Review

Sustainable Development of Eco-Cities: A Bibliometric Review

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Abstract: With the increase in the urban population, nearly 70% of future people will live in cities, which will not only bring massive consumption of resources but also cause irreversible damage to the urban ecological environment. Therefore, the study of sustainable development of eco-cities (SDEC) has received wide attention from academics. In this paper, a bibliometric analysis of journal articles on sustainable development of ecological cities using the Web of Science Core Collection database from 1990 to 2021 is conducted to analyze the current status, hotspots, and research trends in this field. The results of this study reveal the evolution of the number of publications, major research disciplines, authors, countries, and institutions in this research field over the last three decades. Regarding research hotspots, SDEC research has focused on cleaner production, sustainable buildings, municipal solid waste management, energy policy, and carbon emissions in China. With the emergence of climate change, carbon emission limitation, and sustainable development requirements, scholars’ research targeting performance analysis and whole life cycle assessment of urban ecosystems will gradually become a mainstream trend. In the future, technological innovation still needs to be strengthened, and we should enhance the research on stakeholders in ecological city construction and study the impact of urban ecological transformation on social, economic, and environmental changes.

Keywords: sustainability; urban ecology; climate change; carbon emission; Web of Science

1. Introduction

Cities are often the political, economic, and scientific centers of their regions. Urban populations now account for more than half of the world’s total population. It is predicted that the proportion of the urban population to the total global population will rise to 60% in 2030 [1]. Cities are the central drivers of economic growth in their surrounding regions, providing about 60% of the world’s GDP. However, these cities also have some of the highest carbon emissions and resource consumption in the world. According to statistics, about 70% of the world’s carbon emissions come from cities, and cities consume more than 60% of the world’s resources. Cities, therefore, have an incredibly profound impact on global sustainability [2–4]. Because they occupy smaller areas of land and are highly efficient in transportation, dense cities have a lower potential ecological footprint per capita than sparsely populated areas [5,6]. As a result, building compact cities is often cited as a central element in the world’s response to climate change [7–9]. However, such concentration may also have serious negative consequences, such as the urban heat island effect, regional pollution, and increased consumption of non-renewable energy resources [10–12].

The concept of the “eco-city” was first introduced by the United Nations Educational, Scientific, and Cultural Organization (UNESCO) in the Man and the Biosphere (MAB) report in the early 1970s. It was explained from the perspectives of both social psychology and ecological natural science. Since then, many scholars have studied various aspects of the “eco-city”. For example, R. Register defines an eco-city as an ecologically healthy city, pointing out a series of criteria to measure the city’s ecological health, such as urban traffic and the natural characteristics of biodiversity [13]. Corrado Diamantini summarized the common problems faced by several Italian cities and urban areas based on their sustainable...
development cases and analyzed the urban design of Trento, Italy [14]. After the 21st century, scholars have generally considered the ecological city as an independent economic system and developed detailed criteria for its construction. These criteria include the need to achieve the maximum use of ecological natural resources, the scientific planning and management of ecological cities, and the improvement of the contradiction between the ecological environment and the number of people in the city [15–17].

Eco-city builders define eco-city development as “a complete system approach that combines administration, eco-efficient industry, people’s needs, and aspirations, harmonious culture, and a landscape that integrates the functions of nature, agriculture, and the built environment” [18]. Ecocities are increasingly being promoted as urban sustainability in a world facing the growing challenges of environmental degradation, climate change, and rapid urbanization [19]. In recent years, many studies related to the topic of sustainability-based eco-city construction have emerged in academia, combining land use patterns, transportation patterns, community management, and the greening of urban spaces [20–23]. For example, Roula, F. et al. used the Heritage, Environmental Quality, Diversity, Integration, Social Link (HQDIL) method and the Indicators Impact (INDI) model to assess urban sustainability, and the INDI model of the HQE$^2$R approach proved useful for the assessment of urban sustainability [24].

