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Review

China in the Renewable Energy Era: What Has Been Done and What Remains to Be Done

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Abstract: Climate change is directly linked to a broad array of changes because of disorganized activities within the economic system and human intervention. Climate change affects the well-being status of both non-living and living things. Relevant policies to mitigate and adapt to climate change conditions concentrate on solutions that intend to use renewable energy instead of fossil fuels or other conventional energy sources. This study aims to process a review focused on how renewables advance environmental quality and create relevant benefits within severe economic activities. This study elaborates on the case of China for two main reasons. First, China has a pivotal role in the economic system worldwide. Second, China is making serious attempts to transition into a low-carbon economy. An integrative review was processed to receive selected publications. The advantage of this process is that it considers empirical and non-empirical studies, policy papers, and conceptual frameworks. Inclusion and exclusion criteria were applied to retrieve the final number of publications. Review results from 39 well-acknowledged Journals provided 180 selected publications categorized into seven study groups: data analyses, model optimization studies, market issues, renewable energy technology publications, nuclear energy publications, ocean energy publications, and policy-related studies. Policy implications concern China's efforts to accelerate the integration of renewables in the energy mix. Hence, the country should increase energy efficiency in consumption and process investment plans based on robust research and development efforts.

Keywords: emissions; renewable energy sources; economy; environment

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1. Introduction

Naturally, economies need to use resources (e.g., natural, human, financial, and technical) to become more extensive and competitive globally. In this growth process, overconsumption and overexploitation of ecosystem services (e.g., supporting, provisioning, regulating, and cultural) have created environmental problems (e.g., resource depletion and degradation). Furthermore, severe competition to become "first in class" or "global leaders" represents the main economic driver of market failure phenomena and negative externalities. In a purely economic context, the market fails by creating more greenhouse gas emissions (GHGs) compared to the optimal level with social concerns [1,2], 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. Many air quality problems derive from the extensive use of fossil fuels. This situation does not facilitate sustainable development achievements. 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 [3].

Given its economic potential and role in the global economic system, China can be a crucial reference in this perspective. Specifically, China is the second-largest economy globally and a leading energy consumer. Hence, it is more illustrative to debate the economic consequences of renewables adopted in China as an example of a developing country [4]. According to [5], 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 US dollars [6].

This study aims to identify the role of renewables in China's energy structure, highlighting its multifaceted character at the economic and environmental interface. The urgent need to make a transition toward a green economy and green consumption patterns motivated our scientific interest in implementing this review study.

We attempt to elaborate on the relevant literature through an integrative review process. This approach constitutes a dependable way of gathering, analyzing, and presenting previous studies for a specific research field, topic, or issue. This review process concerns empirical and non-experimental research. Moreover, it offers an opportunity to retrieve studies considering policy issues, theoretical approaches, and conceptual frameworks. Integrative reviews motivate researchers to go one step further from merely analyzing and synthesizing research results. Consequently, it allows researchers to offer new inputs and gather knowledge about a topic [7]. This study concerns how renewables can help decarbonize energy use and limit further environmental degradation. In particular, high-impact developing economies should reconsider, change, and restructure this aspect of their applied or currently run economic activity. Hence, these economies should decrease greenhouse gases (GHGs) and CO_2 emissions and reduce energy resource depletion. GHG emissions are negative externalities hurting society's welfare [8]. In 2021, China released 11.47 billion metric tons of CO_2 emissions, making this country the world's largest polluter in that year [9]. Interestingly, the authors of [10] concluded that emissions of GHGs have increased, as an impact of the 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 [11]. Supportively, the authors of [12] argued that it is highly fundamental to integrate energy efficiency measures into the growth system to control GHGs. The authors of [13] stated 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 CO_2 emissions [14]. Consequently, research questions arise: What is the linkage between environmental quality and renewables? How does this relationship, if evidenced, progress the work needed toward decarbonizing developing economies? Thus, a research opportunity is present to comprehensively review the role of renewables in this effort for developing countries such as China.

Strengthening our presence in renewable energy plans can lead us to a prosperous energy future. Carbon neutrality welcomes a broad repertoire of activities and business options in this anticipated future. Living and performing in a safe and healthy environment where economic activities, human well-being, and nature interrelate to form a system is essential. This system's performance extensively controls our living status [15].

The paper is structured as follows: Section 2 presents the methodology regarding the integrative review process; Section 3 describes the data process followed; Section 4 discusses the research topics; Section 5 concentrates on the key review findings; Section 6 presents relevant policy implications and recommendations; Section 7 summarizes the conclusions.

2. Materials and Methods

To meet this study's aim, 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 [16]. This approach was 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 non-experimental, 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 benefit that this process provides is that it considers discussion papers, opinion justifications, 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 [17–20]. Notably, this review process surpasses the potential to purely review the literature since it overcomes the traditional process of merely analyzing and synthesizing the current study results [21]. One key point behind this approach is that the integrative review process covers mature research fields and new, developing, and emerging ones.

The authors of [22] proposed a five-step approach to process an integrative review: problem identification, literature search, data evaluation, data analysis, and presentation of findings. Hence, researchers can address a particular issue in science as an output of the integrative review process, enriching current knowledge [22].

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

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, and (ii) on the basis of the received results, provide recommendations for future research efforts with applicable practical implications.

