Review

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Posted Date: 4 August 2023

doi: 10.20944/preprints202308.0407.v1

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George Ekonomou and Angeliki N Menegaki *

Agricultural University of Athens
* Correspondence: amenegaki@aua.gr

Abstract: Climate change refers to a wide range of changes due to unstructured economic and human activities that impact the well-being status of all living and non-living things. Many adaptation and mitigation strategies focus on climate change solutions, at the center of which is the replacement of fossil fuels or other conventional energy sources with renewables. Mainly this is a contemporary issue for economies that seek ways to grow sustainably, such as developing countries. The purpose of the present study is to review how these renewable sources might have brought benefits for environmental improvement efforts within intense economic activities. Our effort targets the case of China since its efforts for transmission to a low-carbon country attract the world's research interest, given its significance in the global economic system. Mainly, this study's attempt is based on searching relevant literature for potential changes in limiting greenhouse and carbon dioxide emissions toward China's economic development status. The results of this study aim to become a valuable reference for further elaboration in light of climate change strategies with measurable outcomes in the growth process.

Keywords: emissions; renewable energy sources; economy; environment

1. Introduction

Naturally, economies need to use resources (e.g., natural, human, financial, technical) to become more extensive and competitive globally. In this growth process, in many cases, overconsumption and overexploitation of ecosystem services (e.g., supporting, provisioning, regulating, and cultural) guided by severe competition to become 'first in class' or 'global leaders' mainly in terms of Gross Domestic Product (GDP) levels drive market failure phenomena and negative externalities behind already existing or if not adverse this situation, potential environmental degradation. In purely economic sight, the market fails by creating more greenhouse gas emissions (GHGs) compared to the optimal level with social concerns (Nemet, 2013; Metcalf, 2009). Not to mention the dangers concerning the long-term perspective of disposable natural resources and the long-lasting potential of a nation's economy and human well-being. For instance, GHGs and carbon dioxide releases (CO2) share a large proportion of low air quality, contributing simultaneously to global warming phenomena and abnormal increases in global temperature. This primarily concerns using fossil fuels as the primary energy source to run the economy worldwide. This approach appears as an unpromising way toward sustainable development. Sustainable development must be the never-ending pursuit of each economy (developed or developing). Interestingly, optimizing the energy structure followed by an economy creates a valuable opportunity to achieve greater quality levels (Wang et al., 2018).

In this perspective, China can be a crucial reference, given its economic potential and role in the global economic system: the world's second-largest economy and a main energy consumer. Hence, it is more illustrative to debate the economic implications of renewables adopting China as a developing country example (He & Huang, 2022). According to the World Bank, China's high growth rates have led to economic, social, and environmental imbalances. Limiting these imbalances demands shifts in the economy's structure, including high to low carbon intensity. Moreover, in 2022, the country's GDP amounted to approximately 18.1 trillion U.S. dollars (Statista, 2023).

The present study aims to review if and how renewable energy sources have made a significant and positive impact on environmental quality levels in the case of China. We attempt to elaborate on the relevant literature based on an integrative review process which remains a dependable way of gathering, analyzing, and presenting previous studies for a specific research field, topic, or issue. This analysis is expected to reveal the energy and cost savings aspects under a broad set of advancements (e.g., technology) and actual market conditions (e.g., industry, production lines) questioning energy efficiency issues and the composition of the energy mix used or intended to use. This study concerns how renewables can or may enable a transition into a low-carbon economy, decarbonize energy use, and limit further environmental degradation.

Especially high-impact developing economies should reconsider, change and restructure that part of their applied or currently run economic activity to decrease GHGs and CO2 emissions and reduce energy resource depletion. GHG emissions are negative externalities hurting society's welfare (Simon, 2017). In 2021, China released 11.47 billion metric tons of CO2 emissions, indicating that this country is the world's largest polluter this year (Statista, 2021). Interestingly, Khan et al. (2019) concludes that emissions of GHGs have increased and comprise an impact experienced by energy used. Sustainable economic growth is a unique solution that drastically resolves issues connected with energy, climate, environment, and society at the interface with the economy (Menegaki & Tugcu, 2017). Supportively, Hoang & Wilson (2017) argue that it is highly fundamental to integrate energy efficiency measures into the growth system to control GHGs, whereas Menegaki & Tugcu (2018) state that energy-dependent economies should implement structural changes to increase efficiency toward energy consumption. Exploring the linkages between environmental quality levels and growth variables (e.g., at a macro level) can guide fiscal policies on CO2 emissions (Halkos & Paizanos, 2016). Consequently, research questions arise: What is the linkage between environmental quality and renewables? How does this relationship, if evidenced, progress the work to be done toward decarbonized developing economies? Thus, a research opportunity is present to comprehensively review the role of renewables in this effort for developing countries like China.

Strengthening our presence in renewable energy plans heads us to an energy future where carbon neutrality welcomes a broad repertoire of activities and business options without restricting the potential of that country's economy (e.g., China). Living and performing in a safe and healthy environment where economic activities, human well-being, and nature interrelate to form a system is essential since the system's performance controls our living status extensively (Ekonomou & Halkos, 2023).

