GHG emissions, environmental technologies, and renewable energy status in the Philippines

Conference Paper · October 2022

4 authors, including:

Joan Cecilia Casila
University of the Philippines Los Baños
26 PUBLICATIONS 86 CITATIONS

Carl Ureta
Compassion International
19 PUBLICATIONS 113 CITATIONS

Priya K L
TKM College of Engineering, Kollam
82 PUBLICATIONS 291 CITATIONS

"*GHG emissions, environmental technologies, and renewable energy status in the Philippines*"

Joan Cecilia Casila
LWRED-IABE, CEAT, University of the Philippines Los Baños jmcatubigcasila@up.edu.ph
Julie Carl Ureta
Dept. of Forestry and Environmental Conservation, Clemson, South Carolina jureta@g.clemson.edu
Soufiane Haddout
Dept. of Physics, Faculty of Science, Ibn Tofail University, Kenitra, Morocco soufian.haddout@gmail.com
Krishnamoorthy Lakshmi Ammal Priya
Dept. of Civil Engineering, TKM College of Engineering, Kollam, Kerala, India klpriyaram@gmail.com

ABSTRACT: Economic growth is paramount for a county's development but typically entails environmental tradeoff in the form of greenhouse gas (GHG) emission. The Philippines ranked ninth most vulnerable to disaster and climate change risk due to high exposure to natural hazards and dependence on climate-sensitive natural resources. With clear manifestation of climate change impacts and its relation to GHGs, it is important to understand a country's status. This paper presents trends in GHG emission by sector and fuel from years 1990 to 2020 and identifies the country's primary energy dependency. For 30 years, the electricity sector had the highest GHG contribution as it is aimed to continuously increase the electrification level (currently at 94.5%) leading to 24 million households having access to electricity. The Philippines is highly dependent on fossil fuels with high CO_2 emissions from coal, diesel, and gasoline. The relationship between environmental degradation and economic growth by formulating the Environmental Kuznet's Curve (EKC) through GHG emission and Gross Domestic Product (GDP) per capita were studied. Finally, the status of the renewable energy (RE) sources in the country and its correlation between environmental technologies (ET) and impact to GHG emissions were assessed. The high fossil fuel dependency manifested in the EKC computation with the following results: 1) economic growth and environmental degradation still has not decoupled; 2) RE production has no statistically significant effect in reducing environmental degradation; and 3) although not statistically significant, the relationship between environmental degradation and RE production was inversely proportional indicating that RE could potentially lead to declining GHGs. The percent total ET patents from 2000 to 2019 showed a mean percentage of 13.596, which is higher than the average of G7 countries. A positive correlation between installed RE sources and ET with high R^2 of 0.86 suggests the country's continued pursuit of environmental protection.

***Keywords**:* Philippines greenhouse gases, renewable energy, carbon neutrality, Kuznet's curve, GHG emission

1 INTRODUCTION

One of the main contributors to global warming is the increased amounts of greenhouse gasses (GHG) in the atmosphere. In the latest climate transparency report of the World Bank, the per capita GHG of the Philippines was 1.18 tCO_2e/capita in 2020. Additionally, a 114% increase in GHG emissions was observed between 1990-2017. Most of this increase is a result of industrial processes and energy production.

On average, 20 tropical cyclones enter the Philippines region every year and approximately 8–9 of them directly cross the country. These numbers are the highest in the world and are expected to increase in frequency and severity due to climate change (Davidson et al., 2020). To address the climate crisis, the government of the Philippines pledged reducing 2030 emissions by 75% in the November 2021 Conference of Parties

(COP 26). The Philippines endorsed the phase down of coal-fired power generation projects but not their phase out. Energy security must be prioritized in the country so approved coal-fired power projects may continue but the government will no longer accept proposals to build new coal power plants (Sepe & Maitem, 2021).

The growth in the country's economy is also linked to the degradation of the environment. The Philippines' Gross Domestic Product (GDP) per capita is $3,358.8 in 2021, showing an increasing trend since 1990. This development in the economy is coupled with industrialization and the utilization of resources from the environment resulting in an increase in environmental degradation.