These results will enable readers to draw valuable conclusions that can be further developed and deployed regarding a wide range of research issues that share a joint knowledge base. Additionally, the obtained results from this integrative literature review can be integrated into relevant decision-making processes to advance a better and cleaner environment within China's broad and high-impact economic system. Figure 1 presents the steps followed to receive the reviewed publications. In this process, 39 well-acknowledged journals were reviewed, providing 180 publications for further consideration. Appendix B presents the names of the reviewed journals, studies reviewed from these journals, and a frequency analysis.

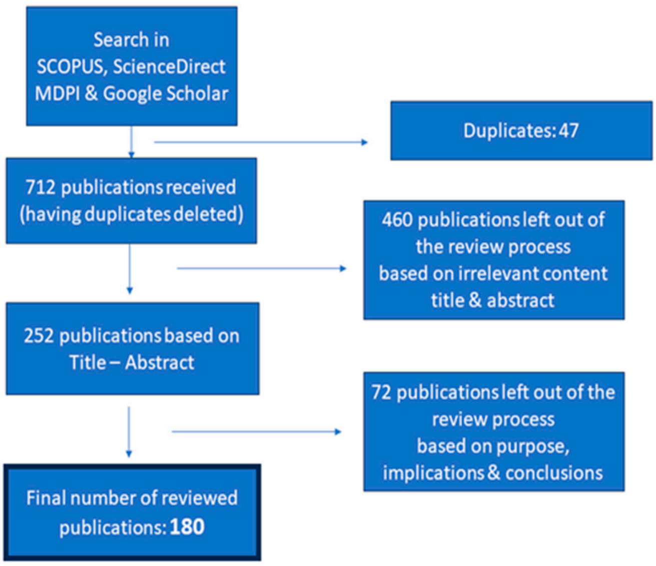

Figure 1. Steps to implement this study's integrative review.

3. Data

The integrative review process draws on diverse research to address the topic of interest under a specific research question [16]. 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. Studies were evaluated on specific eligibility criteria. In turn, the study's title and abstract were carefully reviewed. Practically, two main criteria for proceeding further with the review were considered: (1) the precise study's aim; (2) well-developed and justified practical and theoretical implications for its contribution to the 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 on the basis of the research topic and purpose (e.g., thematic field).

Only studies written in the English language were included. Only studies written in 2000 and beyond were selected for further elaboration. Selected studies needed to have been published after a blind peer-review process in well-acknowledged academic journals. The base year 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 [23]. Studies published following non-peer review process were omitted from this review.

This integrative review process justifies the diverse methods and study results. 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. To become even more consistent with the integrative review process, both authors carefully double-checked the steps followed.

The adopted procedure to extract this study's data returned 180 published papers based on 39 reviewed journals. Then, the received studies were categorized into seven groups focused on their thematic field. Table 1 shows the number of reviewed publications and the relevant thematic areas. Table 2 provides the number of the reviewed studies focused on the year of publication. Figure 2 concerns the number of reviewed studies per thematic field derived from Table 1. Figure 3 shows the total number of reviewed studies per reference year derived from Table 2. Furthermore, Figure 4 presents the relevant trend analysis concerning the reviewed studies given the year of publication to foster a holistic view of this review process.

Table 1. Thematic fields and the number of publications.

Data Analysis	Model Optimization	Market Demand	Renewable Energy Technologies	Ocean Energy	Nuclear Energy	Policy
56	42	19	28	13	9	13

Table 2. Reviewed studies based on year of publication.

2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
0	0	2	0	0	2	0	2	0	3
2010	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
3	7	8	6	7	10	7	10	13	15
2020	**2021**	**2022**	**2023**						
11	16	22	36						

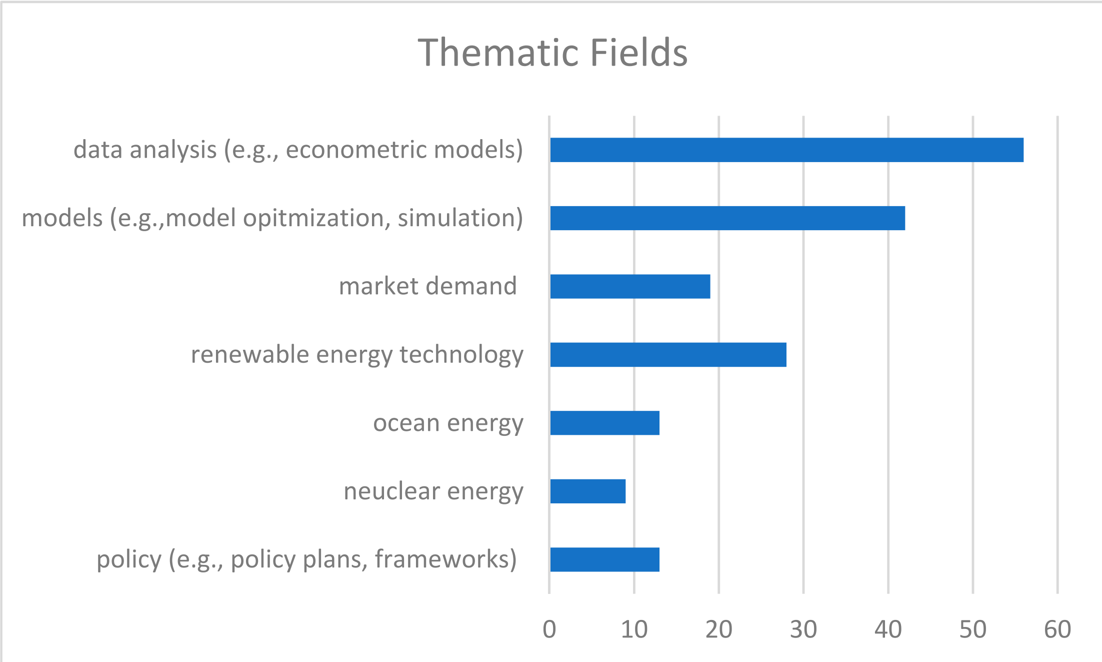

Figure 2. Thematic fields derived from the review process (seven identified categories).