The paper is structured as follows: Section 2 presents the methodology regarding the integrative review process; Section 3 describes the data process followed to receive from literature selected from previous studies; Section 4 presents the review; Section 5 discusses the main results; finally, Section 6 presents relevant recommendations, whereas Section 7 summarizes the conclusions.

2. Methodology

The present study aims to provide a thorough literature review concerning the role of renewables in the economic growth process and environmental quality especially applied to developing economies, particularly in China. To accomplish the purpose of the present study, we adopt the integrative review process as the most suitable option to receive meaningful and interpretable results.

When followed, an integrative review process concerns a wide range of research in literature strands (Bell et al., 2022). This approach has been developed to comprehensively review diverse studies with a clear purpose and detailed content. It accommodates studies under different research or conceptual schemes. For instance, it includes qualitative and quantitative, experimental or nonexperimental, empirical or theoretical, or mixed study designs for a given research issue or topic contrary to a systematic review process that mainly concerns empirical research. Another advantage that this process provides is that it considers discussion papers and opinion justifications, and policy documents, policy research, strategy analysis, and reports which are additional sources of valuable references, establishing a deeper understanding of the particular topic in question (Immonen et al., 2023; de Souza et al., 2010; Grove et al., 2013; Torraco, 2016). Notably, the adopted review process exceeds the potential to merely review the literature since it overcomes the traditional process of merely analyzing and synthesizing the current study results (Soares et al., 2014). One key point behind this approach is that the integrative review process covers mature research fields and new, developing, and emerging ones.

To increase the dependability and applicability of this study, the authors followed the five-step approach proposed by (Whittemore & Knafl, 2005) to increase evidence-based initiatives with workable and long-term practical implications. The five-step approach concerns the problem identification, the literature search, the data evaluation, the data analysis, and the presentation of findings. As a result, all types of retrievable methodologies, tools, and techniques adopted by researchers to address a particular issue in science can potentially be an output of the integrative review process, enriching current knowledge (Whittemore & Knafl, 2005).

Consequently, the main research question of this review study is: What are the impacts (e.g., environmental quality levels) and future challenges (e.g., limitations, restrictions) of renewables in China's growth process and the environment? We anticipate that our approach will shed light on this research question thoroughly.

Mainly, this study's research objectives of this review are to:

(i) Recognize and determine the role of renewables in China's bundles of sustainability levels

(ii) Based on the received results, provide recommendations for future research efforts with applicable practical implications

We anticipate that these results will enable readers to draw useful conclusions that can be further developed and deployed regarding a wide range of research issues that share a joint knowledge base. Additionally, we expect that obtained results from this integrative literature review can be integrated into relevant decision-making processes to advance efforts toward a better and clean environment within China's broad and high-impact economic system.

3. Data

The integrative review process draws on diverse research to address the topic of interest under a specific research question (Bell et al., 2023). To address such an issue, a comprehensive research process was adopted. This study's data extraction method draws on key search terms used in three widely recognized databases: SCOPUS, ScienceDirect, and MDPI. The literature review was additionally supported by exploring the Google search engine and Google Scholar data to find scholarly literature for inclusion in this study. After receiving the studies of interest, publications were screened for duplicates or minor relevance with the desired review field. Retrieved studies were excluded if the primary purpose was not consistent with the use of renewables in China. Then studies were evaluated on certain eligibility criteria. In turn, the Abstract was carefully reviewed. Then a decision was made about inclusion criteria. Practically, two main criteria for proceeding further with the review were considered. First, the precise study's aim. Second, well-developed and justified practical and theoretical implications on contribution to literature and literature enrichment. Moreover, one particular issue the authors considered was the novelty or pioneering use of methodologies (e.g., econometrics) tools or techniques to evidence the study's purpose. All selected studies were then read carefully and thoroughly. They were then categorized based on the research topic and purpose.

Only studies written in the English language were included. Only studies written in 2000 and beyond were selected for further elaboration. Selected studies should have been published after a blind peer review process in well-acknowledged academic Journals. The base year of 2000 was preferred since it highlights a turning point for broader access to internet technology and sources and a shift concerning using the internet for information (Lagan et al., 2006). Publications without 'suffering' a non-peer review process were omitted from this study.

The review process applied in this study encompassed a wide range of methodologies, materials, tools, and techniques adopted in research attempts from interdisciplinary viewpoints underlying the significance and multifaceted dimensions of the research topic in question. This integrative review process justified the diverse methods and study results variations. A wide-ranging analysis of the selected studies was implemented. The findings were compared with research on substantially similar or the same research topics, determining trends and tendencies in the reviewed literature. Then, the integration and outline of the noteworthy findings related to the thematic field of this study's review process was completed.

After completing the review process presented in the previous paragraphs of this section, the authors considered the selected studies based on the scientific topic of interest, such as studies that discussed the impacts of renewable issues on the economy (e.g., impact on growth variables) and the growth nexus discussion.

