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Article

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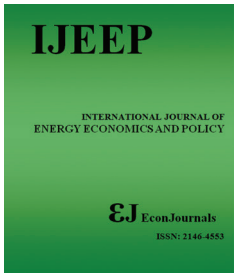

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Reducing CO_2 Emissions through Biogas, Wind and Solar Energy Production: Evidence from Indonesia

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ABSTRACT

CO_2 emission has become a growing concern for most of the countries and many factors or reasons have been found to enhance this emission in one way or the other. In this particular study, the impact of biogas energy, wind energy and solar energy production is supposed to be studied on CO_2 emission in Indonesia. The author has collected data for research purpose from Indonesia. The data covers the period of 29 years and has been collected from authentic databases. After data collection process, several tests and techniques are used for the purpose of analyzing and exploring various aspects related to the study and the variables. The tests used by the author in this study include unit root test and GMM estimation technique. All these tests have distinct features and used for various purposes. The results obtained from the above-mentioned tests indicate that the production of all types of energies discussed in the study i.e. biogas, wind and solar energy have significant impacts on CO_2 emission while the impact of the only control variable, energy consumption is found to be insignificant. Various theoretical, practical and policy making implications have been identified by the author and some limitations of the study have also been discussed in the last.

Keywords: CO_2 Emissions, Wind Energy, Solar Energy
JEL Classification: Q13

1. INTRODUCTION

Indonesia is the largest state with 17,500 islands and 811,000 km of the coastline. Is the fourth populated country of the world with extremely high rates of urbanization (Sandee, 2016). This country has almost third biggest forests that support variety of bio-diversity. Because of all these factors the country has become more vulnerable than others to the global climatic change (Mendelsohn and Dinar, 1999). With the increasing population, the needs of the country have been increased. The country has to meet the increasing demand of its people for basic livelihoods, food, clothes and energy. At the same time, it has to keep a low profile for carbon energy development and climatic change (Ahmad et al., 2011). This is a long-term program and Government has to take steps for this purpose. According to the World Bank's report in 2007, CO_2 emissions form the largest share of the net greenhouse gas emission that is most like being generated by multiple human activities. The gas is so largely increased in the atmosphere as a result of development and urbanization in the recent past and is highly dependent on the energy consumption, which is highly important for the economic growth (Alshehry and Belloumi, 2015; Arneth et al., 2017; La Soa, 2019). According to Demibras, carbon dioxide gas is the most gas in the greenhouse gases as it is involved in the drastic climatic change. Nitrous oxide and chloroform carbons also play an important role in the greenhouse effect. The risen global environmental issues are a hot topic because of the increased global warming and drastic climatic change such as global raise in average air and ocean temperatures, melting of snowcaps and the increased average sea level (Turnbaugh, et al. 2007). The Intergovernmental Panel on Climatic Change proposed that the global temperatures have been increased from 1.1°C to 6.4°C and the sea level has been risen to about 16.5 to 53.8 cm. the risen values are of course a threat to life on this planet especially to those who are living in coastal areas (Bazmi et al., 2011; Majid and Basir, 2019).

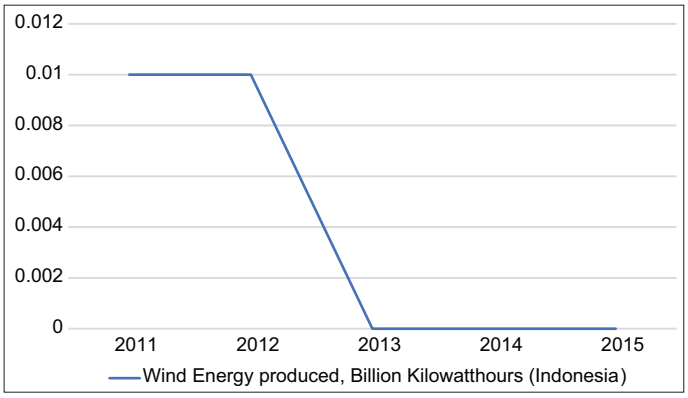
Climatic change is taking a lot of importance these days and Indonesia was the 5th largest greenhouse gas emitter in 2015, which is of course the main cause of global climatic change so it has gained the world's attention. In 2010, the government of Indonesia signed a pact where it was committed to reduce the green houses gases emissions by setting certain targets and by taking certain measures (Aubrée et al., 2016; Baloch et al., 2016; Errami et al., 2015). In the nationally determined contribution to the UN framework convention on climate change Indonesia signed a pact where it was determined to reduce the gases emissions by 26% in 2030. Of course, the reduction of the greenhouse gases is the subject to international financial support, capacity building and technology transfer. The resources such as solar energy, wind energy and geothermal energy can be used in this respect as they are used as the alternative sources of energy. These renewable energy resources are now in the limelight (Ahmad et al., 2011; Twidell and Brice, 1992).

