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RESEARCH ARTICLE

Renewable energy, non-renewable energy, and economic growth: evidence from 26 European countries

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Abstract
This research work examines the nexus among renewable, non-renewable energy consumption, CO_2 emissions, and economic growth in 26 European countries with data obtained from the World Bank database within the time period of 1990 to 2018. Firstly, unit root and panel cointegration approach analyses are conducted to test the stationary. The results indicate that there exists a long-run nexus among non-renewable, renewable energy, carbon-monoxide, and economic growth. Granger causality test was also used to explore the direction among economic growth, carbon emissions, and energy consumption. The results from this test are inconsistent, while it indicated bidirectional causality between economic growth and renewable energy consumption, there was also a unidirectional causality between renewable energy and non-renewable energy consumption as well as renewable energy and CO_2 emissions. This result proves an interdependency and substitutability between both renewable and non-renewable sources of energy.

Keywords Renewable energy · Nonrenewable energy · Carbon dioxide emissions · Economic growth

Introduction

It is widely known that in all countries, energy is an important factor for production (Koçak and Şarkgüneşi 2017) and the demand for energy globally is continuously increasing. For instance, in 1973, the demand for world energy was 4667 MTOE and in 2013, the demand had increased to 9301. According to Hedenus et al. (2010), countries importing energy are also facing energy security issues. Natural gas, oil, and coal which are the customary source of energy contribute greatly to the growth of the economy (Ellabban et al. 2014). However, due to issues surrounding global warming and greenhouse gas emissions, necessary measures need to be taken to avoid environmental disasters (DeCanio 2009). It is estimated that the global warming impact on the economy may lead to a decrease in the global GDP by 25%.

These developments have led to the transition from non-renewable to a renewable source of energy. Therefore, our research is framed around the set objectives of the Europe 2020 strategy by the European Union which is aimed to increase renewable energy and reduce the primary energy consumption so as to lead to a decrease in energy demand and greenhouse gas emissions. In 2015, the European Union formalized the 2015 Paris agreement on climate change with the aim of reducing greenhouse gas emissions by 40% by the end of 2030 (European Parliament 2016).

These concerns have resulted in more focus on renewable energy sources such as biomass, solar, geothermal, wind, and wave (Apergis and Payne 2011). The International Energy Outlook states that there is an increase in the growth of renewable energy worldwide; for example, there is a 13.8% increase in biofuel production likewise a 15.5% increase in wind energy. This change in substitute traditional sources of energy to renewable sources is now a major trend and tool, and by 2050 according to IEA, it is expected that there will be a 50% rise in

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renewable sources (Yildirim 2014). As of 2016 within the 28 European Union countries, out of the total energy production, more than a quarter was gotten from the renewable source of energy (Eurostat 2017).

Therefore, in 2016, more than one-quarter of the total production of primary energy within the EU-28 came from renewable energy sources, and the increase in primary production using renewable energy sources exceeded the share of total primary energy production from other sources of energy (Eurostat, Statistics-explained 2017). Most European countries are encouraging the use of clean energy through tax credits, state fund subsidies among others (Salim et al. 2014).

To this growing interest, the European Union parliament and European council implemented a program for the year 2020 known as the renewable energy directive (RED). Its objective is to make renewable energy reach 20% of its final consumption of energy in 2020. Consequently, a clear understanding of the benefits of renewable energy is important to realize the goals to promote and sustain economic growth (Apergis and Payne 2011). According to Bhattacharya et al. 2016, developments in renewable energy have led to new entrepreneurs around the world. In light of these, it becomes imperative to understand the importance and dynamics of the consumption of renewable energy and energy growth. The search for this relationship between the two concepts will provide a proper design for energy policies and the national environment (Salim et al. 2014). Also, it will provide a long-run equilibrium benefit and impact of a renewable source of energy in the sustenance of economic growth.

The increase in renewable energy usage has led to various research works to analyze the relationship between the consumption of renewable energy and economic growth. While some research indicated the "neutrality hypothesis", i.e., no causal relationship between the two concepts (Bulut and Muratoglu 2018; Omri et al. 2015). Majority of empirical findings found that there is a positive correlation between renewable energy and economic growth (Gyamfi et al. 2020a: Chen et al. 2020, Montassar et al. 2016, Georgeta et al. 2018). On the other hand, Tugcu et al. (2012) categorised previous empirical research as regards causality direction into three clusters. The first cluster examines the link without a qualitative differentiation between a renewable source of energy and economic growth. The second cluster examines the link between renewable sources of energy and economic growth. Lastly, the third cluster examines the link between both renewable and non-renewable as a separate variable to examine its effect on economic growth.