The present data extraction process constitutes a well-organized, detailed, and constructive process in obtaining each study's fundamentals, core points, and research findings. To become even more consistent with the integrative review process, both authors carefully double-checked the steps followed to overcome dysfunctions attributed to potential data entry mistakes and possible misunderstandings of notions, viewpoints, and methods of selected publications.

4. Renewables and low carbon perspectives in China

The literature recognizes the current worrying environmental situation (e.g., climate change impacts). In contrast, increased research interest in recent years has guided many countries to process measures to decrease negative externalities on the environment. China remains a leading reference example in this process.

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One of the environmental and energy policies targets is to transform a country's economy (e.g., China's economy) more eco-friendly. However, such an endeavor requires implementing solutions to fundamental challenges such as climate change, the scarcity of natural resources, the release of polluting gases, and unsustainable consumption and production. The energy transition concept is extensively accepted in the literature as a shift in the so-called 'energy paradigm,' replacing fossil fuels with renewable energy sources to widely decarbonize energy systems (Bompard et al., 2020). Lo (2014) states that China's renewable energy and energy efficiency (REEE) policies are connected with energy security, which is defined as "unimpeded access or no planned interruptions to sources of energy" (Chester, 2010, p.887). Supportively, a popular topic in literature is the issue of energy security in regard to fossil fuels since relevant extracted energy is becoming progressively depleted with limitless extraction and use (Song et al., 2022). Forecasts for China's renewable energy capacity reveal an expanded 67% (438 GW) to just over 1 TW in 2023, with growth spurred by government policy support to treat local air pollution and decarbonize the power mix. Moreover, solar PV amount to 58% of total renewables expansion, followed by wind, including offshore projects (120 GW), hydropower (47 GW), and bioenergy (14 GW). By 2023, non-hydro renewables account for 48% of China's 2 500 terawatt hours (TWh) of renewable generation. Renewable policies to reduce the cost of subsidies and curtailment strongly influence this year's forecast, especially for solar PV (IEA, 2018). Also, Shen & Low (2015) claim that subsidy plans concerning renewables lengthened wind and solar power scales and enhanced their deployment.

Figure 1 presents the contribution of renewables to energy consumption for China, the European Union, the United States, Brazil, and India from 2017 to 2023.

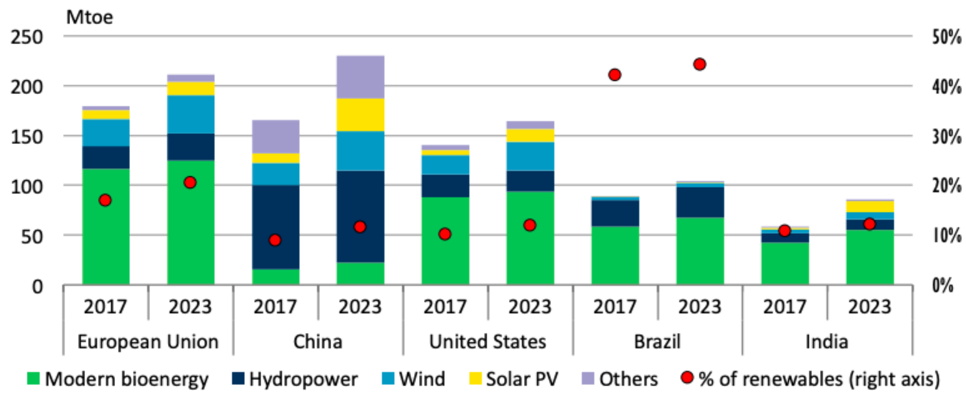

Figure 1. Contribution of renewables for various countries from 2017 to 2023. (Source: Renewables 2018: Analysis and Forecasts to 2023", International Energy Agency, 2018, *par Lauren Harry-Villain (EnvIM 2018)*).

Energy consumption is rising from approximately 5Gtoe in 1970 to almost 12Gtoe in 2010, with great contributions from China and USA (Aydin et al., 2016). One of the most appealing and interesting issues across academia concerns the replacement of fossil fuels with renewable energy sources. Zhang et al. (2018) claim that we should attach great importance to China's undeveloped potential regarding renewables. Technological innovations and lifestyle are anticipated to increase energy demand rapidly, whereas compared to traditional and conventional energy sources (e.g., fossil fuel use), renewable energy is a promising way to experience cleaner energy and future demand needs (Lee et al., 2023). This is widely acknowledged in relevant studies (Miremadi et al., 2019; Dogan et al., 2020; Zhu et al., 2020). Such an approach profoundly concerns the importance, contribution, and significance of financially supporting relevant high-impact research and development projects and establishing mature conditions for efficiently launching advanced technology in consumers and markets.

