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Impacts of renewable energy consumption on the German economic growth: Evidence from combined cointegration test

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ABSTRACT

Germany is the largest economy in Europe and the leading renewable energy user comparable to none in the entire of the European continents. It is in reference to these developments that this study investigates whether the impacts of renewable energy have consolidated the economic growth prospects of the country. To ensure this, quarterly time series data from 1971Q1 to 2013QIV was used. The study employed the Clemente-Montanes-Reyes detrended structural break test, the Bayer-Hanck combined cointegration test and the ARDL bounds testing approach to cointegration. In addition, the causality analysis was observed using VECM Granger causality framework. The results confirmed the existence of cointegration among the variables. The results show that renewable energy consumption in Germany consolidates the country's economic growth prospects to the extend that a 1% increase in renewable energy consumption boosts German economic growth by 0.2194%. In addition to that, a 1% increase in capital lead to the rise in economic growth by 1.1320%. While a 0.5125% increase in economic growth is due to 1% increase in labor productivity. The causality analysis on the other hand, revealed the existence of feedback effect between renewable energy consumption and economic growth. While the relationship between renewable energy consumption and capital is found to be bidirectional and same inference was found to exist between capital and economic growth. The study proposes solid mechanisms that will help in averting renewable energy market failure locally and internationally among others.

1. Introduction

Energy is an essential element to both human and industrial existence. This is in the sense that a secure, sufficient and accessible supply of energy is a crucial requirement for the sustainability of modern societies and its economic well-being. This is irrespective of the level of economic growth attained. In addition to that, energy is an indispensable element in boosting and sustaining the level of economic growth of a country. Supporting the direction of this assertion, Ucan et al. [1]; Rafindadi [2,3]; Rafindadi and Ozturk [4] and Rafindadi and Ozturk [5] argued that high energy consumption is one of the basic indicators of economic development level achieved by a country. However, Halıcıoglu [6] stressed that economic development and output may be jointly determined because economic growth is closely related to energy consumption. In addition, higher economic development requires more energy consumption. As a result of this, a more efficient energy use needs a higher level of economic development. Several energy sources exist in the world today among these source. Yamusa and Ansari [7] pointed out that renewable energy has the best distinguishing features among all existing energy sources. They established that renewable energy is a natural endowment with a more accessible and sustainable ability that provides a balanced economic, social and environmental development. The authors also point out that it is only renewable energy among other energy mix that can strike a balance between human wellbeing and the ecology at large. This is because renewable energy has an infinite and unharmful sufficiency as well as a viable means of attaining veritable green economic growth prospects. Apart from that, the authors argued that renewable energy is the only energy source that could provide unflinching energy sufficiency and its supply level(s) cannot be over-stretched.

Underscoring the direction of these arguments, multiplicities of studies have established that due to the significance of renewable energy, Germany has decided to phase out its nuclear power by 2022 and polls have shown that over 80% of the German populace supported the need for the country's electricity to come from home-grown wind, sun and geothermal alternatives. With this development, it is envisaged that renewable energy sources (RES) will account for at least 35% of the German gross electricity consumption by the year 2020 [8]. In an earlier development, the proportion of electricity generated from renewable energy in Germany has increased significantly from 6.3%

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in 2000 to more than 25% in the initial half of 2012 and up by 27% in the first quarter of 2014 thus providing a supply of 40.2 billion Kilowatts/hour of electricity as against 35.7 billion Kilowatts/hour in the same year [9]. The key expected target generation by 2030, 2040 and 2050 are estimated to be around 50%, 65% and 80%, respectively [10]. In addition to that, the German renewable energy market was also found to have risen from 0.8 million of residential consumers in 2006 to 4.9 million residential consumers in 2012, this increase constitute more than 12.5% of all private households in the country. Another significant point to mention is that, in 2011, it was estimated that there was a purchase of green energy by over 10.3 TWh [11] similar to this development, the proportion of renewable power in total of energy utilisation increased to 20% in 2011 from 10% in 2005. The structural composition and contributions of renewable energy generation reserve in 2012 in Germany comprised of: Wind energy 36.6%, biomass 22.5%, hydropower 14.7%, photovoltaic 21.2% and bio-waste 3.6% [10]. By the end of 2011, it was estimated that the total energy generated from the renewable sector was put at 65.7 GW, with the solar energy contributing 22 GW. The contribution of this 22 GW was estimated to be as much as what 20 nuclear reactors could generate. This amazing development enabled the achievement of 50% of the German's mid-day electricity consumption requirements [12].

The height attained by the German renewable energy sector positioned the country to lead and shape the world renewable energy market and to equally allow the country to set standards and a global example on clean energy security [9]. This development also made it possible for Germany to escape the high costs of fossil fuel importation, gas and uranium from foreign sources. Apart from these costs, thousands of green-energy jobs were created [13,14], and also saving countless lives from unprecedented nuclear energy disaster bearing in mind of what happened during the Fukushima energy disaster in Japan in 2011. Available statistics have shown that to attain a sustainable height of renewable energy leadership in the world, Germany projected the need to have 80% of renewable energy generation by 2050. With this requirement, the country proceeds to install larger quantities of solar photovoltaic (PV) power. According to Climate Progress [9], Germany has installed considerable solar power capacity per capita more than any country in the world. With 7.6 GW in 2012, which is higher when compared with what countries like the U.S., Japan and China produced in that period. Although there was a record of PV energy decline to 3.3 GW in 2013 in Germany. Notwithstanding that the wind power energy was said to reach a significant record of 25.2 GW and this accounted for 39% of the electricity supply on a single day in December in Germany. The unprecedented growth of solar PV and wind power energy in Germany is said to have been fueled in large part by policies that incentivize clean energy.

Moreover, Germany being the front runner in the EU aims at ensuring a significant decrease in greenhouse gas emissions and climate change mitigation, as promulgated in the recent clean energy meeting by the European Union [2,15]. This development was entitled the 20/20/20 vision. The vision, suggests that (i) a 20% savings in energy consumption from fossil fuel, and (ii) attaining 20% generation of energy from renewable sources of energy and finally (iii) a 20% decrease in greenhouse gas emissions compared to 1990 levels and this according to the vision is to be achieved in 2020. Having regard to the foregoing development and considering the key economic issues facing Germany in the contemporal millennium, this study uncovered a significant research gaps left by Büsgen and Dürrschmid [16]; Schill [17]; Monstadt and Scheiner [18], Pegels and Lütkenhorst [19], Ucan *et al.* [1], Stigka *et al.* [20], and Rafindadi [2]. In those studies, the authors failed to establish empirically the consolidating and comparative economic impacts of renewable energy on the economic growth prospects of the countries under survey. In addition to that, a number of researches have failed to establish the economic indicators accruable from the means of going purely green in energy generation. It is in the light of this foresight that this study aims to uncover the comparative impacts of renewable energy, capital, and labor to the GDP growth prospects of Germany. It is imperative to note that, this study focus more on Germany considering its global leadership in the field of renewable energy consumption. Also, Germany as the leading country in renewable energy consumption in the world was reported to have faced key economic hurdles. These range of hurdles made the German economy to contract by about 0.1%. The escalation of this situation was saved by the rising forces of household consumption and exports which again saw the rebounding of the economy to the same figure of 0.1% in the same year of 2014. Also this development was seen as a better position compared to the 2009 German economic contraction of −3.70% [21].

In this respect, this study tries to uncover if renewable energy is of any economic importance to the German economic growth prospects. The study ensures this by providing key statistical indicators which will delineate to policy makers on what could a 1% increase in renewable energy consumption in Germany cause to the GDP of the country.