The goal of sustainable eco-city construction is to make cities inclusive, resilient, competitive, and efficient in resource use, as well as to mitigate and adapt to climate change for sustainable eco-city development. Sustainable construction of eco-cities includes sustainable construction of urban ecosystems and renewable energy management. Research on sustainable construction of urban ecosystems focuses on the complex interactions and practical conflicts among three perspectives: social, economic, and environmental. Renewable energy management mainly focuses on solar energy, and the management and utilization of solar energy have become indispensable conditions for the sustainable construction of ecological cities [25]. In addition, the impact of urban lifestyles and built environments on urban ecosystems and their ecological processes has also been regarded as a key impediment to the sustainable development of ecological cities [26]. These indicate that the subject is an evolving field of knowledge. An accurate understanding of the research progress and academic trends of SDEC is essential for conducting follow-up studies.

Bibliometrics first appeared at the beginning of the 20th century, and in 1969, it formed a separate discipline and was widely used in documentary analysis [27]. Bibliometric analysis provides a quantitative method for reviewing and surveying the extant literature in a given field [28]. Studies are analyzed by bibliometric means to gain a quick understanding of research progress in specific areas [29]. With the help of modern computer technology, graphical and visual results can complement bibliometric analysis. Co-citation is also often used in bibliometric analysis. A co-citation relationship is defined if two articles are cited by one or more other articles at the same time. In addition, most of the items associated with the paper can be applied to this method, including authors, keywords, institutions, and countries. Visualization helps to uncover intrinsic connections between this information, such as different authors having the same research topic, the research focuses of different institutions, and new theories from existing institutions [30].

Ecological cities and sustainable urban development have been analyzed by bibliometric methods [31–33]. For example, Rodrigues and Franco innovatively used the Prisma and Vantage Point methods to conduct a bibliometric analysis of eco-cites and sustainable urban development [34]. Although their study has contributions, it also has shortcomings. First, the number of papers used for the bibliometric analysis was too small, being only 70. Secondly, the earliest published paper year analyzed in this study was 2012. Finally, their article only discussed the number of papers, authors, journals, keywords, etc., and there was no good discussion on the inner connection between this information. Overall, the generality and breadth of their research results are relatively insufficient. Therefore, it is necessary to conduct a new comprehensive bibliometric analysis to supplement their research.
Therefore, based on the core collections of the Web of Science (WOS) database, this paper combines the advantages of CiteSpace and VOSviewer software for bibliometric analysis to systematically and visually analyze the literature on sustainable ecological urban development through visualization and explore the current status of the research, hotspots, and trends. The results obtained help the scientific community to understand the current environment and future trends in these subject areas of research and to make decisions before starting research.

2. Methods

2.1. Bibliometric Analysis

As a quantitative research method based on publications, citations, and textual data, bibliometrics is used to describe and analyze the development and progress of a research field. The findings of bibliometrics include the analysis of descriptive statistics, keywords, citations, authors, institutions, and their associations. Therefore, scholars often use bibliometric methods to explore patterns of publication evolution, research hotspots and trends, author collaboration networks, and other elements of a field [28]. Bibliometric analysis techniques have been widely used in many fields of science and engineering. For example, Baker et al. collected over 25 million papers and used bibliometric techniques to deeply analyze the progress of research on the use of drugs [35]. Kamalski et al. demonstrated the bibliometric analysis potential in an urban research context and explored how the field of urban research has been constructed [36]. In this paper, bibliometric visual analysis is performed with the help of CiteSpace (version 6.1.R2, Philadelphia, PA, USA) and VOSviewer (version 1.6.18, Leiden, The Netherlands) software.

2.2. Data Collection

Web of Science (Core Repository) contains more than 20,000 authoritative and high-impact academic journals and conference papers from around the world, covering natural sciences, social sciences, arts, humanities, etc. Web of Science (Core Repository) has been accepted by many researchers as a high-quality digital literature resource database and is considered the most suitable one for bibliometric analysis [37]. Therefore, in this paper, we selected Web of Science (Core Repository) as the data source, and the indexes selected were SSCI and SCI-Expended. in choosing the sample, our search strategy is shown below. The search period was from 1990 to 2021. Papers published in 2021 were included to ensure that we compared the complete annual cycle. English was chosen as the language, and articles and reviews were chosen as the document type. The search formula was TS = (*sustainab OR renewable energy OR *resilien) AND TS = (urban OR city) AND TS = (ecosystem OR ecologic OR ecology OR ecological OR envir*), where TS is the topic. The researchers screened each article and finally collected 1864 valid documents.