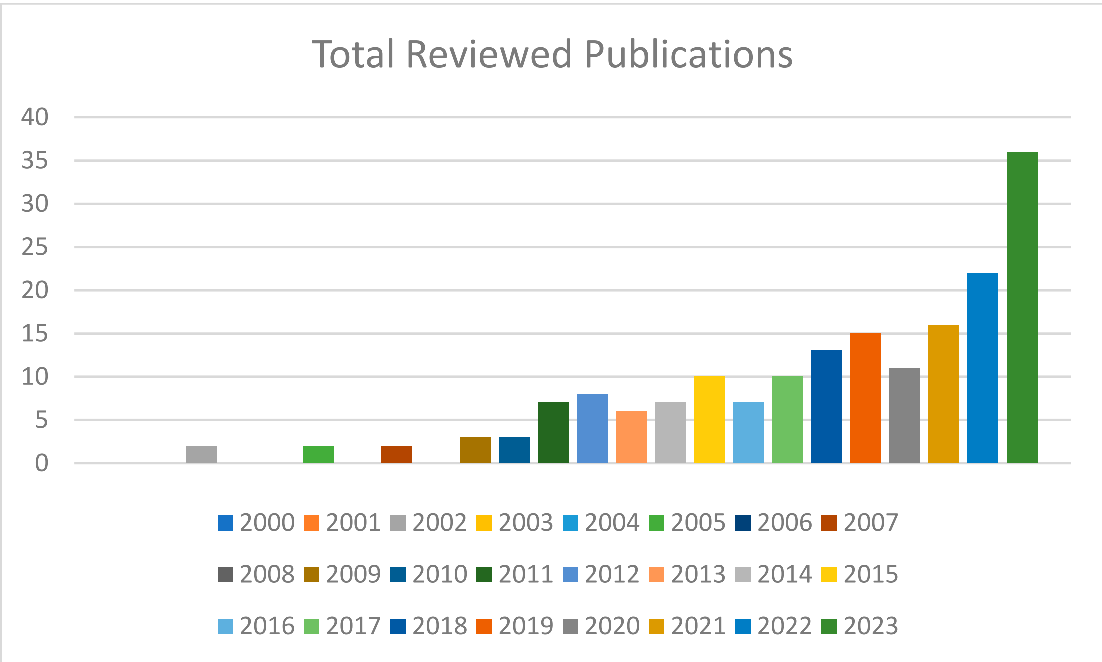

Figure 3. Total number of publications per reference year.