In general, most research work in the field used four already tested hypotheses (Tugcu et al. 2012; Yoo and Kwak 2010). The "growth hypothesis" which is the first hypothesis presumes that there is unidirectional causality from energy consumption and economic growth which means that an increase in the consumption of energy will lead to an increase in the economic growth while the reduction in energy consumption leading to improved quality in the environment and a decrease in economic growth (Payne 2011). The Neutrality hypothesis states that there is no causality between economic growth and energy consumption (Menegaki 2011). The conservation hypothesis presumes an unidirectional causality infers that a decrease in energy consumption leads to having little or no impact on economic growth (Sadorsky 2009). The last hypothesis which is the feedback hypothesis infers bidirectional causality between both concepts and it states that energy consumption has an impact on economic growth and vice versa (Apergis and Payne 2011).

This research aims to investigate the relative effect of non-renewable energy and renewable energy on economic growth within 26 European countries from 1990 to 2018. Most studies have studied only renewable energy on economic growth among European countries. However, this research explores both renewable and non-renewable energy among 28 European countries using the FMOLS, DOLS to investigate the relationship and granger causality tests to access the direction of the variables. Another difference in this research against existing works is that that we also explore not only the causal relationship but also examines the possibility of a long-run relationship between renewable and non-renewable energy and economic growth and its consequence to the stability of the environment. The remainder of the article is laid out as follows; the second session gives an extensive review of relevant literature. "Methodology" section provides data, methodology, and results while "Model and methods" section provides empirical findings. "Empirical discussion of result" section gives a conclusion to the study.

Literature review

As the concept of green energy is fast becoming a trend as an alternate to the customary non-renewable source of energy, it becomes important to have a policy on energy as it is inherently connected to GDP which measures and indicates the vigor of an economy. Grossman and Krueger (1991) specified that the environmental Kuznets curve is quite valuable in exploring the economic growth-energy pollutant relationship (Sugiawan and Managi 2016). According to Shafiei and Salim (2014), the consumption of renewable energy reduces CO_2 emissions while there is a surge in CO_2 emissions due to the consumption of non-renewable energy. Seck et al. (2015) states that in a non-energy demanding industry, a structural change about the consumption of energy will lead to a decline as well as a tremendous effect on the aggregate intensity of energy. Countries like Turkey, Mexico, and Indonesia have been researched to have a long-run equilibrium in the energy-growth nexus (Pao et al. 2014).

Thus, many institutions, policymakers, and government agencies have embarked on both empirical and theoretical research works on the significance and relationship

Table 1 Growth hypothesis literature for REC and economic growth

Author (s)	Period	Country	Methodology	Confirmed hypothesis
Gyamfi et al. (2020b)	1990–2018	E7 Countries	OLS, FMOLS and DOLS	Growth
Destek and Aslan (2017)	1980–2012	17 Emerging economies	Bootstrap panel causality	Growth
Halkos and Tzeremes (2014)	1990–2011	36 emerging and developing countries	Nonparametric techniques	Growth
Inglesi-Lotz (2016)	1990–2010	OECD countries	Panel cointegration approach	Growth
Chien and Hu (2007)	2001–2002	**45 OECD and non-OECD economies**	Data envelopment analysis (DEA).	Growth
Emrah and Aykut (2017)	1990–2012	9 Black Sea and Balkan countries	Co-integration estimate methods and heterogeneous panel causality estimation techniques.	Growth
Mehmet and Alper (2017)	1980 to 2012	17 emerging countries	Bootstrap panel causality	Growth

between renewable energy and economic growth. The majority of these works examined the inverted U-shaped relationship by exhibiting CO_2 emissions GDP squared per capita. However, the use of various types of methodologies, countries, and time periods has resulted in inconsistencies in results. Jaunky (2011) explored 36 countries between the periods of 1980–2005 using the EKC hypothesis and GMM. The result indicates that Portugal, Greece, Oman, UK, and Malta have EKC. Also, Bölük and Mert (2014), in their study found a nexus that the use of renewable energy in 16 EU countries is a sufficient strategy in the advancement of environmental and economic growth. In a multivariate framework, Menegaki (2011) while examining the nexus of output and renewable energy between the periods time of 1997–2007 was unable to identify a causal relationship using error correction mechanism in European countries. Nonetheless, some studies such, as Silva et al. 2012, have also shown that renewable energy can harm the growth of the economy. In light of this, four tested hypotheses will be explored to understand the long-run causal relationship between renewable and non-renewable energy and economic growth and its consequence to the stability of the environment (Shahbaz et al. 2015, (Ozturk 2010). These hypotheses have been grouped into Tables 1, 2, 3 and 4.

