. The Philippines has made substantial efforts over the past three decades to build a modern and globally competitive economy. Administration after another made significant progress in implementing its own economic platforms and pushed through with its own structural reforms.

Table 2.

Gross Power Generation by Plant Type in GWh

Plant Type	Milestone Years				Annual Average Growth Rate		
	1985	2000	2010	2019	1985-2019	1985-2000	2010-2019
Total	15,869	45,290	67,743	106,040	5.7%	5.8%	5.1%
Oil Based	2,040	9,185	7,101	3,789	1.8%	-5.7%	-6.7%
Hydro	5,553	7,799	7,803	9,613	1.6%	1.4%	2.3%
Geothermal	4,929	11,626	9,929	10,272	2.2%	-0.8%	0.4%
Coal	3,347	16,663	23,301	46,849	8.1%	7.1%	8.1%
Natural Gas	0	17	19,518	20,549		60.5%	0.6%
Other Renewables							
Solar	0	0	1	1,203			114.5%
Wind	0	0	62	1,096			37.7%
Biomass	0	0	27	1,015			49.5%

Relative to power supply market development, table 2 illustrates the performance of the country. It can be observed that the country's Gross Power Generation from all plant type in 2019 went up by 106,040 MWh from 15,869 MWh in 1985 which is equivalent to an average annual growth of 5.7%. On a per power plant type basis, Power plants burning oil from 2010 to 2019 experienced a decline. From 7,101 MWh in 2010, it decreased to 3,789 MWh which is equivalent to an average annual decline of 6.7%. On the other hand, gross generation from other power plant types somewhat did not improve significantly except for the emerging renewable technologies (Solar, Wind and Biomass) and coal power plants. The researchers, however, observed that gross generation from coal-fired power plants are experiencing growth that is higher than 5%. It can be observed that coal-fired power plants in 2019 went up by 46,849 MWh from 3,347 MWh in 1985 which is equivalent to an average annual growth of 8.1%. Table 2 serves as the basis for the computation of the HHI.

The Causal Relationship among GHG Emissions, GNI per capita and HHI

Unit Root Test.

It is important to note that before anything else it is absolutely necessary to have examined the series if it has unit roots and determine the degree of integration. The ADF unit root test is frequently used test for stability analysis of the series. Based on the initial results of the Augmented Dickey-Fuller (ADF) unit root test, all variables have no unit root in 1^{st} level the H_0 hypothesis, established as "unit root" in the level values of the variables, was not rejected, and thus was accepted. Therefore, the data it is non-stationary which suggests unreliability due to the unpredictable movements of the dataset.

The test results are shown in Table 3.

Table 3.

ADF Test Results

Variable	ADF P-Value	Decision
GNI Per Capita	test without constant (0.974) test with constant (0.9875) with constant and trend (0.842)	Reject H_0 The dataset is stationary at the 1^{st} level
HHI of power supply options	test without constant (0.5836) test with constant (0.1502) with constant and trend (0.842)	Reject H_0 The dataset is stationary at the 1^{st} level
GHG Emissions from the energy sector	test without constant (1.000) test with constant (0.9999) with constant and trend (0.9986)	Reject H_0 The dataset is stationary at the 1^{st} level

Note: Estimates by the authors using GRETL

Estimation of the VAR Model.

The first issue of the VAR model is to determine Lag Intervals for Endogenous. The larger the Lag Intervals for Endogenous is, the more it can entirely reflect the dynamic nature of the model. But in this case, more parameters will be needed to be estimated to constantly reduce freedom degrees of the model. This is a contradiction in the selection of proper Lag Intervals for Endogenous. There are many methods that can determine optimal lag period for the VAR model. In comprehensive consideration of selecting Lag Intervals for Endogenous, this paper adopted Lag Length Criteria and Ar Roots Graph to determine Lag Intervals for Endogenous, as shown in Table 3. When creating a VAR model, identifying the proper lag length is very important. The right lag length not only ensures the parameters in the VAR model have a strong explanatory power, but also that they maintain a balance with the degrees of freedom. In this research, we choose optimal lag order as dictated by the sequential modified likelihood ratio test statistic (LR), Final prediction error (FPE), Akaike criterion (AIC), Shwarz Bayesian criterion (SC) and Hannan-Quinn (HQ) information criterion.

Table 4.

Test for Lag Order

Var System, Maximum Lag Order 2
The asterisks below indicate the best (that is, minimized) values of the respective information criteria, AIC = Akaike criterion, BIC = Shwarz Bayesian criterion and HQC = Hannan-Quinn criterion

Lags	loglik	p(LR)	AIC	BIC	HQC
1	-183.30207		11.83649	12.380674	12.019591
2	-167.50450	0.00023	11.424515*	12.37638*	11.744943*

Note: Estimates by the authors using GRETL

Figure 2.