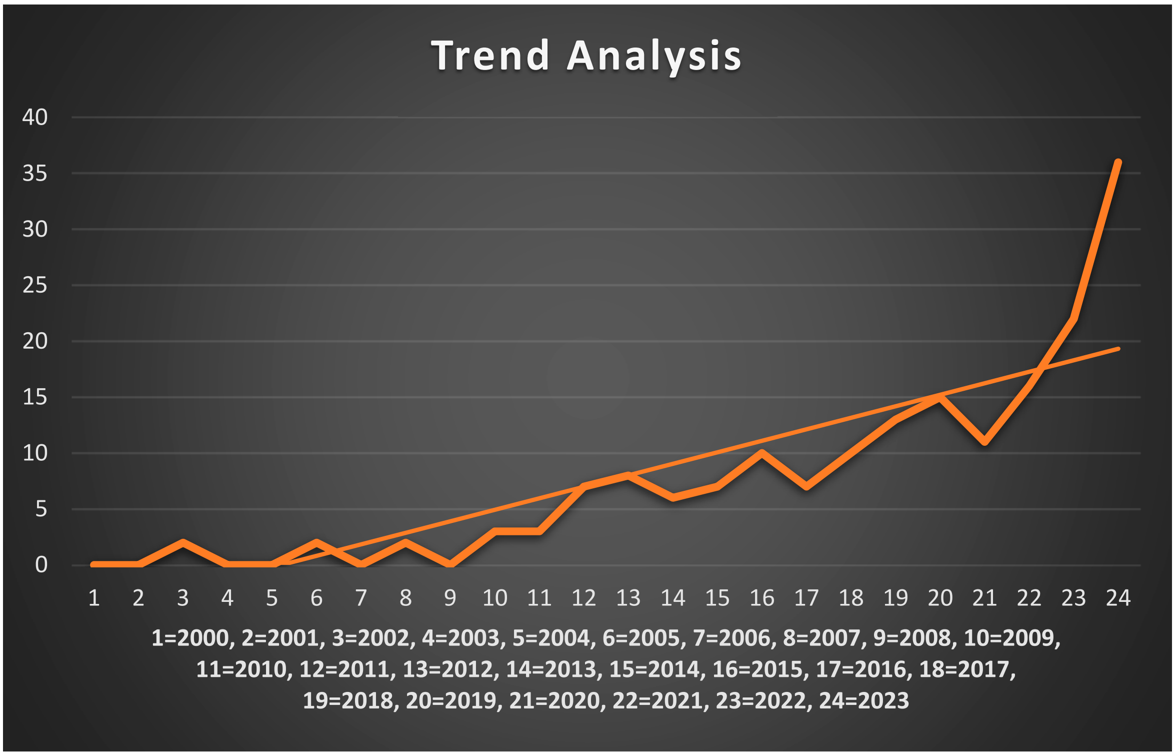

Figure 4. Trend analysis for publications and reference year.

4. Renewables and Low-Carbon Perspective 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.

One of the environmental and energy policies targets is to make a country's economy (e.g., China's economy) more eco-friendly. However, such an endeavor requires solutions to 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 relevant publications as a transition in the well-recognized "energy paradigm" to replace fossil fuels with renewables to profoundly decarbonize energy-related systems [24]. The authors of [25] stated 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" [26] (p. 887). A popular topic in literature is the issue of energy security regarding fossil fuels since relevant extracted energy is becoming progressively depleted with limitless extraction and use [27]. Projections concerning renewable potential in China disclose an extended 67% (438 GW) to just over 1 TW in 2023. Growth supported by government policies aims to handle air pollution and decarbonize the mix to produce power. Furthermore, solar PV contributes 58% of the total renewables. Wind (e.g., offshore projects (120 GW)), bioenergy (14 GW), and hydropower (47 GW) follow the expansion of solar PVs. Interestingly, non-hydro renewables participate in 48% of China's 2500 terawatt hours (TWh) concerning renewable generation by 2023. Policies focused on the targets of renewables to lower the cost of subsidies and curtailment have significantly affected this year's projections, particularly concerning solar PVs [28].

Furthermore, the authors of [29] claimed that subsidy plans concerning renewables lengthened wind and solar power scales and enhanced their deployment. As indicated in [30], Figure 5 presents the contribution of renewables for various countries [31].

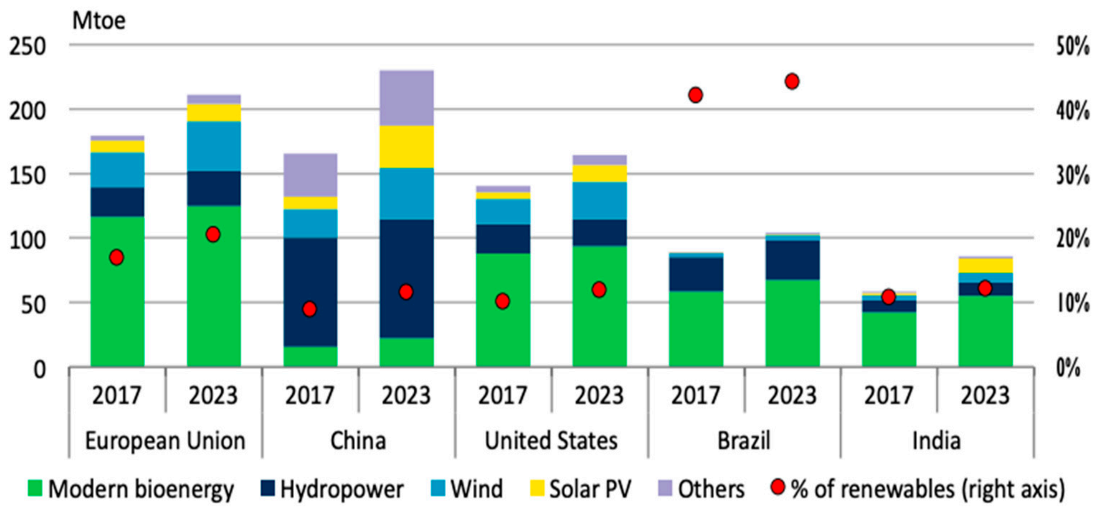

Figure 5. Contribution of renewables for various countries from 2017 to 2023 [30,31].

Energy consumption rose from approximately 5 Gtoe in 1970 to almost 12 Gtoe in 2010, with significant contributions from China and the USA [32]. One of the most appealing and interesting issues across academia concerns the replacement of fossil fuels with renewable energy sources. The authors of [33] claimed that we should attach great importance to China's undeveloped potential regarding renewables. Technological innovations and lifestyles are anticipated to rapidly increase energy demand. In contrast, 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 [34]. This has been widely acknowledged in relevant studies [35–37]. 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.

In 2021, global CO_2 releases from fossil fuels and industry were 37.12 billion metric tons ($GtCO_2$) [38]. As one of the world's high carbon emitters, China pledged to grasp a carbon peak by 2030 and seek carbon neutrality by 2060, where the building sector consumes 40% of the energy and releases 36% of the CO_2 globally [39]. Consequently, accomplishing China's carbon peak and carbon neutral commitments calls for replacing conventional fuels and integrating new technology. The former widely concerns renewable energy sources in the energy mix. The latter considers energy efficiency issues related to mitigation (e.g., limiting CO_2 emissions) and adaptation (e.g., future challenges) strategies. Duan et al. (2022) [40] stated that, as a function of multiple determinants, the linkage between energy consumption and CO_2 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 profound differences in development levels (e.g., economy) and resource endowments concerning the Chinese provinces which might result in spatial heterogeneity (e.g., building CO_2 releases) [39]. As indicated by [41], according to the [42], the energy system is coal-dependent, whereby coal covered approximately 69% of the main energy supply and 59% of energy consumption in 2018. Table 3 presents China's expectations toward carbon-neutral conditions [43].