Specifically, the main contributions of this study are:

- Considering the mere theoretical assertion established by the past studies of Büsgen and Dürrschmid [16]; Schill [17]; Monstadt and Scheiner [18], Pegels and Lütkenhorst [19], Ucan et al. [1], Stigka et al. [20], and Rafindadi [2] which only relied on the determination of the causal relationship between variables, this study contributes to the extent literature by investigating and providing empirically the statistical indicators relating to the comparative contributions of renewable energy, capital and labor in enhancing the economic growth prospects of the German economy. The policy implications with respect to renewable market failure and the remedies to that effect are also provided in this study. This study selects Germany as the case study considering the height of renewable energy it has attained in the world. In addition, it is expected that the empirical findings obtained from this study will provide convincing policy guides to other European and non-European nationalities on the impacts of adopting renewable energy system. With this development, the study hopes that the contributions provided will lead to continental departure from brown energy economy to a more feasible, reliable, secured and sustainable green energy economy for green growth.
- To ensure robust result, quarterly time series data was used in this study. In addition, the study employed the most up to date econometric methodology which consist of the Clemente-Montanes-Reyes detrended structural break test, the Bayer-Hanck combined cointegration test and the ARDL bounds testing approach to cointegration that accommodates the dynamics of structural breaks. Furthermore, the causality analysis was observed using the VECM Granger causality framework. These models were rarely used in most studies of renewable energy.

2. Empirical review

Zhang [22] argued that the investigation in to the nexus between energy consumption and economic growth is a critical area of investigation in the subject matter of energy economics and policy issues. The author established that in the past years Russia was known to be the third largest energy consumer in the world. The author applied the state space model as his methodology. The discovery of this study established the existence of cointegration relationship between the Russian energy consumption and the country's economic growth. To uncover the underlying factors behind the contribution of energy consumption and sustainable economic growth in Russia, the study discovered the Russia's energy efficiency, the level of industrial development, energy structural adjustment and technological progress as the greatest factors to the success attained. In another related development which compliments Zhang [22], Mahmoodi and Mahmoodi [23] studied the existing relationship between renewable energy consumption and income growth. The authors used a panel of 7 Asian countries which include India, Pakistan, Syria, Bangladesh, Jordon, Iran and Sri Lanka from 1985 to 2007. The results of their investigations revealed the existence of unidirectional causality in India, Pakistan, Syria and Iran. In contrast to the earlier development, bidirectional casualty was discovered with respect to Bangladesh and Jordan and no causality was found in the case of Sri Lanka.

Apergis and Payne [24] examined the relationship between renewable energy and output for a panel of 6 Central American countries from 1980 to 2006. The authors' findings established the existence of bidirectional causality between renewable energy and economic growth in both the short-run and the long-run. In another related development, which extends far more than the determination of causality as in the case to the three earlier studies above, Magnani and Vaona [25] tried to determine the existence of any possible relationship that may subsist between renewable energy and economic growth using some regional economies in Italy. The authors used time series data from 1997 to 2007. The findings of the study pointed out that renewable energy generation in the studied regions have significant impacts in lessening the already existing balance-of-payments constraints. According to the authors, this was traced to be as a result of the significant reduction in regional economic vulnerability to the volatility in fossil fuel price. In a similar related development, the study further discovered a significant reduction in environmental issues which enhanced the well-being and quality of life of the populace in the studied regions.

The study of Apergis and Payne [26] was another land mark in the field of renewable energy studies. In that investigation the authors used panel data for 80 countries. The study aimed at examining the relationship that may exist between renewable and non-renewable energy consumption, real gross fixed capital formation, the labor force and real GDP. The findings revealed the existence of feedback hypothesis, and this was found to validate the existence of bidirectional causality between renewable and non-renewable energy consumption and economic growth. Tugcu et al. [27] have also established another landmark which complements the findings of Apergis and Payne [26]. Tugcu et al. [27] studied the relationship between renewable and non-renewable energy consumption and economic growth for 154 countries. The authors obtain robust results applied the classical and augmented production function in a multivariate framework as their methodology. The findings show that both renewable and non-renewable energy consumption matters for economic growth. However, the study portrayed the superiorities of the augmented production function in explaining the direction of the relationships. Kazar and Kazar [28] studied how electricity productions from renewable sources could aid in economic development instead of economic growth for 154 countries. The result from this research established that in the long-run economic development leads to renewable energy production, and bidirectional relationship was found to exist only in the short-run. In a close analysis to these findings, the study discovered the existence of key variations with respect to individual countries on the basis that, it is the level of human development level that necessitate the urge for renewable energy prospects. Menegaki and Ozturk [29] analysed the relationship between energy and economic growth under political and economic perspective. According to the findings established by the study, bidirectional causality (feedback hypothesis) was found between economic growth and political stability, as well as capital and political stability. The authors emphasised that an economy's political prospects should not be ignored when looking at the relationship between energy consumption and economic growth particularly among individual continents.

Ucan et al. [1] conducted a study that analysed the causal relationship between renewable and non-renewable energy consumption and economic growth. The authors used panel of 15 European countries from 1990 to 2011. The findings indicate that an increase in renewable energy consumption leads to an increase in real GDP, and there is a positive relationship between greenhouse gas emissions and real GDP. Non-renewable energy consumption was found to have a negative impact on the real GDP of those continents. The findings of the study further established that when non-renewable energy was separated from the overall study, the direction of the research findings varied, and in this new development, the study discovered solid fuels to exhibit a negative impact on real GDP. In addition to that, petroleum energy consumption was found to have positive impact on real GDP. From the foregoing analysis, the authors conclude that solid fuels consumption does not lead to economic growth while total petroleum was found to cause economic growth but with attendant increase in CO_2 emission. In a finding with the study of Ucan et al. [1], and while using time series data Shaaban and Petinrin [30] presented his findings on the impacts of renewable energy potentials in Nigeria, the results of their study indicated that decentralized renewable energy resources not only improve the well-being of rural Nigerian communities, but also enhance Nigeria's energy and economic prospects which herald to potential global investment.

Schill [17] examined the effects of increasing amounts of fluctuating renewable energy on residual load, which is defined as the difference between actual power demand and the feed-in of non-dispatchable and inflexible generators. Schill [17] draws on policy-relevant scenarios for Germany and make use of extensive sensitivity analyses. Monstadt and Scheiner [18], using the cases on renewable energy policy and emission trading, analyze the subnational interests and institutional mechanisms that shape the intergovernmental negotiations and policy outcomes within the federated system. The cases confirm assumptions made by general research on German federalism, according to which strategies for the externalization and compensation of costs are of particular importance for redistributive policies, and the EU plays a major role in dissolving potential barriers to the process of federal policy formation. Pegels and Lütkenhorst [19] address the challenge of Germany's energy transition (*Energiewende*) as the centerpiece of the country's green industrial policy. They aim to provide an up-to-date assessment of what has become a fierce controversy by comparing solar photovoltaic (PV) and wind energy along five policy objectives: (1) competitiveness, (2) innovation, (3) job creation, (4) climate change mitigation, and (5) cost. They find mixed evidence that Germany reaches its green industrial policy aims at reasonable costs. Wind energy seems to perform better against all policy objectives, while the solar PV sector has come under intense pressure from international competition. Stigka et al. [20] present a literature review addressing the public acceptance of renewable energy as a replacement for fossil fuels in electricity production. This review was motivated by the global tendency for a substitution of conventional fuels by renewable energy sources (RES) during the global financial crisis. It studies research on the preferences and attitudes of local communities towards investments in renewable energy projects and their perception of the use of new energy technologies in their daily lives, through various case studies worldwide.

Shifting from the ordinary determinations of causal relationships between renewable energy and economic growth, Cochran [31] on his part commissioned a study on meta-analysis of several recent empirical studies. In his new development, the author aims to evaluate the implications of high level of renewable sources of electricity (RES-E) consumption in power systems. The findings of the author establish that renewable energy resources are a veritable mechanism that has the unique features of providing an enduring energy supply for sustainable future power systems. In contrast to the findings of Cochran [31], Spiecker and Weber [32] noted that despite the essentiality of renewable energy system, yet, the on-going transformation of the European energy with renewable sources of energy could be besieged by key notable challenges, among these are the likely possibilities of intermittent renewable energy generation sources such as wind and solar which could be precarious on the basis of the European ecological conditions. The authors further maintained a striking oblivion with respect to how true is it likely that CO_2 emission reduction can be reached in the future and what the future power system will look like is equally not clear in practice. Finn and Fitzpatrick [33] maintain that the installed capacity of wind renewable energy generation in Ireland is expected to have a significant increase in power generation to the tune of 40% by 2020. However, the authors lamented the possibility of reaching that target considering the turbulent conditions of wind frequency in generating the required level of energy towards the satisfaction of existing demand and for attaining the envisaged target. Following to this development and in order to find an accurate solution, the authors in their study analysed the price-based demand response of existing industrial consumer in proportion to their requirements of wind electricity generation prospects. The study aim at determining if there may be any likely possibility of these major consumers to shift their demand towards low price energy consumption in peak and non-peak periods. The findings of the authors reveal that while a reduction in the price of wind electricity consumption in peak periods has insignificant impact. However it was discovered that the propensity of wind electricity demand is elastic when prices continue to fall and this was found to have a significant increase in demand by about 5.8% for every 10% saved on the consumer's average unit price of electricity.