Annually, the mean amount of energy consumed worldwide is 24,430 TWh, indirectly contributing to 36.7 billion tons of carbon footprint generated merely by fossil fuels worldwide (Ritchie, 2023; Statista, 2023). Indicatively, as one of the world's high carbon emitters, China pledged to grasp a carbon peak by 2030 and seek carbon neutrality by 2060, whereas the building sector consumes 40% of the energy and releases 36% of the CO2 globally (Huo et al., 2022). Consequently, the accomplishment of China's carbon peak and carbon neutral commitments needs the replacement of conventional fuels and the integrating of new technology. The former widely concerns renewable energy sources in the energy mix, whereas the latter considers energy efficiency issues as major parts of mitigation (e.g., limiting CO2 emissions) and adaptation (e.g., future challenges) strategy. Duan et al. (2022) state that as a function of multiple determinants, the linkage between energy consumption and CO2 releases across China's provinces is not evidenced separately but appears to have a certain spatial relation. As a result, each province must accomplish its emission reduction task (e.g., variances in energy demand) considering the effect on and from the other provinces. In this effort, attention should be paid to the deep differences in the economic development and resource endowments across Chinese provinces resulting in spatial heterogeneity (e.g., building CO2 releases) (Huo et al., 2022). As indicated by Jie et al. (2021), according to the National Bureau of Statistics of China, the energy system is coal-dependent, namely coal covers approximately 69% of the primary energy supply and 59% of energy consumption in 2018. Table 1 presents China's expectations toward carbon-neutral conditions.

Table 1. Development situation anticipation of China's coal industry under the background of carbon neutrality (Source: Wang et al. 2021).

Main situation	2021–2030	2031–2050	2051–2060
Developing stage	Early Stage (Preparation)	Medium Stage (Competition)	Final stage (Completion)
Orientation statement	Major strategic window, namely 10-year preparation before carbon peak	Competing, cooperating, and coexisting with new energy in terms of technology, carbon sink, and proportion	Completion date of transformation development and carbon neutrality goals
Tendency for coal consumption	Entering platform stage	Continuing to drop but descending rate unquantified	Dropping to a stable level
Energy orientation	Foundational energy	Major energy	Alternative energy

Ecological processes control energy fluxes while energy generated from renewable sources is available without emitting damaging environmental components. According to the International Energy Agency (IEA), renewable energy is a form of energy that comes from nature and has its own sustainable mechanisms, replenishing faster than it is consumed. Furthermore, renewable energy sources are replenished again at the same rate as the utilization rate (Lei, 2022), whereas these sources depend on nature's ecosystem services (e.g., provisioning services) and location-specific characteristics (e.g., availability) (Chauhan & Saini, 2016). Despite the advantages of renewables over conventional energy (Saha et al., 2022), rigid China policies or effective energy-saving technologies to limit CO2 emitters (e.g., buildings) are absent (Pan et al., 2023).

The literature recognizes that on the supply side, fossil fuels have a large proportion, while difficulties of overcapacity need to be determined (Zhao et al., 2022). Notably, Xu (2021) mentions a 'paradox' of the energy revolution in China in the context of a socio-technical transition. The author argues that this paradox restricts renewable energy from challenging the domination of fossil fuels in energy in the short term. This 'paradox' is attributed to social and economic difficulties at the macro and meso levels rather than technological aspects at the micro level. Interestingly, Zou et al. (2016) and Jiang & O'Neill (2004) note that this energy revolution concern changes in production, consumption, technology, and management, whereas it includes shifts to renewable energy sources and relevant energy consumption structure toward a 'green' economy and a sustainable energy future (Du, 2015). Green technology, or green growth, and many relevant 'green-terms' deeply rely on renewable energy that are sustainable (Shahzad et al., 2022b).

In the work of Sun (2020), a direct reference to China's "13th Five-Year Plan (2016-2020)" is made. This plan concerned the development of a renewable energy plan with a clear target toward a clean and sustainable development style. The outcome reveals that significant progress has been made in China during this period. Ruhang et al. (2018) selected 77 references to shed light on cost and marketability issues regarding renewable energy after the power market reform in China. The authors concluded that China can provide a power structure targeted for production, dispatch, coordination, and demand with a specific goal of renewable energy penetration., mainly because of the non-independence of system operators, a surplus of thermal power, and market constraints. Interestingly, the authors stress the importance of viable mechanisms for proper cost allocations to overcome obstacles to launching renewables in the country's market (e.g., spot market, auxiliary service market). Moreover, Ming et al. (2013) highlight difficulties in advancing renewables without the supportive contribution of appropriate tariff policies (e.g., for development and utilization issues).

A wide range of publications discusses policy issues, law frameworks, and regulations to successfully develop renewable energy sources in the domestic market and reap environmental benefits (Lo, 2014; He et al., 2016; Liu, 2019). These policies, regulations, and frameworks should be adjusted and optimized on current growth patterns and environmental issues, given the climate change experienced so far. In particular, He et al. (2016) refer to a 'future evolution path' regarding renewables under the premise of three core principles: the principle of development, coordination, and innovation. Another interesting point is analyzed in this framework by Li et al. (2015). The authors refer to the curtailment of renewable energy sources by The National Development and Reform Commission (NDRC), which concerns grid connection expenses of renewable energy power generating projects. These approaches highlight that each policy should be practical and target a smooth transition from conventional energy sources to renewables. Figure 2 presents China's installed solar power capacity.