A study conducted in 69 industrial and 45 developing countries by Cederborg and Snobogm (2016) revealed that a positive relationship exists between CO_2 emissions and the GDP per capita for both industrial and developing countries due to the scale effect. The scale effect assumes that the increase in environmental degradation and pollution is the effect of increased production. However, no turning point was observed where the CO_2 emission level decreases as the per capita GDP increases. This is also true in the case of the Philippines. Palanca-Tan et al. (2016) showed economic growth and CO_2 emission have a positive linear relationship for the period 1971-2010.

In 1955, Simon Kuznets formulated the Kuznets curve to describe the relationship between per capita income and income inequality. Kuznets asserted that economic growth has an effect on the environmental performance of the country after some time of economic growth. The Environmental Kuznets Curve (EKC) hypothesis is an empirical energy framework that links economic growth with environmental degradation (Ozcan and Ozturk, 2019). Another study by Grossman and Krueger (1995) showed that the harmful effects of continuous economic growth may be compensated by improvements in technologies and innovations. Additionally, the study revealed that the initial stage of economic growth corresponds to an increase in pollution, where the maximum value is observed during the economic growth, while at higher income levels, the increased demand and supply for the protection of the environment lead to improvement.

Carbon neutrality aims to have a balanced emission and absorption of carbon in the environment. According to the Intergovernmental Panel on Climate Change (IPCC) (2014), carbon neutrality is the realization of net-zero carbon emissions when anthropogenic carbon emissions are offset globally for a specific time. An increase in energy consumption is directly related to the increase in carbon emissions leading to the greenhouse effect (Dong et al., 2021). IPCC also mentioned that the main reason for the abrupt increase in the emission of carbon is the continuous burn of fossil fuels. Fossil fuel burning activities that release CO_2 have been revealed responsible for the drastic change leading to climate change. It also alerted countries to achieving zero carbon emission output by implementing policies and strategies with its primary goal of carbon neutrality.

In order to improve the system and achieve carbon neutrality the promotion and development of renewable energy is a key factor as mentioned by Blohm (2021). The utilization of renewable energy paves a long-term effect on the environment and people. In a research by Wang et al. (2022), it was mentioned that the achievement of carbon neutrality would give access to the control of global warming, lessening the harm brought to the environment by climate change. The "Carbon Neutral Alliance Statement", which was signed by 29 countries last December 2017, aims to achieve carbon neutrality in the following years focusing on GHG reduction.

The growth of a country's economy has unaccounted environmental costs associated with it. As the country develops, the natural resources are excessively used. The primary option for energy source is fossil fuel which have led to serious environmental degradation. Policies have been imposed so that the environment will not be compromised. Incentives have been given to promote renewable energy. Still, there are clear manifestations of continued climate change impacts as reflected on stronger typhoons, flooding, and rise in climate temperature. This study aims to understand and evaluate the country's situation in terms of economic growth in relation to greenhouse gas (GHG) emissions, renewable energy and environmental technologies. The results of this study could be used for the roadmap of the Philippines towards achieving zero carbon emission output. The effectivity of the implemented policies and strategies with the primary goal of carbon neutrality could be validated.

2 METHODOLOGY

2.1 Country Situation

The Philippines is an archipelagic country with more than 7,600 islands, 18 major river basins and 421 principal rivers. Coastal countries like the Philippines are most at risk with sea level rise due to climate change. The Philippines was ranked as the ninth most vulnerable to disaster and climate change-related risk, among 180 countries examined. This is due to its high exposure to natural hazards, dependence on climate-sensitive natural resources, and vast coastlines (Day et al., 2019).

The mean annual temperature is 26.6°C but the observed temperature is warming at an average rate of 0.1°C/decade. It is projected that the country-averaged mean temperature could increase by as much as 0.9°C-1.9°C (assuming the moderate emission scenario, RCP4.5) and 1.2°C-2.3°C (assuming the high emission scenario, RCP8.5) from 2036-2065. Warmer conditions or increase in mean temperature relative to the baseline climate are further expected by 2070-2099 ranging from 1.3°C-2.5°C (RCP4.5) to 2.5°C-4.1°C RCP8.5) (DOST-PAGASA, 2018).