Creutzig et al. [34] pointed out that it is high time for the world to understand that, the likely threats that changing climatic condition could pose to the global ecosystem. In addition to that, these threats emanating from the global ecosystem will continue to degrade human value and welfare. Following to this, the authors opined that the use of fossil fuel needs to be eliminated in the current millennium by wide use of renewable energies. The authors in their theoretical research wisdom advocated for the wide use of renewable energy in Europe. According to them, this will have a significant economic stimulus. In addition to that, it will help greatly in decreasing trade deficits and the generation of significant employment. The authors continue to establish that in trying to ensure the operationalisation of renewable energy prospects a stronger European coordinated effort in terms of efficient regulatory frameworks, coordinated investment efforts need to be established through supportive funding schemes. This development will have the potentials of leveraging-out country-specific weakness and other poor planning prospects. In their opinion, this can reduce the repercussions established in the findings reported by Kazar and Kazar [28] and Menegaki and Ozturk [29].

The study of Jenssen [35] on the other hand**,** lamented that a 100% energy supply based on biomass is technically possible. However, the possibilities of the costs involved and the land use for generating this mode of energy is of vital concern. Yildiz [36] provided key solutions to the financing prospects of renewable prospects in Germany as found in the study of Jenssen [35]. The author reported that decentralizing the financing prospects of renewable energy infrastructures in Germany is a complex issue. This is due to the fact that public authorities lack the needed capital to handle these projects. In addition to that, institutional investors are risk averse. This is when considering the huge investment costs involved and the long period it takes for a return on investment. Following to this, the author identified the term “financial citizenship participation” as a key alternative investment plan. According to him, instead of a single individual to handle a single or group of project, however, group of interested private individuals could come together and collectively share fortunes and risks if any in both the long-run and the short-run using varied business models and arrangements. Advancing the major gains accruable for this participatory plan is found in the study of Yildiz [36], Shafiei and Salim [37], in their contributions**,** and while applying the STIRPAT model in their study for the OECD countries. The authors established that renewable energy increases the welfare and health prospects of a community by lessening the impacts of CO_2 emissions. This will in turn reduce health cost and prolong life expectancy as against non-renewable energy that was found to increase significantly the rate of CO_2 emissions particularly in a closed community.

Strunz [38] on his part studied the overall German concept of *Energiewende*. This study aims to overhaul the likely problems of this transition programme. The key findings of the author established the need for cohesive commitment, and formidable efforts that will ensure viable, comprehensive and unfailing energy transmission grid. The author, opined on the need to cover Germany as a whole if the concept of *Energiewende*, is to realise its intent and purpose. The reasons foresighted by the study of Strunz [38] can be seen in the study of Ketterer [39]. In that study, the author investigated the existing relationship between intermittent wind power generation and its likely consequences to the overall electricity price behaviour in Germany. In his study, the author applied the GARCH framework. The findings of the study established that volatile wind power supply has dramatic effects on price which in turn affect profitability and thereby, heralding the consequence of unsystematic risk factors. In this respect, the author noted for the need of resilient, concerted and articulated policies and regulatory frameworks that will shape the wholesale price of renewable energy in Germany. In addition, there should be the need to ensure a secured and stable renewable energy supply if the committed investment in the sector is to be gainful. He further argued for the need to overhaul the renewable energy marketing mechanisms in Germany.

Schaffer and Bernauer [40] pointed out on the key developmental prospects attained by the industrialised countries in renewable energy supply in Germany. Following to this, the authors focused their study on the policy dynamics that drive the international market determinants of renewable energy in these continents. Their findings while using a panel of 26 countries established how three key factors play significant role in shaping the marketability, viability and acceptability of renewable energy products in Europe. According to them, this shapes the consolidative economic gains of the continents. The findings of the study further establish how these factors**:** (i) the current quality**,** features and the efficiency of renewable energy products over and above the old existing energy once. (ii) the political system and its commitment towards this mode of energy (iii) EU membership and their energy goals particularly towards alleviating CO_2 emission and the dangers of nuclear energy. The authors argued that renewable energy is a strong and foremost the most viable energy resource that not only fuel economic growth, but is also a factor that reduces political bottlenecks in terms of public welfare enhancement among others.

Gullberg et al. [41] while complementing the findings established by Schaffer and Bernauer [40] undertook a broader study on the theoretical relevance of renewable energy. The authors investigated the economic, political, environmental and technological factors that act as success and impediments to renewable energy actualisation between Germany and Norway. They argued that German actors see Norwegian electricity as a means for enhancing the stability of their electricity system, particularly as Germany is shifting to a greater reliance on renewable energy. Following to this, it is expected for Germany as the market leader to provide favourable energy alliance with the local Norwegian investors. With respect to this development, the Norwegian energy-intensive industries and consumers were found to be sceptical on the possibilities of possible rise in renewable energy prices as the main impediment of the alliance. In another related study which aims at pointing out the complications of the German-Norwegian renewable energy alliance was found in the study of Lupp et al. [42]. The authors in their research cautioned on the demise of renewable energy market between operators. In their submission, the authors establish that the increased cultivation of energy crops used in generating renewable energy in Germany can lead to severe negative impacts to the ecosystem services (ES). As a result of this development, they maintain the view point that there is the necessity for a better regulation with respect to bioenergy production in Germany. They continue to analyze the possible implications of an increased biomass production on the German Ecosystem. With this development, the degeneration of the German renewable energy source was thought to be having futuristic consequence to the renewable energy market as a whole.

Ackah and Kizys [43] underscored the need for renewable energy as a means of veritable energy security and accessibility by the urban and rural communities, and a means of combating climate change in the oil producing African continents. The authors continued to establish that these African continents are naturally blessed with abundant but highly untapped renewable energy sources. To provide key policy guides and investment prospects, the authors while using three panel data models applied the random effect model, the fixed effects model and the dynamic panel data model as their methodology. The aim of the study is to uncover what could be the drivers of renewable energy demand in the selected continents. The findings of the study established the points that, for renewable energy to thrive, real income per capita, energy resource depletion per capita, carbon emissions per capita and energy prices must be optimally efficient. To ensure the attainment of this, policy guides must be established towards a careful encouragement of commercial sources of renewable energy consumption that should be efficient enough to attract crucial investment in the sector. In another study which provided sufficient guide to the studies of Gullberg et al. [41]; Schaffer and Bernauer [40]; Lupp et al. [42], and Ackah and Kizys [43] was found in the study of Abdmouleh et al. [44]. Abdmouleh et al. [44] provided key guidelines on how to avoid renewable energy projects failure and market failure as well. To ensure this, they pointed out for the need of sound regulatory framework that requires the establishment of the interplay and those mechanisms that will encourage renewable energy production the world over. In addition to that, they pointed out that, the regulatory framework should be fashioned to capture the heterogeneous nature of continental renewable energy sources, financial, fiscal, legislative, political, technological and environmental differences.