Figure 1 is elaborating the wind energy produced in Indonesia through 2011-2015. According to the literature reported and the risen demand of the world's state, Indonesia has to take steps and measure to control the carbon oxide emission. The government should devise a roadmap to reduce the emissions by clearly disrupting the activities responsible for the emissions of the greenhouse gases to ensure the target is achieved right on time (Budiman et al., 2018). As it is now the need of the hour that the CO_2 emissions must be reduced so this study will focus on the ways to decrease its production. Carbon dioxide is basically a gas produced from the non-renewable energy resources and is proving to be hazardous for the environment (Green and Stern, 2017; Kaloi et al., 2016; Lajunen and Lipman, 2016). Moreover, the non-renewable energy resources as known are not recyclable and they cannot be generated again hence, in order to avoid their depletion, it is very necessary to replace them with the renewable energy resources (Chel and Kaushik, 2011). Up till now no study has been conducted that focuses on the reduction of carbon dioxide gas emission by using wind energy production, solar energy production and biogas energy production (Sadiq et al., 2013; Sawayama et al., 1999; Sciubba, 2003; Zedtwitz and Steinfeld, 2007).

Hence, the objective of the study is stated below,

1. The role of biogas energy production in the reduction of CO_2 emissions
2. The role of solar energy production in the reduction of CO_2 emissions
3. The role of wind energy production in the reduction of CO_2 emissions.

Figure 1: Wind energy produced, billion kilowatt-hours (Indonesia)



Researchers across the globe are putting an extra effort in uncovering the efficiency of different energy resources that will provide an alternative to the non-renewable energy resources and thus the dependency on the irreplaceable energy resources would be much limited. Along-with this unrecyclable resource have a negative impact on the climate, as they are involved in the release of the greenhouse gas emission (Hossain et al., 2015).

2. LITERATURE REVIEW

2.1. Background

Human life has energy as an important and key element. For the sustainability of life huge and adequate supplies of energy is very important. With the growing population, the use of energy is also enhanced and the requirements to provide energy are growing fast in order to meet the needs and as expected the trend will continue to grow in the future (Iskandar, 2019). Non-renewable energy resources are depleting and furthermore, they are also having adverse effects globally on the climate hence, in order to replace them it is very important to consider the use of renewable energy resources to meet the energy demand, especially in the countries like Indonesia which were the great emitters of the greenhouse gases (Asif and Muneer, 2007; Del Río, 2007). The literature review is shown in three different sections, in order to study the role of biogas energy production, solar energy production and wind energy production in the reduction of carbon dioxide emission (Li et al., 2017; Li and Li, 2017; Matter et al., 2016).

2.2. Reduction of CO_2 Emission and Biogas Energy Production

Biogas is a natural non-synthetic fuel, which is produced on the degradation and decomposition of organic waste material. Using an anaerobic digester system in a cow farm having 7000 cows can decrease 99% of global warming potential (Dibenedetto, 2011). Anaerobic environment is the one, which is oxygen free. The waste management system must install the system at the farm that will ultimately produce biogas and energy for electricity. Special role is played by these digesters that have a unique way of converting the energy found in organic matter of manure into biogas (Wang et al., 2020). Biogas is then transported to a combustion turbine. Bonds of the methane molecules have special energy stored in them, which is converted into the mechanical energy as it spins the turbine (Fehr and Schmidt 1999). Bond energy is converted into the mechanical energy, which produces electricity (Boontome et al., 2017). This is the modern method, which involves industrialization and agriculture and is considered to be very competitive in global markets as it meets the demands of the people and is more efficient without causing any hazard to the environment (Paramati et al., 2017). By using this modern method, animal waste generated from the livestock would be taken care of. Biogas technology is very important in the world full of greenhouse gases as it reduces the global warming effect. The old methods that were utilizing the non-renewable energy resources and were involved in the production of greenhouse gases especially carbon dioxide will no longer be used (Bekhet

and Harun, 2016). Therefore, based on the literature following hypothesis can be formulated,

H_1. Biogas energy production helps in the reduction of CO_2 emission.