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) [28], renewable energy comes from nature with sustainable mechanisms and can replenish faster than consumed. These sources depend on nature's ecosystem services (e.g., provisioning services) and location-specific characteristics (e.g., availability) [44]. Despite the advantages of renewables over conventional energy [45], rigid policies or effective energy-saving technologies to limit CO_2 emitters (e.g., buildings) are absent in China [46].

Table 3. Development situation anticipated for China's coal industry in the background of carbon neutrality.

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

The literature recognizes that, on the supply side, fossil fuels have a large proportion, while the difficulties of overcapacity need to be determined [47]. Notably, the authors of [48] mentioned a "paradox" of the energy revolution in China in the context of a socio-technical transition. The authors argued 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, the authors of [49,50] noted that this energy revolution concerns production, consumption, technology, and management changes. This includes shifts to renewable energy sources and relevant energy consumption structures toward a "green" economy and a sustainable energy future [51]. Green technology or green growth and many relevant "green terms" deeply rely on sustainable renewable energy [52].

The authors of [53] stressed the importance of clean energy by exploiting wind energy elaborating on spatial characteristics concerning efficiency issues. The authors of [54] selected 77 references to shed light on cost and marketability issues regarding renewable energy after the power market reform in China. These authors concluded that China could provide a power structure targeted for production, dispatch, coordination, and demand with a specific goal of renewable energy penetration. This is based on the country's non-independence of system operators, a surplus of thermal power, and market constraints. Interestingly, the authors stressed 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, the authors of [55] highlighted difficulties in advancing renewables without the supportive contribution of appropriate tariff policies (e.g., for development and utilization issues). A wide range of publications have discussed policy issues, law frameworks, and regulations to successfully develop renewable energy sources in the domestic market and reap environmental benefits [25,56,57]. 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, the authors of [55] referred to a "future evolution path" regarding renewables under the premise of three core principles: the principle of development, coordination, and innovation. Another interesting point was analyzed in this framework [58]. The authors referred to the curtailment of renewable energy sources by the National Development and Reform Commission (NDRC), which concerns the 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.

Notably, empirical research was processed to decode linkages and relationships between pollution indicators and growth variables. For instance, the authors of [59] 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, the authors of [37] empirically explored the spatial pattern concerning air pollution in 31 Chinese provinces regarding innovations in technological issues in renewables. Technology innovations in renewable energy were evidenced to reduce respirable suspended particles (PM10) and nitrogen oxide (NOx) concentrations. Another related empirical study concerning 30 Chinese provinces from 2001 to 2019 [60] confirmed that green financing initiatives "sped up" (accelerate) the alteration (transformation) of China's energy industry toward increased shares of renewables in its overall fuel mix. Keeping the momentum, the authors of [61] investigated potential links among human capital, energy consumption, and economic variables concerning China between 1971 and 2018. Empirical results indicated that economic growth, dirty energy usage, and clean energy usage were interdependent, signifying a feedback causal relationship. As indicated in [62], Figure 6 presents China's installed solar power capacity [63].

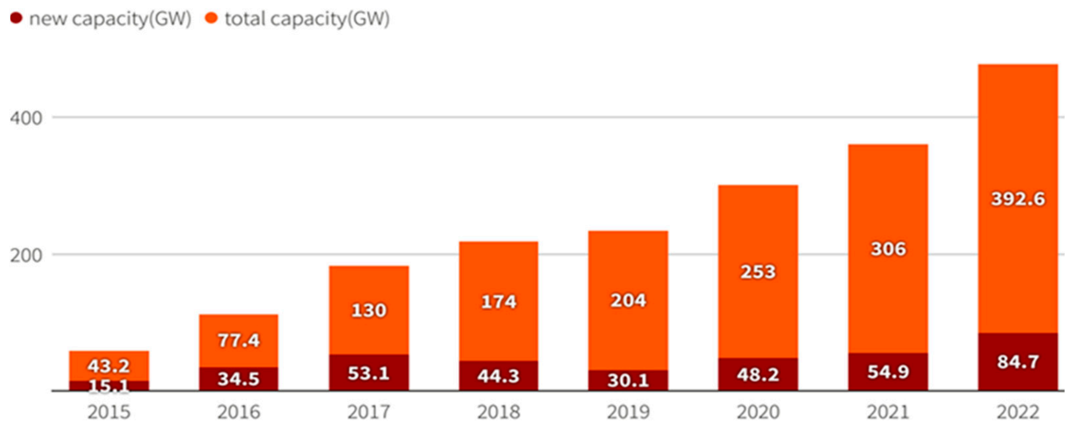

Figure 6. Solar power capacity in China [62,63].

Uncertainties in forecasting energy demand and CO_2 releases remain central issues for further elaboration. For instance, energy savings and emission reduction measures depend on projections that should consider differences in socioeconomic parameters, technological advances, climate-changing behavior, and electrification pathways. This is primarily 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 primary 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 among renewable forms of energy, economy-related variables, and the environment.