Amidst the ongoing economic crisis and the high cost of household utilities the electricity cost remained high. The Philippines has the second highest electricity cost in Southeast Asia. Unlike other Asian neighbors Thailand, Indonesia and Malaysia, electricity rates in the Philippines are not subsidized by the government (Fernandez, 2020). In 2020, the overall average retail rate of electricity decreased by 10 per cent to 7.96 PHP/kWh (0.15 US$/kWh) from an 8.87 PHP/kWh (0.17 US$/kWh) average rate in 2019 (Davidson et al., 2020).

The electricity gross generation of 101.8 terawatt-hour (TWh) in 2020 fell by 4% from the 106 TWh in 2019. Because of recession, the economy-wide demand for electricity has been reduced. Coal continued to dominate the power generation mix in 2020 at 57.2% share (58.2 TWh). Natural gas contributed 19.2% (19.5 TWh), geothermal had 10.6% share (10.8 TWh), and hydropower had 7.1% share (7.2 TWh). A total of 3.7 TWh combined generation output of solar, wind and biomass during the period represented 3.6% of the power generation mix (Department of Energy, 2020).

2.2 Data collection and analysis

The total GHG emission by fuel was obtained from the Department of Energy (DOE, 2020a). The total emission by sources (CO_2, N_2O, and CH_4) with the distribution according to sectors of agriculture, commercial, electricity, energy (own-use), industry, residential, and transport were also obtained (DOE, 2020b) and analyzed. Only years 1990 to 2020 were available online.

The data on renewable energy in the Philippines were obtained from the Department of Energy (2020). The percent total patents on environmental technologies from 2000 to 2019 was obtained from OECD (2022). The installed renewable energy technologies and the patents on environmental technologies were then correlated.

2.3 Environmental Kuznets Curve

To analyze the relationship of the GHG emissions and GDP, we employed a reduced form model of the EKC as adopted by Sinha and Shahbaz (2018). The reduced form model was based from the generalized EKC framework (Panayotou, 1993) which considers that emissions as a function of income and its square as explanatory variable Eq. (1).

$$C_t = f(Y, Y^2, \mu)_t \quad (1)$$

$$\ln C_t = \beta_0 + \beta_1 Y_t + \beta_2 Y_t^2 + \varepsilon_t \quad (2)$$

Where C is the GHG emission of the country at time t, Y denotes the GDP per capita and Y^2 is its square, and μ is an error term. Eq. (2) is a transformed model which provides different forms of EKC based on the coefficient of income such that: a) $\beta_1 = \beta_2 = 0$: income has no effect on environmental quality; b) $\beta_1 > 0$ and $\beta_2 = 0$: income has linear and positive effect on environmental quality; c) $\beta_1 < 0$ and $\beta_2 = 0$: income has linear and negative effect on environmental quality; d) $\beta_1 > 0$ and $\beta_2 < 0$: income-emission takes the inverted U-shaped form which implies that economic activity initially had positive relationship with emission but had reached a point where it is improving the environmental quality as it continues to grow; and

e) $\beta_1 < 0$ and $\beta_2 > 0$: income-emission takes the U-shaped form which implies that economic activity initially had negative relationship with emission but had reached a point where it is becoming detrimental to the environmental quality as it continues to grow (Sinha & Shahbaz, 2018).