2.3. Data Processing

After collecting the data, first, we analyzed the evolution of the number of articles and subject areas in the SDEC field over the period from 1990 to 2021. Secondly, we analyzed the most prolific authors, countries, and institutions in the SDEC field and the cooperative networks among them. Third, we determined the major journals in the field of SDEC, as well as their SJRs, JIFs, and the number of citations of published papers in SDEC in 2020. Finally, we performed a visual analysis of the co-occurrence network of keywords and highlighted words in the field to identify research hotspots and trends. In Figure 1, we summarized the bibliometric analysis process.
3. Results

3.1. Evolution of the Sustainable Development of Eco-Cities (SDEC)

To better study the main characteristics of the sustainable development of the geographical environment (SDEC) over 30 years of research, our study period was divided into four periods based on 8 years. These four periods were the 1990–1997 period, the 1998–2005 period, the 2006–2013 period, and the 2014–2021 period, as shown in Table 1.

Table 1. Major characteristics of the sustainable development of eco-cities (SDEC) research.

| Period       | Articles | Authors | Journals | Countries | Citations | Average Citations |
|--------------|----------|---------|----------|-----------|-----------|-------------------|
| 1990–1997    | 11       | 26      | 9        | 6         | 271       | 24.64             |
| 1998–2005    | 43       | 109     | 30       | 21        | 3059      | 71.14             |
| 2006–2013    | 254      | 804     | 130      | 55        | 12772     | 50.28             |
| 2014–2021    | 1556     | 5608    | 349      | 101       | 33934     | 21.81             |
| **Total**    | **1864** | **6547**| **518**  | **183**   | **50036** | **26.84**         |

In Table 1, there were 11 publications on SDEC in the 1990–1997 period, while there were 1556 publications in the last period (2014–2020), an increase of more than 100-fold. This growth trend was reflected not only in the number of publications on SDEC research but also in the other variables considered in the table.

In terms of authors, a total of 26 scholars participated in the first period of the study (1990–1997), representing 0.40% of the total number of authors in the sample, while in the fourth period (2014–2020), the number of authors was 5608, representing 85.66% of the sample. This means that with the change in time, more and more scholars are focusing on the field and actively publishing related publications. In terms of journals, the number of journals increased from 9 in the first period to 349 in the fourth period, an increase of 3778%. In addition, the change in the number of journals in each period doubled. In terms of countries, a total of 101 countries were involved in research on SDEC up to the fourth period, accounting for about 51.26% of the global number of countries, which means that more than half of the countries worldwide are involved in SDEC research. It is worth noting that the sample recorded a total of 50,036 citations over the time frame analyzed, with an average of 26.84 citations per article for the four periods combined. Although the average number of citations per article increased approximately twofold from the first period to the second period, there was a decreasing trend in the third and fourth periods. Even the fourth period was lower than the total average of the four periods. This could also indicate that SDEC research is currently at a bottleneck. Although the number of publications is the highest, the related research lacks a large number of breakthrough results. However, it is also possible that the number of citations was relatively low because the fourth period had the shortest period up to the current one and was limited by time.
From 1990 to 2006, there were only a few papers on SDEC research publications in each of these 10 years. All of the numbers were no more than 10, and the growth was small. However, this trend improved as time went on. As shown in Figure 2, the number of publications has been steadily increasing since 1990, surpassing 100 for the first time in 2016 and reaching a staggering 408 articles in 2021. This may be because the impact of climate change is causing more and more scholars to focus on this area of research [38]. By fitting the curve with $R^2 = 0.9856$, we predict that the annual number of publications for SDEC research is expected to exceed 1000 by 2027.