Wesseh and Lin [45] maintained that the significant and indispensable need for energy usage world over cannot be over emphasised. The authors continue to argue that energy is a quintessential source of economic growth and development. However, the dominant use of fossil fuels in energy generation in Africa and its implications to the economic and environmental degradation needs careful attention. To reduce the level of this repercussion, the authors foresaw the need for renewable energy technology as the remedy. According to them, this has become necessary due to the high level of uncertainties that exist in the non-renewable energy price and the flexibility over timing. The findings of study established the need for renewable energy technologies that should be economically attractive and that the cost in the generation of this type of energy should be internalized. Apart from that the study was able to provide key comparative advantages when renewable energy replaced non-renewable energy system in Liberia. According to this development the study established that renewable energy in Liberia can optimally reduce carbon emissions by 13.9% in 2015 when compared to what existed in 2008. Studying the varieties of renewable energy technology and process, Ghaffour et al. [46] in their keen observations regarding the high energy consumption when using the conventional desalination technologies in the provision of renewable energy, offered some hope in solving that problem. In reference to that, they argued for the need of integrated approach in using renewable energy production. This is in the sense that strong reliance on solar and geothermal desalination technologies should be given priority. In addition to that Innovation and creativity should be made supreme in ensuring sustainable desalination processes. This development according to them should focus more on integrated renewable energy systems that provide the greatest technological and economic benefit while their limitations should be studied.

Li et al. [47] on their contributions developed a focus on the implications of global warming and how to curtail greenhouse gas emission. To ensure this, varieties of technological innovation mechanism were used in order to device appropriate and optimal means of curtailing greenhouse gas emission and promote the global usage of renewable energy utilisation. Following to this ambitious development, the authors emphasised on the need for the wide use and integration of technologies that will help in carbon capture and efficient renewable energy storage (CCS). In addition to that a substantial integration of wind and solar energy source in to continental renewable energy system were seen as key alternative options. Along the line, the authors complimented the assertions established by Ghaffour et al. [46] by highlighting the existence of enormous problems regarding the uncertainties in the output of renewable energy generation. They argued for the existence of large amount of curtailed electric energy (CEE), which means some of the renewable energy generation are wasted to keep real-time balance between load and generation of power. In the review paper presented by the authors, the modalities of capturing CO_2 emissions, and the mechanics of estimating worldwide CCE were provided.

Kalinci et al. [48] while in support of Li et al. [47] developed a hybrid renewable energy system using hydrogen energy as energy storage option. The mechanical and technical accuracy of establishing this storage system were devised mainly for the Bozcaada Island in Turkey. Two scenarios were considered in the study and these are wind turbine and wind turbine/PV hybrid systems. According to the authors, using the wind turbine/PV array system, as against using wind turbine only, is found to have a significant effect of reducing the net present cost (NPC) from $14,624,343 to $11,960,698. In addition, there is the possibilities of a significant decrease in the hydrogen tank capacity to 400 kg this will in turn affects the sizes of vital supply equipment and the NPC. In this respect the cost of energy (COE) will vary between $1.016/kWh and $0.83/kWh. According to the findings of the study, the mechanism of increasing the potential of renewable energy generation, such as annual average wind speed or solar radiation absolutely depends on the relative increases or decrease of either the COE or the NPC. For instance if the annual average solar radiation increases to 5 kWh/m^2/d, the NPC and *COE will* decrease to $11,673,704 and $0.81/kWh respectively. Additional findings of the study discovered that an increase in the annual average wind speed will decrease the costs to $11,452,712 and $0.795/kWh, respectively. Also, increasing the real interest rate i, to 5% will lead to an increase in the COE by about $1.043/kWh, as discovered by study.

Apart from the above review, researchers that established the existence of causality and/or bidirectional causality with respect to renewable energy consumption and economic growth include Sari et al. [49]; Apergis and Payne [24]; and more recently Komal and Abbas [50]; Radomes and Arango [51]; Tigas et al. [52]**;** Kaplan [53]**;** Zhang et al. [54]; Zhang and Da [55]; Ben Jebli et al. [56]; Bhattacharya et al. [57]. In a similar direction, Sari et al. [49] studied the two-way linkages between renewable energy consumption and industrial output using ARDL approach in the USA their study established the existence of the conservation hypothesis. In the case of panel studies, different authors like Apergis and Payne [24]; Omri and Chaibi [58]: Woo et al. [59]; Inglesi-Lotz [60] applied different econometric methodologies and were able to obtain varied results. For instance, Woo et al. (2015) tried to identify the environmental relevance of renewable energy in 31 OECD countries while Apergis and Payne [24] identified the existence of feedback hypothesis in six Central American continents they studied. In similar research efforts, Inglesi-Lotz [60] establish how the influence of renewable energy system led to positive and significant contributions to economic growth in the studied areas.

Fig. 1 indicates how green energy consumption help in ensuring green economy for sustainable development. While Fig. 2 shows the trends in new capacity of renewable energy installed annually for electricity generation in Germany for the periods of 2000–2020 and 2030. In Fig. 3, the trends in electricity generation from renewable energies for the period 2000–2030 is also presented in that figure.

3. Data and methodological framework

The prime objective of this paper is to examine the consolidating

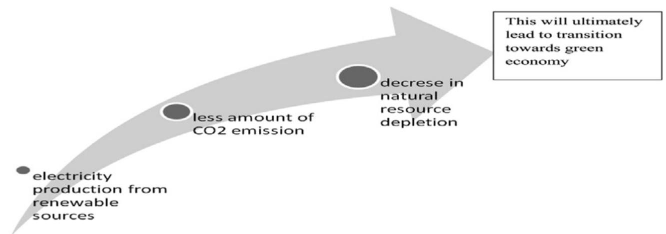

Fig. 1. Green economy for sustainable development.
Source: Zeb et al. [61]

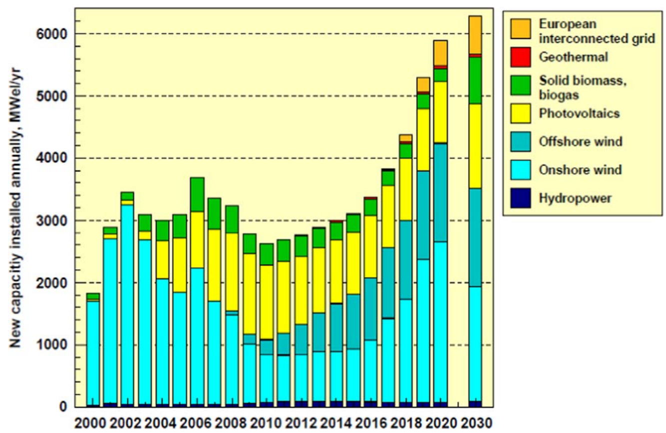

Fig. 2. shows the Trends in new capacity installed annually for electricity generation from renewable energies for the period 2000–2020 and 2030.
Sources: Büsgen and Dürrschmidt [16]

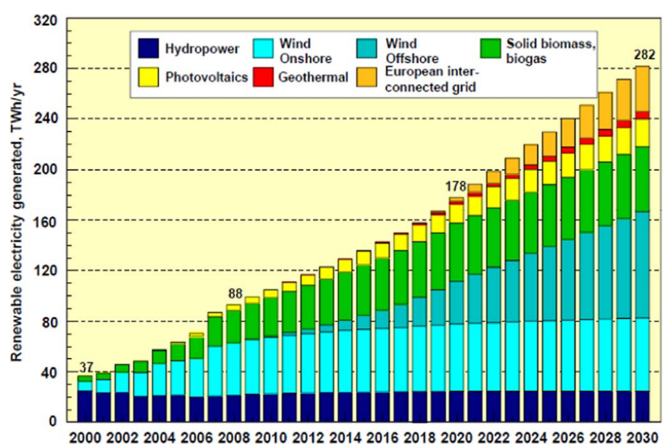

Fig. 3. Trends in electricity generation from renewable energies 2000–2030.
Sources: Büsgen and Dürrschmidt [16]

impacts of renewable energy on the economic growth prospects of a country when it operates renewable energy system in its energy mix. To ensure this, the study used Germany as the case study and incorporates capital and labor in energy demand function. The time span of the present study is 1970QI-2013QIV. The functional form of energy demand function is given as following:

$$Y_t = f(RE_t \times K_t \times L_t) \tag{1}$$

The series were transformed into logarithms and the model is developed as follows:

$$\ln Y_t = \beta_1 + \beta_2 \ln RE_t + \beta_3 \ln K_t + \beta_4 \ln L_t + \mu_i \tag{2}$$