To test the impact of renewable energy (R) to the EKC, we included the share of renewable energy produced within the economy (Eq. 3).

$$C_t = f(Y, Y^2, R, \mu)_t \tag{3}$$

3 RESULTS AND DISCUSSIONS

3.1 GHG emissions (CO_2 and non-CO_2 emmisions)

The total GHG emissions have been continuously increasing up to year 2019. There is a consistent downtrend in energy demand in 2020 which is reflected in the emissions in Fig. (1). For 30 years, the electricity sector had the highest contribution to GHG emission. This was followed by transport industry, commercial, residential, energy (own-use) then agriculture. The highest emission in the year 2019 from the electricity sector was 69.1 million tons of CO_2 equivalent metric tons of carbon dioxide equivalent ($MTCO_2e$) of which, 69.4 $MTCO_2e$ and 0.3 $MTCO_2e$ are CO_2 and non-CO_2 emissions, respectively. Electricity sector emissions is ever increasing as it is a continued target to increase the electrification level (currently at 94.5%). This led to 24 million households, 98% urban and 93.5% rural population, having access to electricity. On the other hand, agriculture consistently had the lowest GHG contribution for 30 years among all sectors. This shows that mechanized technologies may have been minimally adopted or data for GHG emission in the sector may have not been well documented. Traditional farming is still being practiced in the country with the use of carabao to plow the land instead of tractors with implements. During harvest, instead of combines to increase the speed of the activity, manual labor is preferred. Kaingin is the cutting down and burning of trees and plant growth in an area for cultivation purposes. This practice is still evident in some areas in the Philippines which may be a huge source of CO_2 emission.

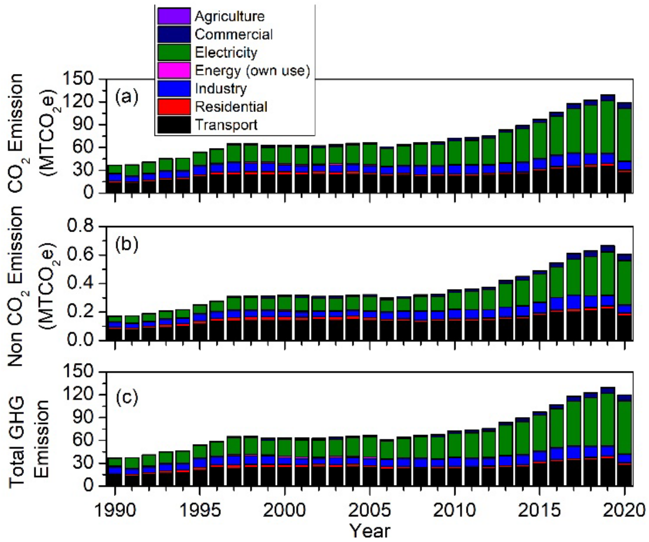

Figure 1. GHG emissions by sector from years 1990 to 2020

The analysis of GHG emission by fuel type from years 1990 to 2018 showed that the highest GHG contributor in the country transitioned from residual oil in 1990 to bituminous coal by the year 2000. The trends of fuel type including crude oil, gas/diesel oil, gasoline, jet kerosene, LPG, natural gas (dry) and their CO_2 and non-CO_2 emissions are seen in Fig. (2). On 31 December 2015, the in-situ coal reserves in the Philippines amounted to 470 million metric tons or 19.7% of the country's total coal resource potential of 2.39 billion metric tons.