2.3. Reduction of CO_2 Emission and Wind Energy Production

Coastal and other windy regions are very crucial source of energy. India is very successful for the development of wind energy in the world and utilization of this energy will definitely play a great role in the CO_2 mitigation (Qi et al., 2014). But gains or losses are a part of this revolutionized method and is highly dependent on the region. The studies that has been conducted so far in this regard shows that there are huge resources for the wind production around the world (Lee and Chang, 2018; Panwar et al., 2011). It is a pollution free technology, which is used in various parts of the world. This method if replace the energy production method from non-renewable energy resources will ultimately have a positive effect on the climate as fewer amounts of greenhouse gases will be emitted (Moreira and Pires, 2016; Ouyang and Lin, 2015; Sahu et al., 2018). This technology converts the wind energy into electricity or mechanical power of wind is utilized to run the turbines (Balat, 2005). This method is extremely cost-effective and several barrels of the oil can be used, saving the non-renewable energy resources and million tons of carbon emission would be stopped (Murugesha). Hence, the following hypothesis can be deducing from the above literature.

H_2. Wind energy production helps in the reduction of CO_2 emission.

2.4. Reduction of CO_2 Emission and Solar Energy Production

Solar energy is the form of renewable energy resources and is the most abundant found on this planet, directly or indirectly. Emission of energy from sun is at the rate of 3.8 × 1023 kW and almost 1.8 × 1014 kW is intercepted by our planet (Thirugnanasambandam et al., 2010). Solar energy can be utilized vastly such as in crop drying, water heating and many more, starting from the simpler ones to the complex ones. It is predicted that the carbon dioxide emissions annually by a domestic solar water heating system of 1001/day capacity are 1237 kg and in hotter regions it is about 1410.5 kg (Wong et al., 2015). Hence, on using solar energies, these greenhouse gas emissions can be reduced without having environmental hazards to the environment. Moreover, solar energy is cost-effective, time saving, providing results (Karyono, 2017), which meet the international standards and is efficient. It is found in the literature that the carbon dioxide emission from a drying system uses 100 k what hours per day of the electricity and according to the data it was noted this procedure produces the carbon dioxide gas to about 14.77 tons/year, which is a huge amount. If the things are kept easy and solar energy was used for the production then the environment could be saved from the hazards. In the light of the above literature,

H_3: Solar energy production aids in the reduction of CO_2 emission.

3. METHODOLOGY

3.1. Data

Being one of the most important steps of a research process, data has been collected by the author in a very careful manner (Mengistu et al., 2015). This data collection has been performed according to the particular context of the study. As the author is to find out the impact of biogas, wind and solar energy production on CO_2 emission in Indonesia, the data has been collected in this particular context from Indonesia. Comprising the time period of 29 years, data has been gathered relative to biogas, wind and solar energy production as well as CO_2 emissions.

3.2. Model Specification

All the variables of the study can be divided into three categories i.e. dependent, independent and control variables. CO_2 emission is the dependent variable while the production of three types of energy i.e. biogas, wind and solar energy are the independent variables of the study. Apart from them, there is one control variable that has been considered by the author is energy consumption. Moving towards the measurement units, first of all the measurement unit of CO_2 emissions has been taken as the amount of CO_2 in the atmosphere (Mirzabaev et al., 2015). In the same fashion, the measurement unit of all kinds of energy production i.e. biogas energy BE, wind energy WE and solar energy SE have been taken as billion kilowatt hours (Moriarty and Honnery, 2019). Not only these, but the same unit has also been taken for energy consumption EC, the only control variable of the study. Considering all these variables and their measurement units, the author has come up with the following first model or equation:

$$CO2_t = \alpha + \beta_1 BE_t + \beta_2 WE_t + \beta_3 SE_t + \varepsilon_t$$

As the above equation is based only on the independent variables, after the addition of the control variable of the study, energy consumption, the following second model has been generated by the author:

$$CO2_t = \alpha + \beta_1 BE_t + \beta_2 WE_t + \beta_3 SE_t + \beta_4 EC_t + \varepsilon_t$$

It must be noted here that in the above given equations, CO_2 is particularly used to present the amount of CO_2 emissions. In addition, BE, WE and SE are the notations that have been used to represent the production of three types of energies i.e. biogas, wind and solar energy. In the last, the control variable, energy consumption has been denoted by EC and representing the error term.