where, $\ln Y$ is natural log of real GDP per capita proxy for economic growth,$\ln RE$ is natural log of renewable energy consumption per capita, $\ln K$ is natural log of real capital per capita and $\ln L$is natural log of labor force per capita. Theμ is residual term. With respect to this development, the study proceeds to apply Pesaran et al. [62] ARDL bounds testing approach. A number of advantages exist with this approach that can be compared to the Johansen cointegration techniques [63]. In the first instance, a smaller sample size is required to compare it with the Johansen cointegration technique [64]. See also Rafindadi [86,87,82,84].Secondly, the ARDL bounds testing approach does not require the variables to be integrated at the same order. The ARDL approach can be applied whether the variables are purely I(0) or I(1), or mutually integrated. In order to implement the ARDL bounds testing approach, Eq. (1) is transformed in to the unconditional error correction model (UECM) and this model is indicated below:

$$\Delta \ln Y_t = c_0 + \sum_{i=1}^{p} c_i \Delta \ln Y_{t-i} + \sum_{i=1}^{p} d_i \Delta \ln RE_{t-i} + \sum_{i=1}^{p} d_i \Delta \ln K_{t-i} + \sum_{i=1}^{p} d_i \Delta \ln L_{t-i} + \pi_1 \ln Y_{t-1} + \pi_2 \ln RE_{t-1} + \pi_3 \ln K_{t-1} + \pi_4 \ln L_{t-1} + \pi_D DUM_t + u_t \tag{3}$$

$$\Delta \ln RE_t = c_0 + \sum_{i=1}^{p} c_i \Delta \ln Y_{t-i} + \sum_{i=1}^{p} d_i \Delta \ln RE_{t-i} + \sum_{i=1}^{p} d_i \Delta \ln K_{t-i} + \sum_{i=1}^{p} d_i \Delta \ln L_{t-i} + \pi_1 \ln Y_{t-1} + \pi_2 \ln RE_{t-1} + \pi_3 \ln K_{t-1} + \pi_4 \ln L_{t-1} + \pi_D DUM_t + u_t \tag{4}$$

$$\Delta \ln K_t = c_0 + \sum_{i=1}^{p} c_i \Delta \ln K_{t-i} + \sum_{i=1}^{p} d_i \Delta \ln Y_{t-i} + \sum_{i=1}^{p} d_i \Delta \ln RE_{t-i} + \sum_{i=1}^{p} d_i \Delta \ln L_{t-i} + \pi_1 \ln Y_{t-1} + \pi_2 \ln RE_{t-1} + \pi_3 \ln K_{t-1} + \pi_4 \ln L_{t-1} + \pi_D DUM_t + u_t \tag{5}$$

$$\Delta \ln L_t = c_0 + \sum_{i=1}^{p} c_i \Delta \ln L_{t-i} + \sum_{i=1}^{p} d_i \Delta \ln Y_{t-i} + \sum_{i=1}^{p} d_i \Delta \ln RE_{t-i} + \sum_{i=1}^{p} d_i \Delta \ln K_{t-i} + \pi_1 \ln Y_{t-1} + \pi_2 \ln RE_{t-1} + \pi_3 \ln K_{t-1} + \pi_4 \ln L_{t-1} + \pi_D DUM_t + u_t \tag{6}$$

Where Δ denotes the first different operator, the c_0 and d_0 are the drift components, DUM is dummy variable to capture the structural break date, p is the maximum lag length and u_t is the usual white noise residuals. The procedure of the ARDL bounds testing approach has two steps. The first step is the determination of the F-test for the joint significance of the lagged level variables. The null hypothesis for the non-existence of a long-run relation is denoted by H_0: $\pi_1 = \pi_2 = \pi_3 = \pi_4 = 0$ against H_a: $\pi_1 \neq \pi_2 \neq \pi_3 \neq \pi_4 \neq 0$. Pesaran et al. [62] generate lower and upper critical bounds for the F-test. The lower bound's critical values assume that all of the variables are I(0) while the upper bound's critical values assume that all of the variables are I(1). If the F-statistic exceeds the upper critical bound, then the null hypothesis of no cointegration among the variables can be rejected. If the F-statistic falls below the lower bound, then the null hypothesis of no long-run relation is accepted. The next step is the estimation of long-and-short run parameters by using the error correction model (ECM). To ensure the convergence of the dynamics to long-run equilibrium, the sign of the coefficient for the lagged error correction term (ECM_{t-1}) must be negative and statistically significant. Further, the diagnostic tests comprise the testing for the serial correlation, functional form, normality, and the heteroscedasticity [65]. Once the variables are cointegrated for the long-run relation, then long-run as well as short-run causality can be investigated Rafindadi [75,77].See also Rafindadi [82,83,84,85]. The existence of a long-run relation between the variables requires us to detect which direction the causality takes between the variables by applying the VECM (vector error correction method) and the Granger causality framework. The vector error correction method (VECM) is as follows:

$$\begin{bmatrix} \Delta \ln Y_t \\ \Delta \ln RE_t \\ \Delta \ln K_t \\ \Delta \ln L \end{bmatrix} = \begin{bmatrix} b_1 \\ b_2 \\ b_3 \\ b_4 \\ b_5 \end{bmatrix} + \begin{bmatrix} B_{11,1} & B_{12,1} & B_{13,1} & B_{14,1} \\ B_{21,1} & B_{22,1} & B_{23,1} & B_{24,1} \\ B_{31,1} & B_{32,1} & B_{33,1} & B_{34,1} \\ B_{41,1} & B_{42,1} & B_{43,1} & B_{44,1} \end{bmatrix} \times \begin{bmatrix} \Delta \ln Y_{t-1} \\ \Delta \ln RE_{t-1} \\ \Delta \ln K_{t-1} \\ \Delta \ln L_{t-1} \end{bmatrix}$$
$$+ \ldots + \begin{bmatrix} B_{11,m} & B_{12,m} & B_{13,m} & B_{14,m} \\ B_{21,m} & B_{22,m} & B_{23,m} & B_{24,m} \\ B_{31,m} & B_{32,m} & B_{33,m} & B_{34,m} \\ B_{41,m} & B_{42,m} & B_{43,m} & B_{44,m} \end{bmatrix} \times \begin{bmatrix} \Delta \ln Y_{t-1} \\ \Delta \ln RE_{t-1} \\ \Delta \ln K_{t-1} \\ \Delta \ln L_{t-1} \end{bmatrix}$$
$$+ \begin{bmatrix} \zeta_1 \\ \zeta_3 \\ \zeta_3 \\ \zeta_4 \end{bmatrix} \times (ECM_{t-1}) + \begin{bmatrix} \mu_{1t} \\ \mu_{2t} \\ \mu_{3t} \\ \mu_{4t} \end{bmatrix} \quad (7)$$

where TO_t refers to exports, imports and trade openness, the difference operator is $(1 - L)$ and the ECM_{t-1} is generated from long-run relation. The long-run causality is indicated by the significance of the coefficient for the ECM_{t-1} by using the t-test statistic. The F statistic for the first-differenced lagged independent variables is used to test the direction of short-run causality between the variables. The study used time series data from 1971 to 2013 for the case of Germany. The Quadratic match-sum method in E-views 7 is employed to convert annual frequency into quarterly frequency over the period of 1971Q1-2013Q4. These data was obtained from the World Development Indicators [66]. The data collected are on real GDP, renewable energy consumption, real capital stock and labor force. The study used population series to transform data into per capita terms. Fig. 4 is a graph showing the compositional development of renewable energy in Germany. The same Figure shows renewable electricity production in Germany in the range of Gwh/year, total: 136 Twh out of 22.9% of annual demand.

4. Empirical results and discussions

The prime step is to test the unit root properties of the variables to examine the cointegration relationship for the long-run relationship. To ensure this, the study applied Ng-Perron [67] unit root test in order to determine the unit root properties of the variables. The results of Ng-Perron unit root test are reported in Table 1. This shows that all the series are found to be non-stationary at level with intercept and trend, but at 1st difference, the null hypothesis of unit root problem was rejected. This indicates that all the variables are cointegrated at I(1) at 1% levels. This implies that the orders of the variables are I(1).