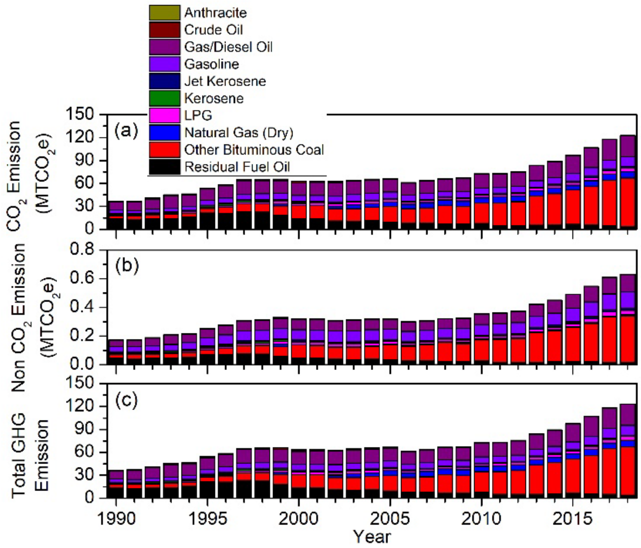

Figure 2. GHG emissions by fuel from years 1990 to 2018

The methane (CH_4) and nitrous oxide (N_2O) emissions per sector were further studied. Fig. (3) shows that the transport sector had the highest CH_4 contribution which is followed by industry and electricity. This shows that this emission is due to industrialization since industries use electricity. Economic growth is also reflected with the increase in purchasing power where people have more capability to own their own private transportation. The inconvenient public transport in the country made people choose private vehicles because it is faster, more reliable and more comfortable. Although minimal in contribution, the agriculture sector considered recommending alternate wetting and drying of rice to reduce methane emissions. Emissions of N_2O agriculture are produced through fertilizer use (synthetic and animal manure), animal waste management, agricultural waste burning (nonenergy, on-site), and savannah burning (Knoema.com, n.d.)

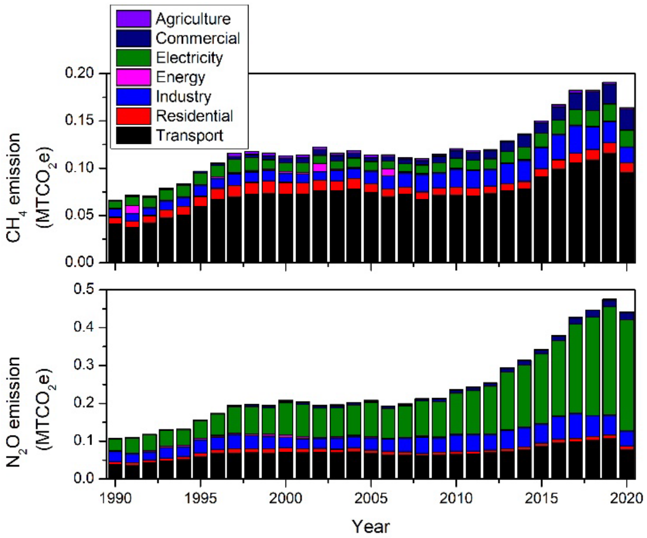

Figure 3. CH_4 and N_2O emissions by sector from years 1990 to 2020

The N_2O trend follows the CO_2 emissions where electricity has the highest contribution. This was followed by transport industry, commercial, residential, energy (own-use) then agriculture.

Although the transport sector had the highest methane contribution, electricity remained the highest CO_2 contributor at 70.0 $MTCO_2e$, equivalent to 58.3% share of the total CO_2 emissions. This was driven by the increased utilization of coal as fuel input for power generation. In 2019, a total of 1,559 MW new coal-fired power plants were installed and added to the electricity source capacity (Department of Energy, 2019). The CO_2 emission of the transport sector dropped to 27.4 $MTCO_2e$ or 22.8% share due to closures and lockdowns.

3.2 Electricity generation, renewable energy sources and patents on environmental technologies

In the year 2019, the Philippines had a total of 25,531 MW power supply in terms installed capacity (Department of Energy, 2019). The major contributing electricity source was coal at 10,417 MW or 40.8% of the total installed capacity, followed by renewable energy sources at 7,399 MW or 29 per cent. Oil and natural gas contributed 4,262 MW or 16.7 per cent and 3,453 MW or 13.5 per cent, respectively. For the renewable energy sources, hydropower contributed the highest at 3,760 MW or 14.7% followed by geothermal at 1,928 MW or 7%, solar at 921 MW or 3.6 %, wind at 427 MW or 1.7 %, and biomass at 363 MW or 1.4 per cent Fig. (4). From 23,815 MW in 2018, the installed capacity grew by approximately 7.2 precent. A total of 1,675 MW new capacities were added to the country's supply in 2019 due to new coal-fired (1,559 MW), oil-based (8 MW), hydropower (31 MW), biomass (52 MW) and solar (25 MW) power plants.