The inverse unit roots.

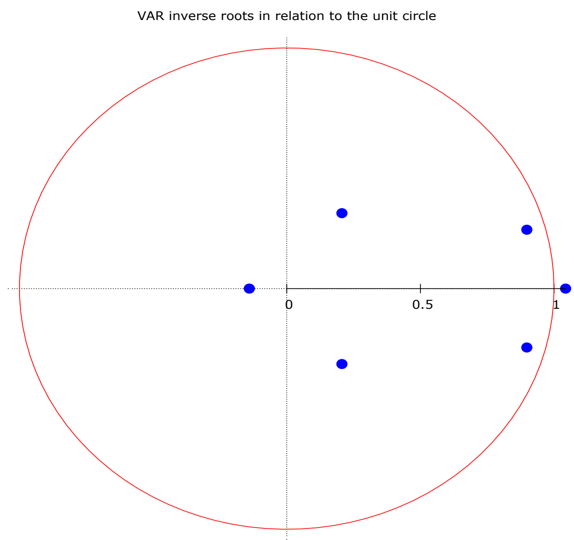
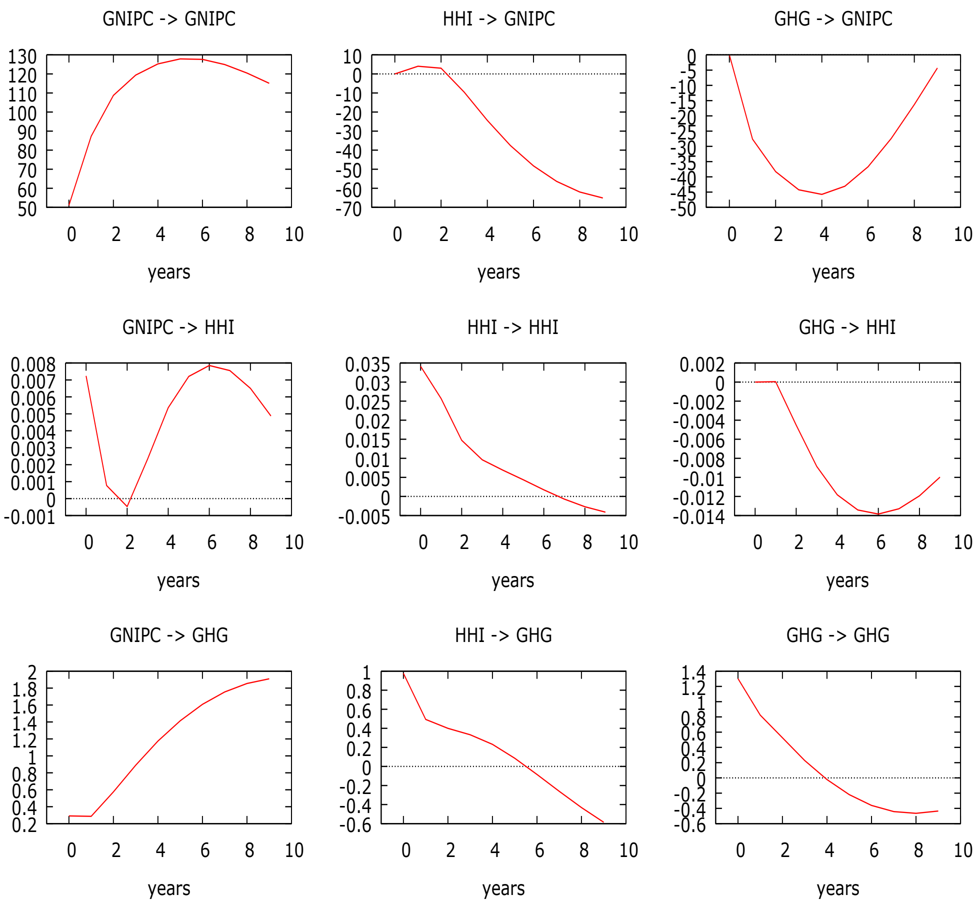


Figure 2 shows the position of the inverted roots in the unit circle. All of the roots need to be placed in the unit circle. When the figure is examined, it is obvious that the created model does not have any problems in terms of stability.

Figure 3.

Impulse response function



Note: Estimates by the authors using GRETL

On the other hand, figure 3 shows the impulse reaction function for the following g variables: gross national income (GNI) per capita, diesel price (HHI) and greenhouse gas (GHG) emissions. It presented the movements of its curves in accordance with the interaction of its three variables with interchanging the dependents and independent variables to clearly find the different dimensions of each variables test together.