3.2. Main Areas of Study in SDEC Research

A bibliometric analysis of the paper disciplines of SDEC research in the WOS data was conducted to explore the main areas of SDEC research. It should be noted that the same article could be simultaneously classified under more than one category. Therefore, the results were analyzed as percentages. Figure 3 shows the major areas of SDEC research for the study period from 1990 to 2021. Among the many research areas, Energy Fuels was the dominant discipline with 23% of the total, followed by Environmental Sciences (17%) and Green Sustainable Science Technology (16%). Lastly, there were Environmental Studies (7%), Engineering Environmental (7%), Thermodynamics (4%), and Engineering Chemical (4%). The disciplines labeled “Other” (22%) included a wide range of fields, with no field having a percentage higher than 4%, such as Construction Building Technology, Engineering Civil, Economics, Mechanics, Engineering Electrical Electronic Technology, Ecology, and Chemistry Physical. The key issues studied in the Energy Fuels category are related to renewable energy consumption [39], CO$_2$ emissions [40], sustainable planning [41], sustainable energy performance [42], etc. The categories of Green Sustainable Science Technology and Environmental Sciences focus on issues related to urban energy trajectories [43], ecological footprint [44], and green city strategies [45].
3.3. Main Authors of Study in SDEC Research

Analyzing the collaborative network of authors in the literature allowed us to understand the representative scholars and core research strengths in SDEC research. Therefore, we visualized the author collaboration network using VOSviewer software, and the results are shown in Figure 4. The top 10 authors’ information is presented according to the number of publications (Table 2). In Figure 4, the collaboration between authors can be understood by observing the connections between nodes, and the more complex the node connectivity, the more frequently the authors collaborated. We found that the network characteristics among the authors were not obvious, suggesting that highly productive author research teams and collaborative networks are not yet fully established in the SDEC field. Among the top 10 authors, Guohe Huang has published the largest number of papers but did not have the highest average number of citations per paper. Kristina Orehounig has published only 7 articles in the field of SDEC but has 733 total citations, with an average of 104.71 citations per paper. According to Price’s law, Equation (1) for measuring the minimum number of published works by the core authors in the field is presented below:

\[ m = 0.749 \times \sqrt{n_{\text{max}}} \]  

(1)

where \( m \) is the minimum number of publications by the core authors and \( n_{\text{max}} \) is the number of articles published by the first-ranked author.

The calculation results showed that \( m = 3.18 \). Therefore, the authors who published more than four articles (including four) were the core authors in the field, and there were 60 core authors with 301 published articles, accounting for 16.15% of the total sample size, which was lower than 50%. This indicates that after more than 30 years of development, a core group of authors in the field of SDEC formed initially, but further development is still needed.
Figure 4. Author cooperation network map.

Table 2. Top 10 authors by the number of publications.

| Rank | Author                | Count | Citations | Average Citations/Publication | Rank | Author                | Count | Citations | Average Citations/Publication |
|------|-----------------------|-------|-----------|-------------------------------|------|-----------------------|-------|-----------|-------------------------------|
| 1    | Huang, Guohe          | 18    | 551       | 30.61                         | 6    | Orehounig, Kristina   | 7     | 733       | 104.71                        |
| 2    | Duic, Neven           | 11    | 223       | 20.27                         | 7    | Yang, Hongxing        | 7     | 301       | 43.00                         |
| 3    | Senju, Tomonobu       | 10    | 68        | 6.80                          | 8    | Chen, Xin             | 6     | 294       | 49.00                         |
| 4    | Li, Yongping          | 8     | 178       | 22.25                         | 9    | Danish, Mir Sayed Shah| 6     | 51        | 8.50                          |
| 5    | Mostafaeipour, Ali    | 7     | 141       | 20.14                         | 10   | Mavromatidis, Georgios| 6     | 517       | 86.17                         |

3.4. Main Countries of Study in SDEC Research

The national collaboration networks in the SDGE field were analyzed using VOSviewer and Citespace software, and the results are shown in Table 3 and Figure 5. SDGE research is distributed worldwide, and the crucial countries engaged in SDGE research include China, the USA, Italy, England, and Turkey. According to Table 3, among the top 10 countries ranked by the number of publications, China, the USA, Italy, England, and Turkey published more than 100 articles, among which China published more than 350 publications, which was significantly higher than the amounts for the other countries. These 5 countries accounted for 19.10%, 12.66%, 8.58%, 6.60%, and 5.47% of the total number of publications, respectively, adding up to more than 45% of the total number of publications. This indicates that five countries—the USA, China, Italy, England, and Turkey—contributed the most papers to SDGE research. In Figure 5, the between-node centrality of China, the USA, England, and Spain is higher than 0.1. This indicates that these countries are at the core of the SDGE research field, and the related research has a significant impact on SDGE. In addition, as SDGE research is paid more and more attention to by scholars, regionalization and globalization will become essential trends in SDGE research.
3.5. Main Institutions of Study in SDEC Research