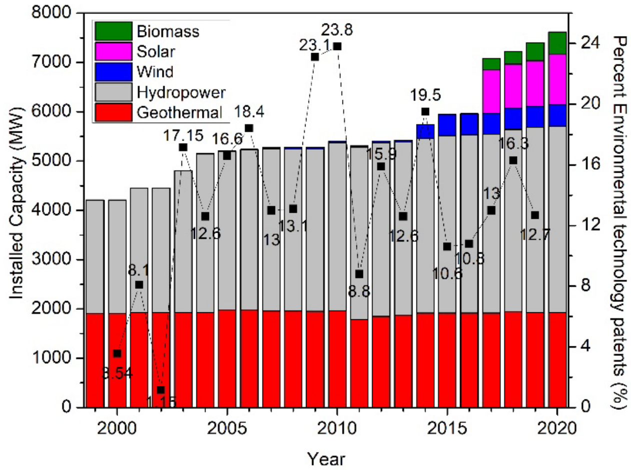

Figure 4. Installed renewable energy capacities and percent environmental technology patents

The Philippines had largely fluctuating percent total patents on environmental technologies with a mean percentage of 13.596 from 2000 to 2019 (Fig. 3). Compared with the average of G7 countries from year 2000 to 2019 (Canada at 10.75%, France at 11.16%, Germany at 12.7%, Italy at 9.37%, Japan at 11%, United Kingdom at 10%, and United States of America at 9.7%) this average is higher which shows the country's pursuit of environment protection.

From 2002 to 2012, a decade in which innovation was being promoted in the renewables sector, the number of patent applications published under the Patent Cooperation Treaty (PCT) for renewables increased by 547 percent. The correlation between installed renewable energy sources and environmental technologies resulted to a high R^2 of 0.86 (Fig. 4). This suggests the country's continued pursuit of environmental protection.

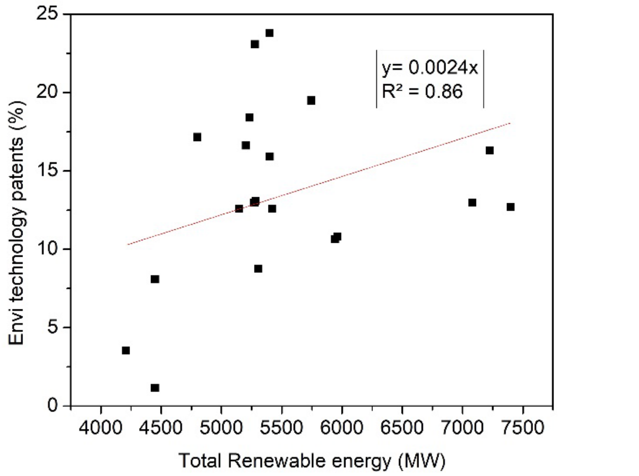

Figure 5. Correlation between installed renewable energy sources and environmental technologies

3.3 Environmental Kuznets Curve

The results of the EKC following equation 1 is shown in Table (1) and visualized in Fig. (6).

Table 1 Regression analysis of GHG Emissions as a function of Income

Var	coef	SE	p-value
GDPcap (Y)	0.0007411	0.000312	0.025
GDPcap2 (Y^2)	$-4.85e^{-08}$	$5.59e^{-08}$	0.392
cons	2.808523	0.4188513	0.000

R-squared: 0.8545

The result of the model shows that there is a linear relationship between the GHG emissions and the country's income. The positive and significant p-value of the GDPcap (Y) indicates that the economic growth affects the environmental quality as it also produces significant amount of GHG emission. On the other hand, the GDPcap2 (Y^2) shows a negative relationship but not statistically significant. This indicates that, while the negative relationship shows signs that the EKC might hold, the effect is negligible as the economy is emitting more GHGs. This result is also consistent with the findings of Apergis and Ozturk (2015) as they tested the EKC hypothesis in Asian countries using annual data from 1990 to 2011. In their result, the Philippines' EKC does not hold as it yielded similar income-emission relationship in both GDPcap and GDPcap2 but not statistically significant in any of the coefficients (Apergis & Ozturk, 2015).