3.3. Estimation Procedure

The estimation procedure of this study is divided into three parts involving unit root test, co-integration test and GMM estimation technique. These tests are used in order to study the order of integration, co-integrated relationships and the significant impacts of different variables. The detailed characteristics and properties of these techniques and approaches have been given in detail in this section:

3.4. Unit Root Test

Unit root tests are used in order to find out the order of integration of the variables for which the study has been conducted. In addition to order of integration, the scholastic properties or stationary properties of the collected data is also studied by the use of this test. Many different types of unit root tests are generally used for the same purpose, but the author has employed Levin et al. LLC and Im et al. IPS unit root tests so that the above mentioned

objectives can be effectively achieved. In both these tests, null and alternate hypotheses have great importance as the final evaluation of the result is based on the consequences of these hypotheses (Im et al., 2003; Levin et al., 2002). To explain these hypotheses, it can be stated that the null hypothesis involves the presence of unit root along with non-stationarity of data. On the other hand, the alternate hypothesis involves the absence of unit root along with the stationary of the data. The results of unit root tests clearly indicate whether the null hypothesis is accepted or rejected and based on this indication the final result is drawn.

3.5. GMM Estimation

Arellano and Bover (1995) introduced GMM estimation technique for the purpose of studying and exploring the impact of independent variables on the dependent one. There are many points that can be considered as the reasons of using this particular estimation technique instead of the other ones. The first point in this regard is that GMM test can be used to eliminate the errors that occur due to heteroscedasticity and autocorrelation related problems and issues. Another important point is that GMM estimation technique uses large number of instruments due to which very authentic and accurate results are obtained. Moreover, the regressions of level and first difference series can also be joined together through the use of GMM estimation approach. For first difference series, the lagged values of explanatory as well as dependent variables are used while on the contrary in level series, the lagged values of just explanatory variables are used as instruments of regression. Two types of this particular approach are identified i.e. first difference and system approach of GMM. First difference GMM is not that much preferred because it does not provide authentic results due to the usage of very small sample size. Therefore, system GMM approach is preferred to obtain most accurate results. As large number of instruments is used in system GMM approach, this adds to the accuracy and authenticity of the results obtained.

4. EMPIRICAL ANALYSIS

4.1. Results of Unit Root Test

The results of LLC and IPS unit root tests, employed by the author, have been presented in Table 1. The results of both these tests have been shown in context of level as well as first difference series separately. Let us discuss IPS unit root test first. In the level series, it is evident that all the variables except energy consumption have rejected the null hypothesis while in first difference series all the variables have completely rejected the null hypothesis. This result of IPS indicates that data is stationary in first difference series. Now when the results of LLC unit root test are considered, it is evident in the level series that all the variables have rejected the null hypothesis except biogas energy production. In the same way, in the first difference series, it is clearly visible that all the variables have rejected the null hypothesis in this particular series. This LLC unit root test's result has shown that there is no unit root in this series and the data is stationary. The reason behind applying the LLC unit root test after IPS test was to ensure and confirm the results of IPS unit root. After this, when the results of both the approaches were complied, the collective result was obtained. The unit root was found to be absent while the data was found to be stationary. After these results, the data is ready to be further tested and evaluated.

4.2. Results of GMM Estimation

As discussed in the model specification section of the study, two models can be designed one involving all the independnet varibales and the other one involving all the independent as well as control variables. The results of GMM estimation technique for both these models have been given in the Table 2. When the first model is considered, it can be seen that biogas and wind energy production have significant by 5 and 1% significance level respectively. This impact is positive on CO_2 emission. It can be stated that with 1% increase in biogas energy production, CO_2 emission is increased by 25.1%. In the same way, with 1% increase in wind energy production, CO_2 emission will increase by 16.4%. However, the impact of the last independent variable has been found as insignificant. When the model two is considered, it is clear and evident that the impact of all the independnet variables have 5% significant and positive impact on CO_2 emission. In other words, with 1% increase in biogas, wind and solar energy production, the amount of CO_2 emission will be increased by 21.3%, 28.5% and 22.8% respectively according to the GMM results. When the control variable from the model two is viewed, it is found that the impact of the only control variable, energy consumption is insignificant on CO_2 emission in the atmosphere. To sumup the results of GMM estimation approach, it can be stated that biogas energy, wind energy and solar energy production has significant positive impact on CO_2 emission in the atmosphere. It means that when the production of any of the above mentioned types of energy is increased, it will result in the increase in emissions of carbon dioxide in the atmosphere.