The problem with Ng-Perron unit root test is that these tests do not consider the information of structural breaks in the series. This problem will tend to provide ambiguous results. In order to avoid this type of problem, the study applied the Clemente-Montanes-Reyes [68] detrended structural break test with single and double unknown structural breaks in the series. The Clemente-Montanes-Reyes [68]

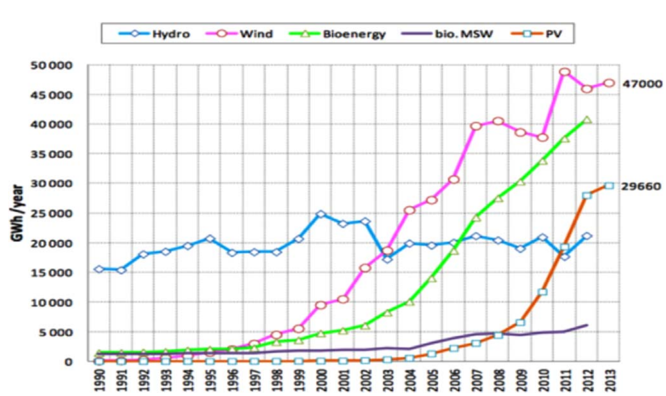

Fig. 4. The compositional development of renewable energy in Germany. Source: Climate Progress [9]

Table 1
Unit root analysis.

Variables	MZa	MZt	MSB	MPT
$\ln Y_t$	−3.0160 (3)	−1.1088	0.3676	27.2961
$\ln RE_t$	−7.1395 (3)	−1.8785	0.2631	12.7824
$\ln K_t$	−3.0700 (1)	−1.1207	0.3650	26.9071
$\ln L_t$	−0.3925 (5)	−0.2581	0.6577	88.3736
$\Delta \ln Y_t$	−62.828 (2)*	−5.5920	0.0890	1.5094
$\Delta \ln RE_t$	−36.5843 (3)*	−4.2618	0.1164	2.5746
$\Delta \ln K_t$	−36.7629 (4)*	−4.2873	0.1166	2.4790
$\Delta \ln L_t$	−88.3161 (5)*	−6.6447	0.0752	1.0334

Note:
* Indicates significacen at 1% level Lag length of variables is shown in small parentheses.

Table 2
Clemente-Montanes-Reyes detrended structural break unit root test.

Variable	Innovative Outliers			Additive Outlier		
	T-statistic	TB1	TB2	T-statistic	TB1	TB2
$\ln RE_t$	−2.336 (1)	1975QII	....	−5.158 (2)**	2008QII	....
	−2.538 (2)	1975QII	1987QIII	−5.701 (2)*	1984QII	2008QII
$\ln Y_t$	−1.175 (2)	1976QII	....	−5.717 (3)**	1977QII	....
	−3.318 (3)	1976QII	1991QII	−6.296 (1)*	1977QI	2003QII
$\ln K_t$	−4.271 (2)	1978QII	....	−5.771 (2)**	2008QII	....
	−3.750 (1)	1975QIV	1978QIV	−6.869 (1)*	1994QII	2008QII
$\ln L_t$	−0.094 (2)	1988QIII	....	−7.326 (2)*	1984QII	....
	−1.438 (1)	1988Q3	2008QII	−9.205 (3)*	1978QII	1984QII

* and ** Indicates significant at 1% and 5% significance levels respectively.

unit root test follows an additive outliers (AO) model to plug out sudden changes in the mean of the series as well as gradual change in the mean of the variables is tested by innovational outliers (IO) model. But, the additive outlier model is preferable for series having sudden structural deviations as compared to gradual shifts. Table 2 shows the results of Clemente-Montanes-Reyes [68] unit root test. See Rafindadi, 2016 and Rafindadi [2,3]; Rafindadi and Ozturk [4] and Rafindadi and Ozturk [5] for similar model application in recent studies. The results for present study show that in the presence of two structural breaks at level all the variables are non-stationary, and there is problem of unit root in the all the variables in the case of Germany. The structural breaks as found in this test are in the periods of 1975QII, 1976QII, 1978QII and 1988QIII in the series of renewable energy consumption, economic growth, capital and labor. The variables are found to be stationary at first difference. Similarly, in the presence of two structural breaks, all the variables of the model become stationary at first difference. In this respect the study concludes that the series are in the same order of integration and that is I(1).

To examine the existence of cointegration among the variables, the Bayer-Hanck [69] combined cointegration approach is used. The AIC criteria is used for lag selection and the maximum lag length is 6 (Table 3).

Numerous econometric methodologies that aim at providing an insight into the likely possibility of whether key economic variables have attained the required level of cointegration have been in existence for quite a long time. Notable among them are the Engle-Granger [80] residual-based cointegration test, the Johansen [63] system based cointegration test and, the Boswijik [79] and Banerjee et al. [78] cointegration test which has the lagged error correction based approaches to cointegration. In modern times, all these cointegration tests were found with key econometric weakness. For instance Pesavento [88] established that the potency of these tools to provide

Table 3
The lag order selection.

VAR Lag Order Selection Criteria						
Lag	LogL	LR	FPE	AIC	SC	HQ
0	1739.132	NA	1.26e−14	−20.6563	−20.5819	−20.6261
1	3420.653	3262.952	3.08e−23	−40.4839	−40.1120	−40.3330
2	3900.168	907.6535	1.24e−25	−46.0020	−45.3325	−45.7303
3	3908.267	14.9436	1.36e−25	−45.9079	−44.9410	−45.5155
4	3917.377	16.3769	1.48e−25	−45.8259	−44.5614	−45.3127
5	3970.105	92.2729	9.56e−26	−46.2631	−44.7011	−45.6292
6	4092.737	208.7663[a]	2.70e−26[a]	−47.5325[a]	−45.6730[a]	−46.7779[a]
7	4099.886	11.8312	3.01e−26	−47.4272	−45.2702	−46.5517
8	4103.763	6.2303	3.50e−26	−47.2828	−44.8283	−46.2867

LR: sequential modified LR test statistic (each test at 5% level).
FPE: Final prediction error.
AIC: Akaike information criterion.
SC: Schwarz information criterion.
HQ: Hannan-Quinn information criterion.
[a] Indicates lag order selected by the criterion.

Table 4
The results of Bayer and Hanck cointegration analysis.

Estimated Models	EG-JOH	EG-JOH-BO-BDM	Cointegration
$F_Y(Y/RE, K, L)$	20.250*	31769*	✓
$F_{RE}(RE/Y, K, L)$	25.231*	39.595*	✓
$F_K(K/Y, RE, L)$	21.497*	43.382*	✓
$F_L(L/Y, RE, K)$	8.445	13.878	X

Note:
* Represents significance at 1 per cent level. Critical values at 1% level are 15.845 (EG-JOH) and 30.774 (EG-JOH-BO-BDM) respectively.

robust outcome is limited due to their insensitivity to filter the infiltrating level of nuisance inherent in most time series data basically due to recurring cases of financial crises, currency collapse and other macroeconomic ups and downs which the other cointegrating test could not observe. In addition to that, the author further established that the possibility of obtaining uniform outcome among the mentioned cointegration tools is virtually difficult. According to him, while one cointegration test rejects the null hypothesis another may be bound to accept it, and this is not supposed to be in real economic sense. It is following to this shortcoming that Bayer and Hanck [69] developed a more parsimonious method that helps in eliminating the likely bias of the old existing estimators with respect to determining the cointegrating properties of time series data. The methodology of the Bayer and Hanck [69] cointegration test as applied in this study aim at providing efficient estimates by eliminating the undue multiple testing procedures that is the common problem with other cointegration methodologies. To ensure its robustness, the Bayer and Hanck, [69] when formulating their cointegrating model followed Fisher, [81] formula, and this is given below:

$$EG - JOH = -2[\ln(P_{EG}) + \ln(P_{JOH})] \tag{8}$$

$$EG - JOH - BO - BDM = -2[\ln(P_{EG}) + \ln(P_{JOH}) + \ln(P_{BO}) + \ln(P_{BDM})] \tag{9}$$

In determining the possibility of the existence of cointegration among respective variables, Engle-Granger [80]; Johansen [89]; Boswijik [79] and, Banerjee et al. [90] used the following notations as a key econometric guide: P_{EG}, P_{JOH}, P_{BO} and P_{BDM} respectively. However, in the case of the Bayer and Hanck [69] their cointegration test mechanism was guided by the Fisher statistic. In this respect, to establish whether cointegration exists between the variables the null hypothesis of no cointegration must be rejected, and this can be ascertained when the critical values generated by Bayer and Hanck analysis are found to be less than the estimated Fisher statistics and vice versa.