An inverted U-curve with three stages represents the EKC relationship. The findings in this study are similar to that obtained by Palanca-Tan et al. (2016) where both the core and expanded EKC models that they used provided no evidence for an inverted-U relationship between CO_2 emissions and GDP from 1971 to 2010. The study showed that urbanization has a highly elastic negative impact on carbon dioxide emissions. Another similar results were obtained by Martinico-Perez et al. (2018) where they investigated the relationship between per capita processed output (DPO) and the environment with respect to per capita affluence (GDP) in the Philippines from 1980 to 2014. The relationship resembled the first half of the inverted "U" of the EKC which they divided into two phases, a modest phase from 1980 to 2007 and a fast phase from 2007 onwards. It was mentioned that the Philippines is still moving up the curve and it is unclear how long the rise will continue.

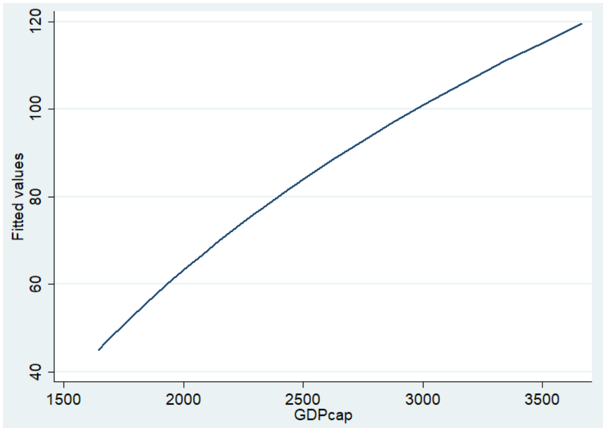

Figure 6. Fitted curve of GDP per capita and total GHG from 1990 to 2020

The effect of the renewable energy in the income-emission relationship was tested which yielded a regression result shown in Table (2).

Table 2 Regression analysis of GHG Emissions as a function of Income and Renewable Energy production

Var	coef	SE	p-value
GDPcap (Y)	-0.0003347	0.0002096	0.128
GDPcap2 (Y^2)	$1.45e^{-07}$	$4.12e^{-08}$	0.003
lnRen (R)	-0.0224262	0.2457685	0.928
cons	4.441256	1.989097	0.039

R-squared: 0.9710

The results show a similar picture as with the original model wherein the overall income-emissions relationship is linearly increasing. However, in accounting for the renewable energy, while the result showed statistically not significant coefficient, the negative relationship of the coefficient shows an indication of a decline in the emission. Hence this implies a potential improvement to the environmental quality. It could be that the amount of renewable produced is not enough to make a significant impact to the current income-emission relationship.

4 CONCLUSIONS

The GHG emissions is increasing in the Philippines which indicates industrialization and utilization of resources that is detrimental to the environment. The abrupt increase in the CO_2 emission is due to continuous burning of the fossil fuels. A moratorium on new coal power plants was issued by the Department of Energy in 2020. Strict implementation of this is a must to boost private investment in renewable energy as mentioned by International Hydropower Association in 2021.

The high fossil fuel dependency manifested in the EKC computation with the following results: 1) The country's economic progress has not yet reached a point where its energy consumption and technological advancement offsets the GHG emission produced by the economy; 2) renewable energy production has no statistically significant effect in reducing environmental degradation; and 3) although not statistically significant, the relationship between environmental degradation and RE production is inversely proportional indicating RE could potentially lead to declining GHGs hence improving environmental quality.

A positive correlation between installed renewable energy sources and environmental technologies with a high R^2 of 0.87 suggests that there is an increasing effort to transition to renewable energy. This complements to the EKC's indication that while the renewable energy variable deemed not statistically significant, this could be because the current share of the renewable energy is still not enough to make an impact. However, its relationship to GHG emission shows that renewable energy production could improve the environmental degradation while pursuing economic growth.

5 REFERENCES

Apergis, N., & Ozturk, I. (2015). Testing Environmental Kuznets Curve hypothesis in Asian countries. Ecological Indicators, 52, 16–22. https://doi.org/10.1016/J.ECOLIND.2014.11.026

Blohm, M. (2021). An Enabling Framework to Support the Sustainable Energy Transition at the National Level. Sustainability, p. 13, 3834.