Notably, empirical research was processed to decode linkages and relationships between pollution indicators and growth variables. For instance, Haviour Chen et al. (2023) evidenced a unidirectional causality from 1990-2022, indicating that renewable energy contributes to decreased air pollution. On the contrary, the authors identified that non-renewable energy sources drive increases in air pollution. Moreover, Zhu et al. (2020) empirically explored the spatial pattern concerning air pollution in 31 Chinese provinces in regard to innovative technologies in renewables. Technology innovations in renewable energy were evidenced to reduce respirable suspended particles (PM10) and nitrogen oxides (NOx) concentrations. Another related empirical study concerning 30 Chinese provinces from 2001 to 2019 by Du et al. (2023) confirmed that green financing initiatives accelerate the transformation of China's energy industry toward increased shares of renewables in its overall fuel mix. Keeping the momentum active, Shabaz (2022b) investigated potential links between human capital, energy consumption, and economic variables concerning China between 1971 and 2018. Empirical results indicate that the linkage between economic growth, dirty energy usage, and clean energy usage is interdependent, suggesting a feedback causal relationship.

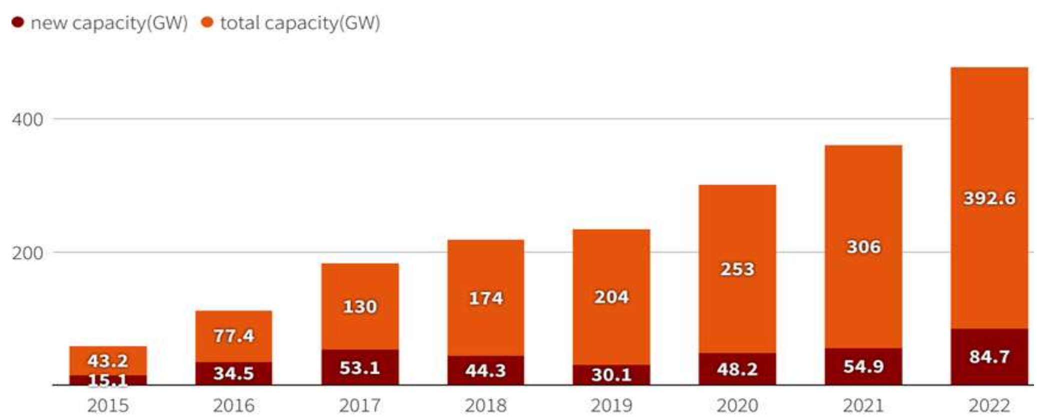

Figure 2. Solar power capacity in China (Source: China's National Energy Administration, Graphic derived from Reuters).

Uncertainties in forecasting energy demand and CO2 releases remain a central issue for further elaboration. For instance, energy savings and emission reduction measures depend on projections that should consider differences in social-economic parameters, technological advances, climate-changing behavior, and electrification pathways. This is especially a core issue given the geographic area of China, the population density, living standards, income levels, and residents' environmental mindset. Additionally, heating degree and cooling degree days (e.g., demand patterns) largely project future energy service needs in China's buildings in light of the main decarbonization process of the energy system. These issues are subjects for further consideration since renewables are not static but differ in time and space within the country. Hence, new 'renewable' concerns may arise as the literature becomes more detailed, and new approaches might appear. Appendix A presents selected studies concerning the relationships between renewable forms of energy, the economy related variables and the environment.

5. Results

Widespread in literature is the reality that the consumption of conventional energy (e.g., coal, petroleum, and natural gas) generates escalated and 'hard-to-fix' environmental pollution problems, whereas these types of energy sources are not abundant, like renewables. Therefore, the literature acknowledges the urgent need to increase efficiency by increasing the renewables percentage in the total energy mix (Chang et al. 2003). Achieving greater energy efficiency rates leads to limiting energy consumption, resulting in protecting the environment. This is an imperative issue in China; hence, energy-saving measures and release reduction are considered developing trends in the country (He et al., 2016). The literature emphasizes the importance of supportive and sufficient law frameworks for smoothly developing renewable energy sources (Liu, 2019). Both government and industries should align their efforts to support carbon neutrality and drive technological innovations (Haviour Chen et al., 2023). Furthermore, the literature recognizes that China has made serious efforts to formulate relevant laws for renewable energy; however, they lack the sufficiency to integrate renewable energy into the energy system nationally (Liu, 2019).

The fundamental issue of establishing an advantageous renewable energy system in China faces many challenges. Many are grounded in market development constraints (e.g., cost), regulatory frameworks (e.g., insufficiency of existing policies), and specific demand-use characteristics in the country's provinces.