Various articles also investigated the possibility of a long-run relationship between renewable and non-renewable energy and economic growth and its consequence to the stability of the environment. Most of the reviewed articles seem to be inclined towards the feedback effect in the long run (Chang et al. 2015; Apergis and Payne 2011; Tugcu et al. 2012; Bloch et al. 2015; Sebri and Ben-Salha 2014). Also, some articles explored the short-term causality and the results support the feedback hypothesis in a short-run relationship (Shahbaz et al. 2015; Sadorsky 2009; Apergis and Payne 2011; Gyamfi et al. 2020a). Studies such as (Pao et al. 2014; Yildirim 2014, Omri et al.), results show that renewable energy leads to economic growth.

The varieties of studies reviewed above show that a nexus between in energy and growth has been well researched; however, there still exists no consensus among the scholars on a valid hypothesis to describe the relationship between energy-growth nexus. Also, most of the studies come with a few shortcomings. Environmental Kuznets Curve (EKC) model was used in the majority of the studies which in itself has a few weaknesses such as the model overlooks essential factors that are important to understand the nexus between emissions, income, and energy. These factors were explicitly included in this study to analyze the GHG emissions of the sampled EU countries. This present article's potential innovations also address the nexus and the impacts among $C0_2$ emissions, REC and non- REC, and economic growth in 26 European countries from 1900 to 218.

Methodology

Data and variables

To identify the type of effect and relationships among renewable energy (RE), non-renewable energy (NREC), carbon dioxide (CO_2), and economic growth (EG) in European countries, data was extracted from the World Bank display (www.databank.worldbank.org) Annual data of frequency from 1990 to 2018 was employed to investigate the relationship between the variables. The variables were converted in logarithm form to minimize the situation of heteroscedasticity. GDP per capita (constant at 2010 US$) represents GDP. REC represents renewable energy (% of

Table 2 Conservation hypothesis literature for REC and economic growth

Author (s)	Period	Country	Methodology	Confirmed hypothesis
Caraiani et al. (2015)	1980–2013	5 emerging European countries	Engle-Granger causality method	Conservation
Ocal and Aslan (2013)	1990–2010	Turkey	ARDL approach; Toda–Yamamoto procedure.	Conservation
Rasoulinezhad and Saboori (2018)	1992–2015	Commonwealth of independent states	Panel cointegration, FMOLS, DOLS	Conservation
Sadorsky (2009)	1994–2003	18 emerging countries	Panel cointegration and fully modified ordinary least squares	Conservation

total final energy consumption); NREC was represented by non-renewable energy; CO_2 was represented by carbon dioxide; and EG was represented by GDP per capita (constant 2010 USD).

Model and methods

This study sets to investigate the contribution CO_2 emissions renewable energy consumption and nonrenewable energy consumption to economic growth in 26 EU countries. As shown in the literature review, several studies have been carried out in this area; we attempt to investigate the nexus between our study variables for EU countries for some distinct reasons.

First, EU countries are responsible for the highest contribution by economic integration globally being outperformed. Hence, to understand the relationship between large scales economic activities and emissions will help in no small way of pursuing a global reduction in CO_2 emissions and the UN-SDGs globally. Second, on the other hand, the EU countries are responsible for a huge share of global CO_2 emissions; thus, it is necessary to understand the contributing factors to such high emissions to enable a reduction in global emissions leading to an improvement in the natural environment and a healthier living environment.