Granger Causality Results at lag order 2

Table 5.

Granger Causality Results

	Null Hypothesis (Ho)	P value	Conclusion
$GNIPC_{T-2}$	$GNIPC_{T-2}$ Does not Granger Cause HHI	0.0249***	Accept
	$GNIPC_{T-2}$ Does not Granger Cause GHG	0.0182***	Accept
	$GNIPC_{T-2}$ Does not Granger Cause GNIPC	0.0002***	Accept
HHI_{T-2}	HHI_{T-2} Does not Granger Cause HHI	0.0000***	Accept
	HHI_{T-2} Does not Granger Cause GNIPC	0.2195	Accept
	HHI_{T-2} Does not Granger Cause GHG	0.1596	Accept
GHG_{T-2}	GHG_{T-2} Does not Granger Cause GNIPC	0.0123***	Accept
	GHG_{T-2} Does not Granger Cause HHI	0.9450	Accept
	GHG_{T-2} Does not Granger Cause GHG	0.0002***	Accept

*/Significant at ***99%, **95% and *90% level of confidence*
Note: Estimates by the authors using GRETL

Table 5 presents the Granger causality test is used primarily to determine whether there is an association between two variables and to analyze whether the relationship is unidirectional or bidirectional. If the P value is greater than 0.05 then there is no evidence to reject the null hypothesis however if the P value is less than 0.05 then there is an evidence to accept the null hypothesis.

According to the results, two order lag values of the var system suggested that all the variables can be explained by its own trend. GNIPC is granger caused by all the variables. Relative to the causal relationship of all variables GNI per capita is granger caused by all variables. It is interesting to note that HHI is not being granger caused by any variable. In terms of GHG emissions, it is granger caused only by GNIPC.

As an integral part of VAR analysis, a decomposition analysis is performed. It is found out that during the fifth period (year) HHI's changes can explain itself by 89.99%, GHG by 9.51% and GNIPC by a 1.49%.

Over the next ten year-period, under business-as-usual scenario to 86.99% (HHI), 15.12% (GHG) and 9.05% (GNIPC) respectively.

Relative to GNIPC, it is found out that during the same fifth period (year) GNIPC's changes can explain itself by 88.15%, HHI by 1.20% and GHG by a 10.64%. Also, over the next ten year-period, also under business-as-usual scenario to 82.99% (GNIPC), 15.12% (GHG) and 6.82% (HHI) respectively.

In terms of GHG, it is found out that during the same fifth period (year) GHG's behavior can explain itself by 39.21%. It can also be explained by HHI by 22.09% and GHG by a 39.21%. Over the next ten year-period, also under business-as-usual scenario to 82.99% (GHG), 15.12% (GHG) and 22.09% (HHI) respectively.

Conclusions

Based on the analysis of the results and discussions, the researchers concluded the fol

- The HHI is valuables for the appraisal of energy supply choices for the Philippines which will give a case to the need to dimmish coal fuel reliance later and empower ventures on the power market utilizing other stockpile alternatives.
- Under the same old thing situation, it is normal that over the course of the following ten years, GNIPC and GHG are relied upon to improve fundamentally. HHI will likewise see some minor upgrades.
- The speculation that GNIPC does not granger cause HHI and GHG is dismissed. It implies that HHI and GHG are critical variables of GNIPC.
- The theory that HHI do not granger cause GNIPC and GHG is acknowledged. It implies that HHI and GHG of are not critical elements of GNIPC.
- The theory that GHG does not granger cause HHI is dismissed. It implies that HHI is huge factor of GHG.
- The theory that GHG does not granger cause GNIPC is acknowledged. It implies that HHI is a huge factor of GHG.

- The hypothesis that GNIPC does not granger cause HHI and GHG is rejected. It means that HHI and GHG of are significant factors of GNIPC.
- The hypothesis that HHI does not granger cause GNIPC and GHG is accepted. It means that HHI and GHG of are not significant factors of GNIPC.
- The hypothesis that GHG does not granger cause HHI is rejected. It means that HHI is significant factor of GHG.
- The hypothesis that GHG does not granger cause GNIPC is accepted. It means that HHI is a significant factor of GHG.

Recommendations

The findings of this research study served as the bases of the researchers for the recommendations:

- Sustain the progress of the country's economic growth and development in terms of gross national income per capita (GNIPC) by empowering the specific sectors concern and the implementations of right and better policies that will highlight its innovation, progress, and development.
- Adopt policies and monitor its implementation on gas emission (GHG) for a sustainable planet.
- Develop electric power as a green economy for a better life and clean environment of the present and the future generation.
- Explore including other variables connected to greenhouse gas emission, gross national income per capital and Herfindahl-Hirschman index that might expand discussion and create more research for policy implication on climate change.
- Explore the study more using Vector Autoregression or VAR to measure the relationships of all the endogenous variables.