Although the 'overwhelming' growth of renewable energy in China, many challenges need consideration, such as huge transition urgency and pressure, technology issues, and policy aspects (Zhao et al., 2022). Wind and solar power systems supported by relevant infrastructure seem promising and safe ways toward a low-carbon economy and consumption mindset, especially since China is a major producer and exporter of technology related to renewable energy (Liu, 2019). Supportively, Shen & Low (2015) and Haviour Chen et al. (2023) recognize five types of renewables in China: hydropower, biomass, wind power, geothermal reserves, and solar energy. Furthermore, the literature highlights that the cost of generating energy power from renewable sources is higher than that of conventional energy (Shen & Low, 2015).

Difficulties on the supply side to integrate renewables into China's energy mix concern the technology challenges, namely covering long-term demand for core materials (Zhao et al., 2022). Authors note that this issue directly interrelates with relevant increased costs for scaling up renewable use. Investment cost-related issues of integrating renewables into the energy system remain uncertain. The demand side (e.g., energy consumption) should be aligned with the output of renewable energy in light of shifting the peak load and experience a more reliable and efficient grid with lower costs (Zhao et al., 2022).

China's energy mix is complex, and shifting the energy sector toward renewables concerns many core determinants, such as government strategies, market aspects, technological developments, and social and cultural attitudes regarding energy use (Haviour Chen et al., 2023). Dominant role in reviewed literature belongs to innovation and technical aspects in association with the use of renewables. The objective is to increase investments in developing green energy technologies (Ao et al., 2023). Green technologies and initiatives profoundly interdepend with renewable energy sources with positive environmental impacts, especially for energy-dependent economies. Coupled with the green energy patterns is China's green growth potential with a long-term perspective for using resources efficiently and managing the environment effectively. The issue of renewables in China is vital since it aids policymakers in perceiving the processes behind the energy transition paradigm and establishes a concrete base for future development concerning green finance initiatives (Du et al., 2023). This study's results indicate that China should create a safe and efficient energy system and strongly develop green technology, offer green products, and provide green services, increasing the contribution of clean energy (Shabaz et al., 2022a). Particularly this is vital since renewable energy directly impacts growth rates and relevant economic development (Li & Leung, 2021). Results in most cases empirically evidence that renewables significantly and positively affect economic growth rates in China. For instance, using renewable energy associated with technological advancement can help achieve new macroeconomic objectives in the case of China (Ding & Liu, 2023).

This study reviewed recently developed literature for decoding trends, challenges, and the current situation regarding the role of renewables in green growth patterns and a sustainable quality status for humans. Results under different scientific viewpoints suggest that renewables comprise an advantageous, workable, and feasible solution to mitigate climate change impacts on China's environment and quality of life. But still, there is much effort to be made from all crucial stakeholders at a national and provincial level to reap the anticipated environmental and social benefits within a prosperous economic system.

6. Recommendations

A wide range of publications stress the importance of renewables in economic growth. From industry to households, renewable is a promising way to reduce GHGs and CO2 releases and protect our planet. Keeping track of sustainable economic growth based on the logical use of natural resources is vital to continue to experience benefits from ecosystem services that nature generously offers us (Ekonomou & Halkos, 2023). Therefore, resource efficiency is crucial to achieving more excellent energy savings rates and emissions reduction (Bambatsou & Halkos, 2019).

Developing economies like China remain crucial since they are part of the broader economic system. These economies should struggle to embody the Sustainable Development Goals (SDGs) launched under the United Nations umbrella into their development process to bring tangible, real, and measurable outcomes (e.g., SDG8 for clean energy and SDG13 climate action). Outcomes reflect all these enduring and leveraged impacts at different scales, levels and time, quality and quantity, intensity and severity, importance and contribution regarding changing performance rates in well-being status and sustainability levels. One can further distinguish detailed and informative climate actions in a sustainable future based on clean energy and inclusive growth, significantly ensuring a better and decent life. China's renewable energy reserves are fairly rich (Zhao, 2022). Renewable energy sources, encompassing solar and wind power, hydropower, biomass, and geothermal power, have been developed noticeably across China. In addition to depressing China's carbon footprint, the growth of renewables has sparked domestic innovation, generated business opportunities, and helped modernize and transform industries (Ding & Liu, 2023). In this effort, the hypothesis of the Environmental Kuznets Curve provides an opportunity to define if economic growth interrelates with environmental degradation rates. Interestingly, Halkos (2003, 2013) offers a robust approach for determining a specific after which the growth process does not impact environmental quality levels. The role of renewables in relevant model specifications can widely help identify such a relationship.

The present study's results reveal the important role of renewables in fostering an eco-friendly environment for the economy (e.g., economic output, national income, GDP) and society (e.g., social benefits). This is especially true for empirically expanding studies under the energy growth nexus discussion. Indicatively, Menegaki & Tugcu (2018) argue that the energy-growth nexus focuses on the influence of energy as a factor of production in the economy. In this context, Menegaki & Tugcu (2017) elaborate extensively on relevant literature contributions when exploring the role of the Index of Sustainable Economic Welfare (ISEW) in the interaction of energy (e.g., energy consumption) and economic growth. All these empirical models concern the role of renewables as a core determinant and test its predictive power against macroeconomic variables to evidence relevant cointegration and causality relationships. The results can advance relevant decision-making processes and decode the economic and ecological footprint in the case of renewable energy sources.