Cederborg, J., and Snobohm, S. (2016). Is there a relationship between economic growth and carbon dioxide emissions? https://www.diva-portal.org/smash/get/diva2:1076315/FULLTEXT01.pd#:~:text=The%20correlation%20is%20positive%2C%20which,GDP%2C%20as%20some%20theories%20claims.

Davidson, K., Gunawan, N., Almeida, M., & Boulle, B. (2020). Green Infrastructure Investment Opportunities Philippines 2020 Report. In Climate Bonds Initiative. https://www.greenfinancelac.org/

Day, J., Forster, T., Himmelsbach, J., Korte, L., Mucke, P., Radkte, K., Thielbörger, P., & Weller, D. (2019). WorldRiskReport 2019 Focus: Water Supply.

Department of Energy. (2019). 2019 Power Situation Report. https://www.doe.gov.ph/electric-power/2019-power-situation-report

Department of Energy. (2020). 2020 Philippine energy situationer & key energy statistics.

DOE, D. of E. P. (2020a). Total GHG Emission by Fuel. https://www.doe.gov.ph/energy-statistics/integrated-key-energy-statistics-and-energy-related-indicators-database?q=key-energy-statistics-dashboards/total-ghg-emissions

DOE, D. of E. P. (2020b). Total GHG Emission by Source. https://www.doe.gov.ph/energy-statistics/integrated-key-energy-statistics-and-energy-related-indicators-database?q=key-energy-statistics-dashboards/total-emissions-by-source

DOST-PAGASA. (2018). Observed climate trends and projected climate change in the Philippines. Department of Science and Technology - Philippine Atmospheric, Geophyisical and Astronomical Services Administration.

Fernandez, H. A. (2020). Has cheaper energy come to the Philippines? | News. Eco-Business | Asia Pacific. https://www.eco-business.com/news/has-cheaper-energy-come-to-the-philippines/?sw-signup=true

Grossman, G.M., and Krueger, A.B. (1995). Economic growth and the environment. The Quarterly Journal of Economics 110(2): 353-377.

International Hydropower Association. (2021). 2021 Hydropower status report.

Knoema.com. (n.d.). Philippines Agricultural nitrous oxide emissions (%), 1960-2021. https://knoema.com/atlas/Philippines/topics/Environment/Emissions/Agricultural-nitrous-oxide-emissions-percent

Martinico-Perez, M. F. G., Schandl, H., & Tanikawa, H. (2018). Sustainability indicators from resource flow trends in the Philippines. Resources, Conservation and Recycling, 138(June), 74–86. https://doi.org/10.1016/j.resconrec.2018.07.003

OECD. (2022). Patents on environment technologies. https://doi.org/10.1787/fff120f8-en

Ozcan, B. and Ozturk, I. (2019). Environmental Kuznets Curve: A Manual. Academic Press, p. 54-56.

Palanca-Tan, R., Dy, T. A., & Tan, A. (2016). Relating Carbon Dioxide Emissions with Macroeconomic Variables in the Philippine Setting. Low Carbon Economy, 07(01), 12–20. https://doi.org/10.4236/lce.2016.71002

Panayotou, T. (1993). Empirical tests and policy analysis of environmental degradation at different stages of economic development.

Sepe, B., & Maitem, J. (2021). Philippines: COP26 Talks Made Some Gains With Pledges on Forests, Coal. Benar News. https://www.benarnews.org/english/news/philippine/philippines-on-cop26-11162021143048.html

Sinha, A., & Shahbaz, M. (2018). Estimation of Environmental Kuznets Curve for CO2 emission: Role of renewable energy generation in India. Renewable Energy, 119, 703–711. https://doi.org/10.1016/J.RENENE.2017.12.058

World Bank. (2020). Climate Transparency Report. https://www.climate-transparency.org/wp-content/uploads/2021/01/Philippines-CT-2020.pdf