In particular, this study varies from Gyamfi et al. (2020b) primarily because we use a separate data collection, which included a comprehensive data of EU nations across the span 1990–2018. The extensive period covered in the study gives room for sufficient observations to draw policy inferential conclusions. Also, several environmentally relevant policy meetings such as the first Copenhagen climate summit 2009 and its succeeding conferences as well as global climate meetings such as the Kyoto protocol and other significant meetings have been held within the study period. This then enables the study to measure the implementation of resolutions from this meeting in mitigating global warming by way of reducing emissions. This study considering the position of renewable energy consumption, nonrenewable energy consumption, and CO_2 pollution ON economic growth and proposes the following model equations:

$$GDP = f\,(REC, CO_2, NREC) \tag{1}$$

$$LnGDP_{it} = \beta_0 + \beta_1 LnREC_t + \beta_2 LnCO_{2t} + \beta_3 LnNREC_t + \mu_t \tag{2}$$

Logarithmic transformation of all variables has been performed to enable the study variables to maintain constant variance across all the series. Where LnGDP, LnREC, $LnCO_2$, and LnNREC are logarithmic transformations of all variables and μ_{it} , α,and β's represent the stochastic, intercept, and partial slope coefficients respectively. Two long run estimation techniques were employed to access the relationship between the investigating variables which are the FMOLS and

Table 3 Feedback hypothesis literature for REC and economic growth

Author (s)	Period	Country	Methodology	Confirmed hypothesis
Georgeta et al. (2018)	1995–2015.	28 countries of European Union	Panel data techniques	Feedback
Xingle et al. (2015)	1952 to 2012	China	Granger causality analysis, static and dynamic regression analysis	Feedback
Montassar et al. (2016)	1980–2012	eleven MENA Net Oil Importing Countries	Granger causality tests	Feedback
Seyi et al. (2019)	1995–2015	EU-28 countries	Sutoregressive distributed lag (ARDL)	Feedback

Table 4 Neutrality hypothesis literature for REC and economic growth

Author (s)	Period	Country	Methodology	Confirmed hypothesis
Menegaki (2011)	1997–2007	27 EU countries	One-way random effect model; panel causality tests	Neutrality
Alper and Oguz (2016)	1990–2009	8 New EU member countries	Asymmetric causality	Neutrality
Payne (2011)	1949–2006	USA	Different econometrics methods	Neutrality

DOLS as well as the Granger causality test which was employed to check the causal relationship between the variables.

Stationary test

It is important to test if there is stationarity between the variables: renewable energy, nonrenewable energy, carbon dioxide, and economic growth. The result revealed that there was no stationarity at all levels. Seemingly, at the first difference between the variables, there was stationarity when a two-unit test was employed. The order of one integration was found from the analysis.

Cointegration test

It was important to check the presence of cointegration among the variables. We applied the Panel cointegration techniques used by Kao (1999) and Pedroni (1995) to examine the presence of a relationship between renewable energy, nonrenewable energy, carbon dioxide, and economic growth for the set of data within the 26 European countries. The outcome of the residual cointegration test (Pedroni 1995) and Kao (1999) provided in Tables 6 and 7 confirms the cointegration between variables. The empirical outcome depicts that the insignificant theory of no co-integration is overruled at a (5%) significant level. The findings advocate Pedroni panel co-integration test which supports the evidence of long-run relation and affirms and Bekun and Gyamfi (2020).

Estimation test

From 26 European countries, the dynamic ordinary least square (DOLS) and fully modified ordinary least square (FMOLS) developed by Pedroni (2004) are employed to determine the long-run elasticity's among the variables. The outcome of the panel DOLS and FMOLS estimations are summarized in the table.

Findings from the pairwise Granger causality test indicated bidirectional causality between economic growth and renewable energy consumption. Also, there was a unidirectional causality between renewable energy and non-renewable energy consumption. The result from (Table 8) again shows a unidirectional causality between CO_2 emission and renewable energy and between renewable energy consumption and non-renewable energy consumption.

Empirical discussion of result

The result in Table 5 indicates that non-renewable energy consumption is negatively associated with economic growth. Again, non-renewable energy has a negative association with renewable energy. Moreover, CO_2 emissions have a significant positive association with economic growth. Also, CO_2 emissions have a negative association with renewable energy while CO_2 emissions positively correlated with non-renewable energy.

The findings in Table 5 depict that the variables are combined in the order I (1), i.e., the same number. It is a measure of the non-stationary of the parameters at the point, but at the first stationary difference, the difference, for example, non-renewable energy consumption is observed to be stationary at [I (1)] under the heterogeneity variance system. As shown in Table 5, the unit root test shows that most of the variables were not stationary at the level but were stationary at the first difference, depicting that the variables were for analysis and that the outcomes could be used for policy decisions.