Table 4, on the other hand, illustrates the combined cointegration tests including the EG-JOH and EG-JOH-BO-BDM. The study found that Fisher-statistics for EG-JOH and EG-JOH-BO-BDM tests exceed the critical values at 1% level of significance as renewable energy consumption, economic growth and capital is used as the dependent variables. This rejects the null hypothesis of no cointegration among the variables. In this respect the study conclude that there is long-run relationship among renewable energy consumption, economic growth, capital and labor over the period of 1971QI-2013QIV for the case of Germany.

Bayer and Hanck [69] combine cointegration approach provides efficient empirical results but fails to accommodate structural breaks while investigating the cointegration between the variables. See Rafindadi [74,77] This issue is solved by applying the ARDL bounds testing approach to cointegration in the presence of structural breaks following Shahbaz et al. [70,71] and Rafindadi [74,76,77] The ARDL bounds test is sensitive to lag length selection. Following to this development, the study, used the AIC criteria to select the appropriate lag order of the variables in Table 3. With this development, it is supported by Lütkepohl [72] that the dynamic link between the series can be captured if appropriate lag length is chosen. The results of this analysis are reported in column-2, of Table 5. In line with this development, the study noted the use of the critical bounds as reported in the study of Narayan [73] for taking decision with respect to the existence of cointegration relationship among the variables or otherwise. The results of this empirical exercise indicated that the estimated F-statistic is greater than the upper bounds as economic growth (Y_t), renewable energy consumption (RE_t) and capital (K_t) is used as the dependent variables. It entails that there are 3 cointegrating vectors. This shows that the ARDL bounds testing analysis has confirmed the earlier discovery for the existence of cointegration relationship as in observed in the preceding analysis, meaning that there is long-run relationship among the series (See Table 5).

The study applied the Johansen cointegration approach to examine and validated the robustness of the long-run relationships as found in other approaches applied in this study, and the results are reported in Table 6. The results show that both the Max. Eigenvalue and Trace Statistics are significant. The null hypothesis of no cointegration is rejected, meaning that cointegrating vectors exist in the three models. This confirms the presence of long-run relationship between the variables. This finding indicates that our long-run results as discovered earlier are robust.

The long-run results are presented in Table 7 which shows that renewable energy consumption has positive impact on economic growth in Germany, and it is significant at 1% level. The study discovered that a 1% increase in renewable energy consumption boosts German economic growth by 0.2194%, keeping other things constant. The impact of capital on economic growth is positive, and it is statistically significant at 1% level. The results show that a 1% increase in physical capital, will lead to an increase in economic growth by 1.1320% if other things remain same. Labor was equally found to be positive, and it has significant impact on the German economic growth. By keeping other things constant, it was discovered in this study that a 0.5125% increase in economic growth is due to 1% increase in labor.

The results of the short-run analysis are reported in Table 7 (lower segment). The results show that renewable energy consumption has positive and insignificant impact on economic growth. Capital is positively and significantly linked with economic growth. The impact of labor on renewable energy consumption is positive, and it is statistically significant. The value of the ECM is negative and statistically significant. The estimate of the lagged ECM is −0.0091. This indicates that short-run deviations towards long-run would be corrected by 0.91% in renewable energy consumption function. The results of diagnostic tests indicate no evidence of heteroscedasticity,

Table 5
The results of ARDL cointegration test.

Bounds Testing to Cointegration				Diagnostic tests			
Estimated Models	Optimal lag length	Structural Break	F-statistics	χ^2_{NORMAL}	χ^2_{ARCH}	χ^2_{RESET}	χ^2_{SERIAL}
$F_Y(Y/RE, K, L)$	6, 6, 6, 6	1975QII	4.442**	0.4694	[1]: 1.2764	[1]: 2.1736	[1]: 1.6892
$F_{RE}(RE/Y, K, L)$	2, 2, 1, 1	1976QII	10.989*	0.2996	[1]: 0.0029	[2]: 0.0585	[2]: 1.6426
$F_K(K/Y, RE, L)$	2, 2, 3, 1	1978QII	6.638*	0.6715	[1]: 2.0572	[2]: 2.6298	[1]: 1.0757
$F_L(L/Y, RE, K)$	2, 3, 2, 2	1988QIII	3.400	0.2760	[1]: 0.2919	[2]: 0.1787	[2]: 4.3578
Significant level	Critical values (T=43)#						
	Lower bounds $I(0)$	Upper bounds $I(1)$					
1% level	3.60	4.90					
5% level	2.87	4.00					
10% level	2.53	3.59					

Note:The optimal lag length is determined by AIC. [] is the order of diagnostic tests.
* Indicates significance at 1% level.
** Indicates significance at 5% level.
\# Critical values are collected from Narayan [73].

Table 6
Results of Johansen cointegration test.

Hypothesis	Trace Statistic	Maximum Eigen Value
R=0	135.2921*	79.6709*
R≤1	55.6211*	25.3070**
R≤2	30.3140**	17.9631
R≤3	12.3508	12.3508

Note:
* Denotes the significant at 1% level of significance.
** Denotes the significant at 5% level of significance.

Table 7
Long and short runs results.

Dependent variable=ln Y_t				
Long Run Analysis				
Variables	Coefficient	Std. Error	t-Statistic	Prob.
Constant	−0.6147*	0.1597	−3.8474	0.0002
ln RE_t	0.2194*	0.0433	5.0601	0.0000
ln K_t	1.1320*	0.0263	43.025	0.0000
ln L_t	0.5125*	0.1741	2.9426	0.0037
Short-Run Analysis				
Variables	Coefficient	T-statistic	Coefficient	T-statistic
Constant	0.0008*	7.69E−05	11.3262	0.0000
Δ ln RE_t	0.0042	0.0165	0.2563	0.7980
Δ ln K_t	0.3740*	0.0367	10.1814	0.0000
Δ ln L_t	0.5393**	0.2239	2.4079	0.0172
ECM_{t-1}	−0.0091***	0.0049	−1.8491	0.0662
R^2	0.6905			
F-statistic	90.9167*			
D. W	1.7876			
Short Run Diagnostic Tests				
Test	F-statistic	Prob. Value		
$\chi^2 SERIAL$	0.9376	0.4941		
$\chi^2 ARCH$	2.5842	0.1098		
$\chi^2 WHITE$	2.8028	0.2614		
$\chi^2 REMSAY$	2.8878	0.1399		

* Indicates 1% level of significance.
** Indicates 5% level of significance.
*** Indicates 10% level of significance.

serial correlation, and ARCH problem. The value of Ramsey reset test shows that the functional form for the short-run models is well specified.

In determining the causal relationship between the variables, the study proceeds to apply the VECM Granger causality framework. This test will enable us to test the direction of causality among the variables of the model. The direction of the causal relationship between the variables is helpful in designing comprehensive renewable energy, capital and labor policies in Germany and this will greatly help in controlling energy demand towards consolidating the economic growth prospects of the country. The results are reported in Table 8. The findings show the results of long-run and short-run causality. In that analysis, the long-run results of the study discovered the existence of bidirectional causal effects between renewable energy consumption and economic growth for the case of Germany. In addition to that, the feedback effect is also found to exist between capital and renewable energy consumption, and same inference is drawn between capital and economic growth. The relationship between renewable energy consumption and capital is bidirectional. Labor was found to Granger cause renewable energy consumption, economic growth and capital. While, in the short-run, economic growth was found to Granger-cause capital and in return, capital Granger causes economic growth. The neutral effect is detected to exist between renewable energy consumption and economic growth. The study discovered that capital does not Granger causes renewable energy consumption and same is true from the opposite direction. The joint causality results confirm short-run and long-run causality findings.