5. Results

This review process indicated that energy generated from fossil fuels and natural resources is used to maximize China's economic potential. The reviewed publications were categorized into seven groups: data analysis, model optimization, market issues, renewable energy technology, ocean energy, nuclear energy, policy issues, and reviews. The group with data-driven analysis featured highly in this integrative review process. Specifically, two main strands of literature dominate the authors' efforts on renewable energy issues in this category. The first strand concerns regression data analysis (e.g., panel and time series analysis), whereas the second considers the environmental Kuznets curve (EKC) hypothesis.

In the case of regression analyses, authors used various renewable energy proxies. For example, they included the level of renewable energy enterprise research and development

(R&D) expenditure, renewable energy firms' fixed investments, and R&D investments [64,65]. Interestingly, in some cases, results indicated that R&D intensity goals are useful for decreasing energy intensity reduction targets, as they considerably impact renewable energy consumption [66]. Supportively, R&D expenditure and economic growth rates positively affect innovation concerning renewable energy technologies [67]. Furthermore, the authors of [68] used hydroelectric and renewable electricity generation to identify causalities when investigating the energy-led growth hypothesis. The authors of [69] adopted the renewable energy transition performance of 178 renewable energy-listed companies by processing panel data analysis. In regression analyses, the authors used mostly the conventional GDP as the growth variables [61,70–73]. Furthermore, the authors of [74] tested the causalities between GDP and hydroelectricity power consumption.

In the case of the EKC, authors explored if economic growth interrelates with environmental degradation. Essentially, authors tested the hypothesis of the inverted U-shaped curve and examined if economic growth does not negatively impact environmental quality after a certain point. They mostly used CO_2 emissions to conceptualize environmental quality [72,75] or carbon intensity [76]. Interestingly, renewable energy generation was used as a metric for environmental quality by [77]. The authors of [78,79] used renewable energy consumption to test the effects on CO_2 emissions. Interestingly, the authors of [75] used nuclear and renewable energy consumption as regressors when testing the EKC hypothesis. In these models, renewable energy proxies play a significant role in sustaining high levels of environmental quality.

This review process disclosed that results varied according to several factors. For instance, results differed on the basis of the adopted econometric methods. Indicatively, authors used the fully modified ordinary least-square method (FMOLS) or generalized method of moments (GMM) [80,81], a panel Tobit model with a bootstrap method [82], autoregressive distributed lag (ARDL) and vector error correction modeling (VECM), or a combination of econometric techniques [64,83–85]. Moreover, review findings revealed that authors processed research based on China's provincial data [53,86–88] or at a national level [61,80] or at a national and regional level [43].

One potential explanation for receiving different results is the time span used by authors and the set of regressors included in the model specifications. As is the case with data-driven analysis, this variability of research findings and differentiation of macroeconomic variables stimulate further research in renewables. This opportunity highlights their multifaceted character, dynamic nature, and broad applicability at the economy, environment, and society interface.

From this perspective, the second category identified in this study concerns model optimization. Optimization models and simulations provide evidence concerning core determinants to increase energy efficiency. On the basis of simulations and scenarios or game theory approaches, these research efforts focus on establishing efficiency in the energy sector. Widespread in literature is the reality that conventional energy consumption (e.g., coal, petroleum, and natural gas) generates escalated and "hard-to-fix" environmental pollution problems. The conventional types of energy sources are not abundant. In contrast, renewables are. Therefore, the literature acknowledges the urgent need to increase energy efficiency patterns.

Energy-saving measures and release reduction are considered developing trends in the country [56]. To this effort, we summarized the key results of selected publications from this study's integrative review process. Review findings indicated key issues in this category. First, achieving an optimal renewable portfolio standard is crucial to maximize social welfare [89]. Second, it is fundamental to "run" development scenarios for China's renewable energy toward 2030 [90]. Third, decaying the trajectory of CO_2 releases in the power sector is highly important according to numerous scenario settings concerning renewable energy penetration [91]. The consumption rates of renewable energy in China are driven by the relevant energy structure and final consumption patterns [92]. To meet these key issues, core statistics of optimal portfolios include technology shares, levelized cost of electricity, and capacity factor at-risk values [93]. This widely interrelates with the third identified category in this review, namely, renewable energy technology. Specifically, in the literature, investments and innovation are considered important to promote renewable energy and green development patterns (e.g., industry, grid infrastructure) (indicatively, see [94–98]). Specifically, hybrid renewable energy generation [99], wind, photovoltaic (PV), and wind–PV hybrid configurations [100], wind turbine industry renewable energy [101], energy storage systems [102], and patents [103–105] feature widely in this review.

Special interest is dedicated to nuclear and ocean renewable energy sources. These two groups remain contemporary in the relevant literature as a trustworthy way to achieve energy efficiency production patterns. In this review, nuclear energy was used for the following purposes: first, it was used as a regressor to test the EKC hypothesis, given its significance in China's energy structure [75]; second, it was included to test its predictive power in panel data analysis [98,106]; third, it was treated as a "vehicle" to meet the global 1.5 °C target [107].