After we determined stationarity among the variables, we then proceeded to identify the probability of cointegration regarding the variables with the aim of accessing the long-run equilibrium among the variables. The Pedroni residual cointegration test by Pedroni (1995) and Kao (1999) was employed to access the cointegration and from the Tables 6 and 7 analysis, it was observed that the variables were not significant at both $r \leq 4$ and $r \leq 5$ which proofs that we reject the null hypothesis by concluding that the variables are cointegrated.

After determining stationarity among variables, we proceeded to identify the probability of cointegration regarding the variables to access the long-run equilibrium among the variables. The existence of cointegration among our modeled variables was checked using Pedroni (2004) and Kao and Chiang (2000) cointegration test (see Table 8). The test result of the cointegration stressed the existence of a long round relationship among our variables, as we will reject the null

Table 5 Unit root test result

Levin, Lin & Chu t*				Im, Pesaran and Shin W-stat			
Level		1st difference		Level		1st difference	
Statistic	Probability**	Statistic	Probability**	Statistic	Probability**	Statistic	Probability
2.98997	0.9986	− 6.72090	0.0000	0.99893	0.8411	− 6.56018	0.0000

*, **, *** denote 10%, 5%, and 1% significance level respectively

hypothesis of the two cointegration tests. Renewable energy, non-renewable consumption, CO_2 emission, and GDP per capital are cointegrated. Under the Pedroni test, about five out of the seven from both within and between dimensions were significant. Therefore, the result suggests the existence of a long round relationship between our variables. Seemingly, Kao cointegration confirms that there exists a long-run relationship among the variables because the cointegration test statistic is significantly suggested by our result.

After confirming the existence of a long-run relationship among the variables, the long round model is estimated utilizing panel FMOL and DOLS. Table 8 disclosed the estimated long-run result. All the European countries were estimated as a group. The result of all the 26 European countries for FMOL depicts that if economic growth increases by one unit renewable energy increases by 0.3257. Again, if renewable energy increases by a unit, economic growth decrease by − 0.291486, if non-renewable energy increase by one unit, economic growth decreases by − 0.291486%, and if CO_2 increases by a unit, economic growth will decrease by − 0.42014% respectfully.

On the other hand, the DOLS result depicts that if economic growth increases by one unit, renewable energy increases by 0.319307. Again, if renewable energy increases by a unit, economic growth decreases by − 0.26706; if non-renewable energy increases by one unit, economic growth decreases by − 0.267067% and if CO_2 increases by a unit, economic growth will decrease by − 0.339009% respectfully. The finding from the robust check from panel FMOLS and pooled DOLS yield a similar negative significant coefficient. It depicts that a rise in the consumption of renewable energy in the 26 European countries marginally decreases economic growth. It was found that a rise in non-renewable energy in the 26 European countries decreases economic growth. Again, it was found that an increase in economic growth increases renewable energy. It was also disclosed that a rise in CO_2 emission decreases economic growth.

On the other hand, the study then adopted the Granger causality technique to establish the direction of causality between the variables. Findings from the pairwise Granger causality test indicate bidirectional causality between economic growth and renewable energy consumption. These outcomes are in line with several research findings in previous studies. These findings are consistent with four research done by Apergis and Payne 2010a, 2010b, 2010c, 2011 which all confirm a bidirectional causality between renewable energy and real GDP. Also, there was a unidirectional causality between renewable energy and non-renewable energy consumption. The result from (Table 9) again shows a unidirectional causality between CO_2 emission and renewable energy and between renewable and non-renewable energy intakes.

Table 6 Pedroni (1995) residual cointegration test

Pedroni	Statistic	*p* value
Panel V-statistics	4.3235	0.0000***
Panel rho-statistic	− 2.4130	0.0079***
Panel PP-statistic	− 5.1470	0.0000***
Panel ADF-statistic	− 1.4989	0.0669**
Group rho-statistic	− 1.0051	0.1574
Group PP-statistic	− 7.3458	0.0000***
Group ADF-statistic	− 1.6205	0.0526**

*, **, *** denote 10%, 5% and 1% significance level respectively

Discussion of findings

The study examined the existence of long-run and causality association between renewable energy and economic growth, evidence from 26 European countries. The empirical result from the correlation matrix indicates that non-renewable energy consumption is negatively associated with economic growth. Again, non-renewable energy has a negative