References

Astana, K. (2011). *Greening the economy: mainstreaming the environment into economic development*. https://sustainable development .un.org/content/documents/796unece2.pdf

Aslan, T., Ayşe, A., & Fatma, Z. (2013). *The Impact of Electricity Consumption on Economic Development in*. Istanbul University School of Economics.

Edomah, N. (2018). Economics of Energy Supply. 10.1016/B978-0-12-409548-9.11713-0..

Elahee, K. (2004). *Access to Energy: The Key to Poverty Alleviation*. Retrieved March 06, 2015, from International Research Foundation for Development Research: http://irfd.org /events/wfsids/virtual/papers/sids_kelahee.pdf

Energy Policy and Planning Bureau - Department of Energy Philippines . (2014). *Philippine Energy Plan 2012-2030*. Department of Energy.

Gradl, C., & Knobloch, C. (2011). *Energize the BoP! Energy Business Model Generator for Low-Income Markets (A Practitioners Guide)*. Enterprise Solutions for Development (ENDEVA).

Gujarati, D. (2003). *Basic Econometrics* (4th Ed.). McGraw-Hill.

Hamilton, C., Kellett, J. & Moore, T. (2021). *Resourcing A Low Carbon Future*.

Hossain, Mondal et al. (2018). The Philippines energy future and low-carbon development strategies. https://www.sciencedirect.com /science/article/pii/S0360544218300458

International Atomic Energy Agency. (2005). IAEA.(2005). *Energy Indicators for Sustainable Development: Guidelines and Methodologies*. IAEA.

International Energy Agency. (2013). *World Energy Outlook 2010*. Paris. IEA.

Kanchana, K. & Unesaki, H. (2014). *ASEAN Energy Security: An Indicator-based Assessment. Energy Procedia*. *56*. 163–171. 10.1016/j.egypro.2014.07.145.

Leuschner, P. (2014). *The Effect of GDP per capita on Renewable Energy Production in China.* University of Colorado Boulder.

Mendoza Jr, C. B., Cayonte, D. D. D., Leabres, M. S., & Manaligod, L. R. A. (2019). *Understanding multidimensional energy poverty in the Philippines*. Energy Policy, 133, 110886.

Modi, V., McDade, S., Lallement, D., & Saghir, J. (2005). *Energy Services for the Millennium Development Goals*. The International Bank for Reconstruction and Development/The World Bank/ESMAP.

Modi, V., McDade, S., Lallement, D., & Saghir, J. (2005). *Energy Services for the Millennium Development Goals.* United Nations Development Programme.

Navarro, A., Sambodo, M. T., & Todoc, J. L. (October 2013). *Energy Market Integration and Energy Poverty in the ASEAN.* PIDS Discussion Paper Series.

Pasternak, A. D. (October 2000). *Global Energy Futures and Human Development: A Framework for Analysis*. Department of Energy.

Phillips, M. (n.d.). *Why electricity demand is linked to GDP*.

Söderholm, P. (2020). *The green economy transition: the challenges of technological change for sustainability*. https://sustainableearth.biomedcentral.com/articles/10.1186/s42055-020-00029-y

Stern, D.I. (2004). *Environmental Kuznets Curve: Encyclopedia of Energy*. https://www.sciencedirect.com/topics/earth-and-planetary-sciences/environmental-kuznets-curve

Stiglitz, J. E., Sen, A., & Fitoussi, J.-P. (2009). *Report by the Commission on the Measurement of Economic Performance and Social Progress*. Institut national de la statistique et des études économiques (INSEE).

University Corporation for Atmospheric Research (UCAR), https://scied.ucar.edu/learning-zone/how-climate-works/greenhouse-effect.

U.S. Energy Information Association. (2013, March 22). *Today in Energy*. Retrieved February 28, 2014, from U.S. Energy Information Association - Independent Statistics and Analysis: http://www.eia.gov/todayinenergy/detail.cfm?id=10491

Wen Center for Social Research Method. (n.d.). *Research Methods Knowledge Base*. Retrieved March 15, 2015, from http://www.socialresearchmethods.net/kb/convdisc.php

World Business Council for Sustainable Development. (2012). *Business solutions to enable energy access for all (The WBCSD Access to Energy Initiative).* WBCSD publications.

Zou,Xiaohua (2018). *VECM Model Analysis of Carbon Emissions, GDP, and International Crude Oil Prices*. https://doi.org/10.1155/2018/5350308