5. Conclusion and policy implications

This paper investigated the consolidating economic gains in renewable energy consumption and how these could impact on the German economic growth prospects. To ensure this, the study incorporated capital and labor in augmented neoclassical production function. The time span of the study is from 1971QI to 2013QIV using data from the German economy. The study applied the traditional and structural break unit root tests in determining the integrating properties of the variables. The Bayer-Hanck combined cointegration test was applied to examine the relationship between the variables while the robustness of the long-run relationship was tested by applying the ARDL bounds testing approach to cointegration accommodating structural breaks in the series. The causal relationship between the variables was investigated using the VECM Granger causality framework. The findings of the study established that renewable energy consumption, economic growth, capital and labor are cointegrated in the long-run. Following to this development, the study further discovered that the consolidating gains of renewable energy consumption add to the German economic growth prospects. Capital stimulates economic growth. Labor was also found to have significant contributions to the German economic growth prospects.

The causality analysis, on the other hand, reveals the existence of

Table 8
The VECM Granger causality analysis.

Dependent Variable	Direction of Causality Short Run $\Delta \ln Y_{t-1}$	$\Delta \ln RE_{t-1}$	$\Delta \ln K_{t-1}$	$\Delta \ln L_{t-1}$	Long Run ECT_{t-1}	Joint Long-run and-Short Run Causality results $\Delta \ln Y_{t-1}, ECT_{t-1}$	$\Delta \ln RE_{t-1}, ECT_{t-1}$	$\Delta \ln K_{t-1}, ECT_{t-1}$	$\Delta \ln L_{t-1}, ECT_{t-1}$
$\Delta \ln Y_t$	....	0.0979 [0.9067]	12.0514* [0.0000]	0.7874 [0.4568]	−0.0074** [−1.9394]	....	4.3722** [0.0541]	35.1171* [0.0000]	4.5623** [0.0499]
$\Delta \ln RE_t$	0.0565 [0.9450]	....	0.1450 [0.8651]	1.0876 [0.3395]	−0.0984* [−3.519]	4.4394** [0.0183]	....	3.6179** [0.0145]	5.5928* [0.0041]
$\Delta \ln K_t$	6.9854* [0.0002]	0.0016 [0.9983]	....	1.7106 [0.1841]	−0.0333* [−4.2816]	56.5622* [0.0000]	6.2960* [0.0005]	....	6.7370* [0.0003]
$\Delta \ln L_t$	0.1339 [0.8747]	0.3314 [0.7184]	0.2401 [0.7868]	....	....	....	....	....	....

* Shows the significance at 1% level.
** Shows the significance at 5% level.

the feedback effect between renewable energy consumption and economic growth. The study also discovered how economic growth Granger causes capital and in resulting circumstances, capital was found to Granger-cause economic growth. The relationship between renewable energy consumption and capital is found to be bidirectional and same inference is drawn for capital and economic growth. Renewable energy consumption, economic growth and capital are Granger caused by labor. To support the direction of our findings, Table 7 shows that renewable energy consumption in Germany consolidates the country's economic growth prospects. In that relationship it was discovered that a 1% increase in renewable energy consumption boosts German economic growth by 0.2194%. In addition to that, a 1% increase in capital will lead to the rise in the German economic growth by 1.1320%. While a 0.5125% increase in economic growth is due to 1% increase in labor productivity.

The major implications of these research findings to the German renewable energy system relates to the issue of market failure of the renewable energy products, if this took place, the likely chances of dwindling the accrued consolidated economic gains from the renewable energy products will undoubtedly wither away. The issue of renewable energy market failure could arise as a result of the complications inherent in the poor application of green energy marketing mix strategies and uncoordinated green pricing programs which can arise as a result of misdirected green power marketing application mechanism. Apart from that, the public-goods notion which breeds the free-rider syndrome could yet be another source of concern that can dramatically inhibit the thriving of green energy marketing efforts in Germany thereby, derelicting the present and future economic gains from the renewable energy products as discovered in this study. As a result of these developments, state policies should be cautiously fashioned towards ameliorating the free-rider syndromes within the German renewable consumer markets and ensure efficient supply of renewable energy products to the market in line with the existing energy demand.

To ensure a greener success for continued renewable energy market consolidation, this study suggests the need for the development of strategic smaller, smarter, but integrated renewable energy marketing systems. This is because efficient market integration will lead to the rise of significant competitive efforts among markets that will in turn decelerate the overall cost of renewable power generation to both the suppliers and the consumers thus creating a synergistic balance among the two parties. This study is equally of the view that the renewable products integration process should be designed to encompass more efficient inclusion and utilisation of green energy marketing mix, which can be achieved through persistent green power marketing efforts. In addition to that customers' value prioritisation, cost benefits offering to individual consumers' and the assurance of continued customer service quality provision should be the key social marketing strategies to be applied. Equally important is the need for the adoption of innovative service differentiation by evaluating consumer knowledge on the basis of his wants and priorities. This should then be incorporated in the process of designing effective green marketing communication that will ensure market leadership with unique green product features that contain vital and wide arrays of environmental benefits and solutions which should at the same time be designed to respect consumers' values. Notwithstanding these points, what the customer requires in modern centuries with regards to green products is the credibility of the products features and its ability to maintain and provide psychological satisfaction. These strategies could as well be applied to capture not only the local market segments but should be designed in such a form that are in themselves qualified to capture international consumers on the basis of their high level credibility in terms of image and prestige of being identified as a user of the German green energy products. These points will also help in avoiding negative post purchase dissonance particularly with respect to the international consumers.

It is also necessary to emphasize that societal inclination towards renewable energy will depend on the sophistication, efficiencies and reliability of the technology, economics of usage and general acceptability within a given range of social networks. Following to this, a careful study on these factors commonly known as the green power consumerism requires concerted efforts in dealing with them and should be the focal points in the social and commercial marketing strategies and are strong candidates that if carefully applied could help in eliminating existing barriers to green power products. This study also emphasizes that in order to retain the consolidative economic gains from the renewable energy market in Germany, social marketing should be used as a prerequisite for all phases of the product's life-cycle as this is the best mechanism that can help avoid market failure of renewable energy products in Germany and elsewhere penetrated by these products in the globe. Following to this, the role of commercial marketing should not be ignored; however, it should be applied side by side with the social marketing effort. In our view, the need for social marketing with respect to renewable energy products will help in the possibilities of arousing consumer motivation towards product repurchase. This could be achieved by communicating to the consumer in such a nationalistic viewpoints and deliver the products through the monitoring of individual values and economic behaviours. To encourage the wide use of renewable energy products for consolidative economic gains the study emphasize that government policies should be directed in such a way that entities' that provide renewable energy in Germany should ensure full customers' satisfaction in line with their expectations, fair pricing, efficient and convincing information on the products, and the distribution mechanism should equally be directed with strict accuracy in all business areas.

It is expected that, this development will help greatly in avoiding market failure of individual and collective renewable energy product(s). At the international scene, renewable energy product marketing should be directed to the demographic need of the society with the assumption that consumers are paying for clean energy that ensures economics of resources, physical compatibility, technological sophistication, political progress, legal and socio-cultural relevance as well as the optimization of individual welfare through reductions in CO_2 emission, etc. These should be emphasised as the core advantages and distinguishing features of the German renewable energy at the international level. Moreover, these should be the core positioning aspects of the product in the eyes of the international consumer of the German renewable energy products. To ensure a sustainable success in this area, social marketing at the international level must also be integrated with commercial marketing in order to pave the way for significant product acceptability without jeopardizing any stage of the product's life-cycle. Finally, the study argues that the German motivational feed-in tariff (FIT) policy issue, which is now fading away should be treated with caution as this development, could be an opening to renewable energy supply and market derelictions. To avoid this fit fall, the study emphasize for a more overt policy options to be pursued with respect to efficient and effective renewable energy policy in Germany.

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