Table 7 Kao (1999) residual co-integration test outcomes

	T statistics	Probability
ADF	− 4.0227	0.0000***
Residua variance	0.0172	
HAC variance	0.0244	

*, **, *** denote 10%, 5%, and 1% significance level respectively

Table 8 Robustness check of long run relationship using FMOLS and DOLS

Variable	FMOLS		DOLS	
	Coefficient	Prob	Coefficient	Prob
LnRE	0.3257	0.000***	0.3193	0.000***
LnNREC	− 0.2914	0.000***	− 0.2670	0.000***
$LnCO_2$	− 0.4201	0.000***	− 0.3390	0.0001***

Prob. represents the *p* value; FMOLS is fully modified ordinary least square; DOLS is dynamic ordinary least square. ***represent 1% significant level

association with renewable energy. Moreover, CO_2 emissions have a significant positive association with economic growth. Also, CO_2 emissions have a negative association with renewable energy while CO_2 emissions positively related with non-renewable energy.

The result from the unit root test shows that most of the variables were not stationary at the level but were stationary at the first difference, depicting that the variables were for analysis and that the outcomes could be used for policy decisions. Again, the study then identifies the probability of cointegration regarding the variables to access the long-run equilibrium among the variables. The Johansen Fisher Panel Cointegration Test by Breitung (2002) was employed to access the cointegration and it was found that the variables are cointegrated. The existence of cointegration among our modeled variables was checked again using Pedroni (1995) and Kao (1999). The test result of the cointegration stressed the existence of a long-run relationship among our variables.

Table 9 Granger causality test

Null hypothesis	*F*-statistic	Prob.
LnRE ≠ LEG	4.3368	0.0135**
LnEG ≠ LnRE	2.6069	0.0746*
LnNRE ≠ LnEG	1.7809	0.1694
LnEG ≠ LnNRE	0.0476	0.9535
$LnCO_2$ ≠ LnEG	1.6222	0.1983
LnEG ≠ $LnCO_2$	3.6432	0.0268*
LnNRE ≠ LnRE	0.3708	0.6903
LnRE ≠ LnNRE	6.0925	0.0024***
$LnCO_2$ ≠ LnRE	0.5560	0.5738
LnRE ≠ $LnCO_2$	7.7147	0.0005***
$LnCO_2$ ≠ LnNRE	0.6792	0.5074
LnNRE ≠ $LnCO_2$	1.9499	0.1432

***, **, and * are 1%, 5%, and 10% significant level respectively while ≠ represents does not “Granger cause”

Renewable energy, non-renewable consumption, CO_2 emission, and GDP per capital are cointegrated. Under the Pedroni test, about five out of seven from both within and between dimensions are significant. Therefore, the result suggests the existence of a long round relationship between our variables. Notwithstanding, Kao cointegration confirms that there exists a long-run relationship among the variables because the cointegration test statistic is significantly suggested by our findings.

After confirming the existence of a long-run relationship among the variables, the long round model is estimated utilizing panel FMOL and DOLS. The empirical result of all the 26 European countries for FMOL depicts that as economic growth increases, renewable energy increases. Again, if renewable energy increases, economic growth decreases. If non-renewable energy increases by one-unit, economic growth decreases by a percentage and if CO_2 increases, economic growth will decrease.

On the other hand, the DOLS result depicts suggestion that if economic growth increases unit renewable energy increases. Again, if renewable energy increases, economic growth decreases; if non-renewable energy increases by one-unit, economic growth decreases by a percent, and if CO_2 increases by a unit, economic growth will decrease by a percent respectfully. The finding from the robust check from panel FMOLS and pooled DOLS yield a similar negative significant coefficient. It was found that a rise in the consumption of renewable energy in the 26 European countries marginally decreases economic growth. It was found that a rise in non-renewable energy in the 26 European countries decreases economic growth. Again, it was found that an increase in economic growth increases renewable energy. It was also disclosed that a rise in CO_2 emission decreases economic growth.

On the other hand, the direction of causality between the variables under study was significant. The study then adopted the pairwise causality technique to establish the direction of causality between the variables. Empirical findings from the pairwise Granger causality test indicate bidirectional causality between economic growth and renewable energy consumption. Also, there was a unidirectional causality between renewable energy and non-renewable energy consumption. Moreover, the table indicates a unidirectional causality between non-renewable energy and CO_2 emissions. The unidirectional causality among the 26 European countries shows that adopting traditional energy policies not only solves the economic boundaries of the 26 European countries but also reduces the demand for non-renewable energy in exchange. The study is vivid from a policy perspective that the 26 European countries depend heavily on non-renewable energy which is important to economic growth. Based on this, it is concluded that more CO_2 is produced.