Individuals' attitude concerning renewable energy use is crucial to our scientific attention. In this context, an additional research opportunity is present. Researchers may elaborate on consumers' preferences for renewables, for instance, household solar panels and photovoltaics for high population density areas. With the help of the stated preference methods and estimating relevant willingness to pay, scientists can attribute monetary values to improving environmental quality levels and formulate effective strategies. Lifestyle trends and ways of acting (e.g., culture, marketing trends) affect energy demand and use. In turn, energy demand interconnects with the contribution of renewables in the energy mix for end users.

The hot, dry, and windy effect of climate change in many regions across the globe is present. In turn, as a chain reaction effect, this situation endangers the equilibrium between natural dynamics, resilience, and integrity of the natural environment in the middle of intense human and economic activities. China should consider its commitments regarding the Nationally Determined Contributions under the Paris Agreement to accelerate its transition toward a low-carbon economy.

A core aspect for reaping benefits from all research studies remains the right and ethical circulation of gathered knowledge across academia. The authors believe that all the methods mentioned in this section (e.g., EKC, energy growth nexus, estimation of consumers' willingness to pay) can benefit climate change mitigation and adaptation plans. For a given issue or topic under research, review efforts provide this opportunity in light of facilitating and promoting the flow of results and conclusions. Then these outputs can enrich current or future endeavors in this field of interest, at the center of which one can place the degrowth debate across academia accompanied by decoupling CO2 emission and economic growth (for instance see Riti et al., 2017). A research field that needs further investigation remains the role of renewables in the notion of degrowth and the extent to which this can be applied to developing economies like China.

All in all, the role of renewables in developing countries like China in protecting the natural and human environment is highly significant. As is the case in every high-impact endeavor, attention should be paid to the multifaceted and multidisciplinary character of integrating renewables in socio-economic systems with a long-term perspective.

7. Conclusions

The present study processed an integrative review regarding the role of renewables in the natural and socioeconomic systems of developing countries, especially applied to the case of China. Contrary to a systematic review, the integrative review process concerns theoretically and empirically evidenced approaches, experimental and non-experimental studies, conceptual frameworks, policies, and discussion papers.

A wide range of issues and topics were analyzed based on inclusion criteria for selected studies obtained from the authors' thorough research obtained from well-acknowledged databases like SCOPUS, ScienceDirect, and MDPI. All selected publications have been peer-reviewed first and demonstrated a clear purpose of the study and concrete conclusions facilitating readership.

Results suggest that renewable energy sources comprise a promising but challenging way to reduce GHGs and CO2 emissions in light of sustainably developing the country's socioeconomic system. Abundant by nature, China's renewables consist of solar and wind power, hydropower, biomass, and thermal power. Relevant Innovations and technological advancements facilitate such a process. But concerns arise for cost-related issues and degree of applicability given the country's individual characteristics at a province level. Renewables seem to significantly and positively impact growth rates within China's economic system. Many authors highlight the need to plan, foster and implement strategies and policies concerning the effective transition from the conventional use of fossil fuels to renewables under robust framework and law schemes. All targets are aligned to decarbonize China's economy and experience a sustainable reality that is supported by clean energy. Thus, climate mitigation and adaptation well-structured and well-organized plans profoundly integrate the use of renewables as much as possible. The authors stress the importance of making robust and precise forecasts for future energy use so as to define the supply and demand relationship back-upped by the power generated by renewables.

New fields for further research are present. For instance, empirical studies can be processed to decode relationships of renewable-related indicators with economic growth rates and environmental degradation in regard to climate change impacts. Specifically, this study's recommendations call for additional and appealing research opportunities, including the use of stated preference methods particularly applied to estimate individual's willingness to pay to use renewables, extensively testing the relationship of renewables and environmental degradation levels under multiple sets of variables, and expanding the energy growth nexus discussion considering special and individual characteristics of China's economy.

Considering all of the above, the role of renewables in experiencing a healthy natural and human environment is at least significant. We believe this study will advance readership and contribute to going safer and faster to experience sustainable developing economies for the long run.

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Appendix A

Table A1. Relationships between renewable energy sources, growth variables and the environment in the case of China.

Authors	Period	Country/Provinces	Variables	Methodology	Outcome
Wang et al. (2005)	1977-2005	China	energy-induced CO2 emission, Total energy consumption Carbon content of fuel	Logarithmic mean divisia index (LMDI) method	Renewable energy penetration also exhibits positive effect to the CO_2 decrease
Fang (2011)	1978-2008	China	real GDP, GDP pc, per capita annual income of rural and urban households renewable energy consumption (REC), share of renewable energy consumption, number of employees, annual R&D expenditure per employee	Cobb–Douglas type production functions, multivariate OLS	Increases in REC increases: real GDP, GDP per capita, per capita annual income of rural households, per capita annual income of urban households
Yalta & Cakar (2012)	1971–2007	People's Republic of China	real GDP, five different aggregated and disaggregated energy consumption measures	Meboot DGP based VAR estimation framework based on Yalta (2021)	Neutrality hypothesis confirmed in 53 out of 60 model estimations
Lin & Moubarak (2014)	1977-2011	China	GDP, Renewable energy consumption, CO2 emissions,	Johansen cointegration test,	Bi-directional long-term causality between renewable energy