Not surprisingly, ocean and marine energy attracted the interest of researchers. This literature review stresses the importance of the marine renewable energy (MRE) industry, indicating relevant policy reforms and constructive suggestions [108]. The authors of [109] suggested a dual-energy-driven distillation desalination system driven by solar and ocean thermal energy to overcome temperature difference restrictions. Ocean-driven solutions to reduce CO_2 emissions in China are highly important [110]. One issue that needs consideration is China's uneven distribution of marine energy production [111]. Furthermore, the literature highlights the efforts to enhance wave energy as a marine resource energy [112] and tidal stream energy [113]. Despite significant progress in these two renewable sources, both fields need further research regarding technical advancements, pricing issues, and broad integration in the energy structure system.

The last identified group of publications considers policy issues regarding China's decarbonized economy and relevant sustainability targets. Several key assumptions were derived. The rapid development of renewable energy sources is recommended to sustain China's socioeconomic system [114]. Poor renewable energy integration greatly challenges China's electricity sector [115]. China needs energy cooperation mechanisms to function locally, establish multilateral cooperation with developing countries, and enhance partnerships with developed countries [116].

The literature emphasizes the importance of supportive and sufficient law frameworks for smoothly developing renewable energy sources [57]. Both government and industries should align their efforts to support carbon neutrality and drive technological innovations [59]. 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 [57]. From this perspective, fiscal decentralization positively affects the demand for renewable energy. Practically, fiscal decentralization increases renewable energy demand [61].

Results were derived from this study's integrative review process. We obtained original publications for review on the basis of this study's specific inclusion–exclusion criteria. This section presented the most high-impact results from selected and recent publications. Additional review efforts based on different criteria can add to the present work and create new dimensions concerning the role of renewable energy in China's economic, social, and environmental sectors.

6. Policy Implications and Recommendations

A wide range of publications stressed the importance of renewables in economic growth. From industry to households, renewable energy is a promising way to reduce GHGs and CO_2 releases and protect our planet. Policy implications for accelerating the rapid expansion of renewable energy and enhancing the low-carbon transformation with high-quality technological advancements are important and complex issues.

One issue that needs attention concerns the carbon trading price and market scale. These issues were found to be tightly connected with multiple factors. For instance, we mention the emissions quota allocation scheme among sectors, participating sector coverage, and renewable energy development level [117]. For instance, the electricity market structure plays a significant role in experiencing renewable electricity. Hence, the competition between utilities benefits renewable energy deployment (e.g., wind power) [118].

Despite the "overwhelming" growth of renewable energy in China, many challenges need consideration, such as huge transition urgency and pressure, technology issues, and policy aspects [47]. Wind and solar power systems supported by relevant infrastructure seem promising and safe ways toward a low-carbon economy and consumption mindset. China is a significant producer and exporter of technology related to renewable energy [57]. Supportively, the authors of [29,59] recognized 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 [29].

Deficiencies characterize China's current regulatory mechanisms. For instance, the inclination toward economic regulation and the lack of a market adjustment mechanism are difficulties in expanding the nation's potential in light of renewables [56]. The tariff policy and additional supporting policies (e.g., market-oriented reforms) should be seriously considered to promote renewable energy [55]. Moreover, the Chinese government should optimize the administrative management system and reinforce financial regulation (e.g., tax regulations) to experience sustainable development [119].

The present study's results reveal the critical 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, the authors of [13] argued that the energy–growth nexus focuses on the influence of energy as a production factor within the economic system. In this context, the authors of [11] elaborated 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 growth. The logical use of natural resources is vital to continue to experience benefits from ecosystem services that nature generously offers us [15]. Therefore, resource efficiency demands high energy-saving rates and limiting emissions [120].

All in all, the role of renewables in developing countries such as China in protecting the natural and human environment is highly significant. As in every high-impact endeavor, attention should be paid to the multifaceted and multidisciplinary character of integrating renewables in socioeconomic 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.

Various issues and topics were analyzed on the basis of the inclusion criteria for selected studies obtained from the authors' thorough research from well-acknowledged databases such as SCOPUS, ScienceDirect, and MDPI. All selected publications were peer-reviewed first and demonstrated a clear purpose of the study with concrete implications and conclusions facilitating readership.

The final number of reviewed papers was 180. This study's review process provided seven groups of retrieved publications: data analysis, model optimization, market issues, energy renewable technology, nuclear energy, ocean energy, and policy issues. In the data analysis group of studies, panel data and time series analysis at a national or provincial level dominated researchers' efforts. Furthermore, the authors tested the EKC hypothesis to identify linkages between economic growth and environmental quality. Renewable energy consumption was widely used as a regressor. Results varied as a function of periods, the econometric method used, and the variables included in model specifications. The second identified group concerned optimization models. Using simulations and scenarios, researchers provided evidence for integrating energy efficiency issues into China's socioeconomic system. From production to consumption, energy efficiency benefits every effort to achieve a sustainable equilibrium between energy supply and demand. The replacement of conventional energy sources with renewables should be accelerated. Arguably, the third group drew attention to cost issues, pricing mechanisms and levels, and energy stakeholders in the energy industry. It concerned energy demand and how consumers behave in renewable energy use. The fourth group concerned renewable energy technology. In this set of studies, the dominating factor was investments and innovations to consume less energy without losing quality and outcome. Many authors concluded that increasing funding for research and development will benefit every well-structured and targeted attempt to limit emissions. The fifth and sixth sets of studies relied on renewables derived from the ocean and nuclear energy sources. In both groups, more research is needed concerning the technology used, integration in the energy system, and increasing share in the country's energy mix. The last identified group considered policy issues, mainly concerning regulation frameworks, law issues, future challenges, and the potential of integrating renewables in the energy structure at a strategic level.