Conclusion and policy direction

The study examined the existence of long run and causality nexus between renewable energy, non-renewable energy, CO_2 emission, and economic growth in 26 European countries. The study found that a long-run equilibrium association exists between economic growth and the independent variables, renewable energy consumption, non-renewable energy consumption, and CO_2 emissions. Again, the result from the FMOL and DOLS shows that a rise in the consumption of renewable energy in the 26 European countries marginally decreases economic growth. It was found that a rise in non-renewable energy in the 26 European countries decreases economic growth. Again, it was found that an increase in economic growth increases renewable energy and a rise in CO_2 emission decreases economic growth.

Empirical result from the pair wise Granger causality test depicts a bidirectional causality between renewable energy consumption and economic growth. The study found a unidirectional causality between non-renewable energy consumption and economic growth. There was unidirectional causality between renewable energy and non-renewable energy consumption. The unidirectional relationship among the variables denotes that the implementation of strategy concerning the implementation of energy convention resolves not solely the scope of the 26 European countries but similarly reduces the quest for energy from the non-renewable energy at the same time. This indicates that government in the 26 European countries should continue to advocate for non-renewable energy consumption guideline persistently. Therefore, it is important that policy makers in the 26 European countries invest massively in the expansion of renewable energy which in the long run generates fewer CO_2 emission. To ensure generalization and larger overview, more countries should be included in future studies. Contrary to the value of renewable energy for global development, expanding renewable energy would reduce reliance on competitive energy, natural gas prices, and global energy supplies on global market and minimize greenhouse gas-related ecological losses in the long-term.

Authors' Contributions AAH wrote the introduction section. BAA wrote the methodology, analyzed, and interpreted the data regarding renewable energy, non-renewable energy, and economic growth. BAM provided the topic and supervised the current study at the same time, and was a major contributor in writing the manuscript. All authors read and approved the final manuscript.

Availability of data and materials The data used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Compliance with ethical standards

Ethical approval Not applicable.

Consent to participate Not applicable.

Consent to publish Not applicable.

Competing interests The authors declare that they have no competing interest.

Appendixes

Table 10 List of European countries

26 European countries					
1.	Austria	11	Hungary	22	Sweden
2.	Belgium	12	Ireland	23	Austria
3.	Bulgaria	13	Italy	24	Belgium
4.	Cyprus	14	Luxemburg	25	Bulgaria
5.	Czech	15	Netherlands	26	Cyprus
6.	Denmark	16	Poland		
7.	Finland	17	Portugal		
8.	France	18	Romania		
9.	Germany	19	Slovenia		
10.	Greece	21	Spain		

Table 11 Definition of variables

Variable	Explanation	Source
Renewable energy consumption (% of total final energy consumption)	Renewable energy consumption is the share of renewable energy in total final energy consumption.	World Bank, Sustainable Energy for All (SE4ALL) database from the SE4ALL Global Tracking Framework led jointly by the World Bank, International Energy Agency, and the Energy Sector Management Assistance Program.
Nonrenewable energy (fossil fuel)	Fossil fuel comprises coal, oil, petroleum, and natural gas products.	IEA Statistics © OECD/IEA 2014 (http://www.iea.org/stats/index.asp), subject to https://www.iea.org/t&c/termsandconditions/
GDP per capita (constant 2010 US$)	GDP per capita is gross domestic product divided by midyear population. GDP is the sum of gross value added by all resident	World Bank national accounts data, and OECD National Accounts data files.

Table 11 (continued)

Variable	Explanation	Source
	producers in the economy plus any product taxes and minus any subsidies not included in the value of the products. It is calculated without making deductions for depreciation of fabricated assets or for depletion and degradation of natural resources. Data are in constant 2010 U.S. dollars.	
CO2 emissions (metric tons per capita)	Carbon dioxide emissions are those stemming from the burning of fossil fuels and the manufacture of cement. They include carbon dioxide produced during consumption of solid, liquid, and gas fuels and gas flaring.	Carbon Dioxide Information Analysis Center, Environmental Sciences Division, Oak Ridge National Laboratory, Tennessee, United States.

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