			labor	Autoregressive Distributed Lag approach (ARDL), Granger causality test	consumption and economic growth
Bloch et al. (2015)	1977-2013 (supply side) 1965-2011 (demand side)	Cina	aggregate output coal, oil and renewable energy consumption, flow of services provided by the existing capital stock, labor employed in production, level of technology, energy measure for combined coal, oil and renewable energy consumption	Autoregressive distributed lag (ARDL) and vector error correction modeling (VECM)	Renewable energy consumption reduces emissions
Long et al. (2015)	1952-2012	China	real GDP, labor, capital stock, coal, oil and gas consumption, electricity generated by wind, hydro and nuclear,	Johansen cointegration test Granger causality test	Bi-directional causality confirmed for GDP and CO2, coal, gas and electricity consumption
Chen (2018)	1996-2013	30 provinces in China	per capita real GDP, CO2 emissions, foreign trade,	dynamic system-GMM panel model	Explanatory variables impact renewable energy consumption

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Dong et al. (2018)	1993–2016	China	urbanization, renewable energy consumption pc GDP, pc CO2 emissions, pc fossil fuel consumption, pc nuclear energy consumption, pc renewable energy consumption	series of econometric techniques allowing for structural break is utilized	EKC confirmed for CO2 emissions, Renewable energy plays important roles in mitigating CO_2 emissions
Solarin et al. (2019)	1970-2014	China	real GDP, hydroelectricity consumption, fossil fuels, capital stock, labor force	VECM Granger causality test	Feedback hypothesis confirmed between economic growth and hydroelectricity consumption
Fan & Hao (2020)	2000-2015	31 Chinese provinces	GDP pc, foreign direct investment pc, renewable energy consumption pc	VECM, impulse response function analysis, Granger causality test	Long-term and stable equilibrium relationship between GDP pc, foreign direct investment pc, and renewable energy consumption pc

Huang et al. (2020)	2003-2017	China	rural household economy, renewable energy (including hydropower, bioenergy, and solar energy)	Two-way fixed effect model, Granger causality test	Investment in renewable energy improve the rural household economy
Sarkodie et al. (2020)	1961–2016	China	GDP per capita/income level, human capital index, CO2 emissions renewable energy consumption, fossil fuel energy consumption, ecological footprint, biocapacity	Neural network, SIMPLS, U test, dynamic ARDL Simulations, Prais-Winsten transformed regression with robust standard errors	EKC hypothesis Confirmed
Wang et al. (2020)	2008-2014	29 Chinese provinces	economic foundation, institutions, technological development potential, energy security and environmental protection, current status of the renewable energy sector	Dynamic principal component analysis technique	Large variations in RE development across provinces in China
Cheng & Yao (2021)	2000-2015	30 Chinese provinces	carbon intensity, renewable energy technology innovation		Renewable energy technology innovation does not affect carbon intensity in the short term,

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					renewable energy technology innovation negatively and significantly affects carbon intensity in the long-term
Sun et al. (2021)	2012-2017	30 Chinese provinces	wind power efficiency	data envelopment analysis (DEA) method	Differences in the spatial distribution of wind power efficiency in China
Wang et al. (2021)	1997-2017 (national and regional levels)	China, Chinese 31 autonomous regions and municipalities	GDP, financial added value, renewable energy consumption (total electricity generation by renewable energy including hydropower, solar power, wind power and nuclear power)	ARDL-PMG model, Granger causality test	Unidirectional causality from financial development to renewable energy consumption for China as a whole and eastern China, economic growth unidirectionally causes renewable energy consumption in China as a whole, eastern and western China
He & Huang (2022)	1990-2020	China	renewable energy consumption, annual percentage growth rate of GDP, gross capital formation,	Mediation model, Granger causality test	Bidirectional causality between renewable energy consumption and economic growth

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			labor force, trade openness, R&D expenditures, foreign direct investment		
Lian et al. (2022)	2011-2019	30 Chinese provinces	dimensions of renewable energy (RE) development	AHP-EM integrated evaluation model	The comprehensive development level of RE in each province is relatively low, and the relatively high-level areas gradually move eastward in terms of spatial distribution
Shahbaz et al. (2022)	1971-2018	China	real GDP, energy usage, fossil fuels, renewable energy, net enrollment in primary, secondary, and tertiary education, net energy imports, R&D expenditures	ARDL bounds testing approach	Feedback effect between economic growth, dirty energy usage, and clean energy usage
Ding & Liu (2023)	2008-2020	China	renewable energy, green finance investment, GDP, renewable energy,	GMM model	Renewable energy and green economic growth (GDP) are critical

	public support policy	determinants for sustainable development

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