5. DISCUSSION AND CONCLUSION

5.1. Discussion

Over a year, based on the amount of electricity wind is currently generating each day, wind turbines save around 6.1m tones of

Table 1: IPS and LLC unit root

Constructs	IPS		LLC test	
	Level	1st diff.	Level	1st diff.
BE	5.674*	10.788***	−2.746	−9.986***
WE	7.586*	13.977**	−7.855*	−14.547**
SE	4.765*	11.354***	−9.865*	−18.966***
EC	2.456	10.576***	−5.679*	−13.354***
CO_2	9.875*	16.878***	−4.876*	−11.786***

In the table, "*" represents the rejection of null hypothesis by 1% significance, "**" represents the rejection of null hypothesis by 5% significance and "***" represents the rejection of null hypothesis by 10% significance

Table 2: GMM estimation results

Variable	Model I		Model II	
	Est.	Err.	Est.	Err.
Constant	4.087	2.745	7.844	1.964
BE	0.251**	0.765	0.213**	0.353
WE	0.164*	0.599	0.285**	0.354
SE	0.032	0.864	0.228**	0.435
EC	-	-	0.035	0.965
ICT (ic)	-	-	0.213**	0.354
R^2	0.789**	0.875	0.725**	0.894
Adj. R^2	0.781**	0.786	0.706**	0.997
D.W.	2.11	-	2.04	-

"*" represents the significance level of 1% and "**" represents the significance level of 5%

carbon dioxide, or about 4% of the Indonesia emissions from electricity (Alfata, 2018). The role of biogas, wind energy solutions and solar energy production is very essential for an economy. For the development of an economy, the role of energy production is very important. The purpose of the given study is to illustrate the reducing process of CO_2 emission through energy production, solar energy, and biogas. The results analyze the co-integration and GMM approach. Basically, in econometrics and statistics, the generalized method of moments (GMM) is a generic method for estimating parameters in statistical models (Creal et al., 2018). These moment conditions are functions of the model parameters and the data, such that their expectation is zero at the parameters' true values (Wei et al., 2016; Zhou and Wang, 2016).

The results and findings illustrate that solar energy, as well as wind energy solutions, help to reduce the CO_2 emission significantly. The results prove a significant relationship use of solar energy and CO_2 emission (Tiwari and Babu, 2016a; 2016b). A previous study also supports the relationship. A study demonstrates that solar power can help reduce CO_2 emissions mainly by being a clean and renewable source of energy. Solar power is not dependent on burning fossil fuels or other products; instead, it uses electrons from captured from the sun's energy for energy creation (Zhou et al., 2018). At the same time, the results also discussed that the use of wind energy affects the CO_2 emission. Overall, using the wind to produce energy has fewer effects on the environment than many other energy sources. Wind turbines do not release emissions that can pollute the air or water, and they do not require water for cooling. Wind turbines may also reduce the amount of electricity generation from fossil fuels, which results in lower total air pollution and carbon dioxide emissions (Kis et al., 2018). Higher is then the role and contribution of energy production sources, the lower is the CO_2 emission and vice versa. Therefore, in different countries, the use of wind energy, solar energy, and other energy production sources has a positive role in reducing CO_2 emission. The following study has also explained the role of energy consumption as a control variable. The findings and results indicate that energy consumption controls CO_2 emission through solar and wind energy. Thus, solar, wind and other useful sources play a significant role in reducing CO_2 emission (Soufi et al., 2016; Tang and Tan, 2015).

5.2. Implications

The results and findings examined that CO_2 emission can be reduced in many ways; however, wind energy, solar energy, and energy production are significant ones. This has indicated that the Biogas, Wind and Solar Energy Production help to reduce the CO_2 emission in Indonesia. Moreover, most wind power projects on land require service roads that add to the physical effects on the environment in Indonesia. There are several other practical, theoretical and policy making implications.

5.3. Limitations/Recommendations

The study highlights the importance of solar, wind and biogas energy. From the results, it has come to the knowledge that the use of solar and wind energy, the CO_2 emission can significantly be reduced. Therefore, it is highly recommended that there must be more and more solar energy projects start in order to reduce CO_2 emission. The sample size must be increased by the future researchers and the geographical region must also be changed.

5.4. Conclusion

The potential of advanced and renewable energy technologies is very promising in the long-term CO_2 emission process. The purpose of this study is to analyze the role of wind, solar and biogas in reducing the CO_2 emission through the role of energy consumption which is a control variable. Moreover, the GMM time series approach is being used to discuss the results and findings. The results indicate that solar energy, energy production sources, and the use of wind energy projects help to reduce carbon emission.

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