New fields for further research are present. For instance, empirical studies can be processed to decode relationships of renewable-related proxies with the economy and environmental quality levels with climate change implications. All in all, the role of renewables in experiencing a healthy natural and human environment is at least significant. This study will advance readership and contribute to going safer and faster to experience sustainable developing economies in the long run.

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Appendix A

Table A1. Relationships among Renewable Energy Sources, Growth Variables, and the Environment in the Case of China.

Authors	Period	Country/Provinces	Variables	Methodology	Outcome
[121]	1977–2005	China	Energy-induced CO_2 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
[70]	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

Table A1. *Cont.*

Authors	Period	Country/Provinces	Variables	Methodology	Outcome
[71]	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
[122]	1977–2011	China	GDP, renewable energy consumption, CO_2 emissions, labor	Johansen cointegration test, autoregressive distributed lag approach (ARDL), Granger causality test	Bi-directional long-term causality between renewable energy consumption and economic growth
[123]	1977–2013 (supply side) 1965–2011 (demand side)	China	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
[124]	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 CO_2, coal, gas, and electricity consumption
[125]	1996–2013	30 provinces in China	Per capita real GDP, CO_2 emissions, foreign trade, urbanization, renewable energy consumption	Dynamic system-GMM panel model	Explanatory variables impact renewable energy consumption
[75]	1993–2016	China	Pc GDP, pc CO_2 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 CO_2 emissions, Renewable energy plays important roles in mitigating CO_2 emissions
[74]	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
[73]	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 among GDP pc, foreign direct investment pc, and renewable energy consumption pc
[95]	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

Table A1. *Cont.*

Authors	Period	Country/Provinces	Variables	Methodology	Outcome
[72]	1961–2016	China	GDP per capita/income level, human capital index, CO_2 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
[126]	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
[76]	2000–2015	30 Chinese provinces	Carbon intensity, Renewable energy technology innovation		Renewable energy technology innovation does not affect carbon intensity in the short term; renewable energy technology innovation negatively and significantly affects carbon intensity in the long-term
[53]	2012–2017	30 Chinese provinces	Wind power efficiency	Data envelopment analysis (DEA) method	Differences in the spatial distribution of wind power efficiency in China
[43]	1997–2017 (national and regional levels)	China, 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, and eastern and western China
[4]	1990–2020	China	Renewable energy consumption, annual percentage growth rate of GDP, gross capital formation, labor force, trade openness, R&D expenditures, foreign direct investment	Mediation model, Granger causality test	Bidirectional causality between renewable energy consumption and economic growth

Table A1. *Cont.*

Authors	Period	Country/Provinces	Variables	Methodology	Outcome
[86]	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
[61]	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
[80]	2008–2020	China	Renewable energy, green finance investment, GDP, renewable energy, public support policy	GMM model	Renewable energy and green economic growth (GDP) are critical determinants for sustainable development

Appendix B

Table A2. Studies Reviewed by Journals, and Frequency Analysis.

Journal	Studies Reviewed	Frequency [% Total (=175)]
Advances in Climate Change Research	1	0.55555556
Applied Energy	3	1.66666667
Applied Soft Computing	1	0.55555556
Asian Perspective	1	0.55555556
Chemical Engineering Research and Design	1	0.55555556
Computers and Chemical Engineering	1	0.55555556
Computers & Industrial Engineering	2	1.11111111
Desalination	1	0.55555556
Economic Modelling	1	0.55555556
Energy	14	7.77777778
Energy Economics	4	2.22222222
Energy for Sustainable Development	2	1.11111111
Energy Policy	43	23.8888889
Energy Procedia	1	0.55555556
Energy Reports	1	0.55555556
Energy Strategy Reviews	6	3.33333333
International Journal of Hydrogen Energy	2	1.11111111
International Review of Economics and Finance	1	0.55555556
Journal of Cleaner Production	13	7.22222222
Journal of Environmental Management	1	0.55555556
Journal of Marine Science and Engineering	1	0.55555556
Marine Policy	2	1.11111111
Procedia Computer Science	1	0.55555556
Procedia Engineering	1	0.55555556
Procedia Environmental Sciences	1	0.55555556

Table A2. *Cont.*

Journal	Studies Reviewed	Frequency [% Total (=175)]
Renewable and Sustainable Energy Reviews	20	11.1111111
Renewable Energy	33	18.3333333
Renewable Energy Focus	1	0.55555556
Resources Policy	6	3.33333333
Resources, Conservation & Recycling	2	1.11111111
Science of the Total Environment	2	1.11111111
Structural Change and Economic Dynamics	1	0.55555556
Sustainability	2	1.11111111
Sustainable Cities and Society	1	0.55555556
Sustainable Energy Technologies and Assessments	1	0.55555556
Technological Forecasting & Social Change	2	1.11111111
Technology in Soceity	1	0.55555556
Utilities Policy	1	0.55555556
Water Science and Engineering	1	0.55555556
Total number of journals reviewed	Total number of reviewed publications	Total (%)
39	180	100

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