To understand the distribution of research power in the field of SDEC, we visualized and analyzed the research institutions as nodes to obtain a collaborative network diagram of research institutions (Figure 6). We also obtained the top 10 major research institutions according to the number of publications (Table 4). In Figure 6 and Table 4, Beijing Normal University has the highest number of publications (32), followed by North China Electric Power University (29) and the Chinese Academy of Sciences (28). It is worth mentioning that the top three institutions were all from China, which indicates that China attaches great importance to research in SDEC. In 2020, China proposed a “double carbon goal” at the 75th United Nations General Assembly, aiming to peak CO\textsubscript{2} emissions by 2030 and striving to achieve carbon neutrality by 2060. This goal brings new opportunities and challenges for China’s urban climate change resilience and low-carbon eco-sustainable development [46]. Many institutions are studying SDEC globally, but none have mediated a centrality of 0.1; that is, there are some collaborative relationships among institutions, but no sizeable collaborative group of multinational institutions has been formed. Therefore, regarding global SDEC research, there is still a need to strengthen the collaboration among different institutions and deepen the research from multiple perspectives.
Figure 6. Institutional cooperation network map.

Table 4. Top 10 institutions by the number of publications.

| Rank | Institution                | Year | Count | Centrality | Rank | Institution                        | Year | Count | Centrality |
|------|----------------------------|------|-------|------------|------|------------------------------------|------|-------|------------|
| 1    | Beijing Normal University | 2009 | 32    | 0.05       | 6    | University of Tehran              | 2008 | 19    | 0.03       |
| 2    | North China Electric Power University | 2015 | 29    | 0.07       | 7    | National University of Singapore | 2014 | 15    | 0.02       |
| 3    | Chinese Academy of Sciences | 2010 | 28    | 0.05       | 8    | Aalborg University                | 2010 | 15    | 0.03       |
| 4    | Islamic Azad University    | 2015 | 22    | 0.04       | 9    | University of Zagreb              | 2016 | 14    | 0.03       |
| 5    | Hong Kong Polytechnic University | 2004 | 20    | 0.05       | 10   | University of Regina              | 2009 | 13    | 0.00       |

3.6. Main Journals of Study in SDEC Research

This section shows the most prolific journals publishing SDEC research articles and analyzes their leading indicators (Table 5). The journals in the table cover various fields, such as cleaner production, renewable and sustainable energy, energy conversion, and energy management. The top 10 journals are from North America (USA), England, and Switzerland. The main journals by the number of papers are the *Journal of Cleaner Production*, *Renewable & Sustainable Energy Reviews*, *Sustainability*, and *Energies*, with 135, 124, 103, and 92 articles, respectively. The papers published in these 4 journals accounted for 24.36% of the total number of articles on this research topic.

The journal with the most published papers was the *Journal of Cleaner Production*, which accounted for 7.24% of the total sample. This journal had an SJR of 1.937 (Q1) and a JIF of 9.297 in 2020 and published 4012 citations of SDEC-related papers. It was followed by *Renewable & Sustainable Energy Reviews*, with 6.64% of the total sample. The journal’s 2020 SJR was 3.522 (Q1), with a JIF of 14.982 and a total of 7737 citations of published SDEC-related papers. In third place was *Sustainability*, with 5.53% of the total sample, an SJR (2020) of 0.612 (Q2), a JIF index of 3.251, and a total of 1108 citations of published SDEC-related papers. In fourth place was *Energies* with 5.20% of the total sample, an SJR (2020) of 0.598 (Q3), a JIF index of 3.004, and 969 citations of published SDEC-related papers.
The journals below these four results are from England, and all have high index scores, all being in the first quartile. It is worth noting that both *Sustainability* in third place and *Energies* in fourth place belong to open access journals, indicating that the strong growth of open access journals in recent years has enormously contributed to research progress in the field. Although scholars still disagree on the best way to achieve open access, the idea that research results should be freely available has been widely accepted [47].

Table 5. Top 10 journals by the number of publications.

| Rank | Journal                                      | Articles | SJR(2020)   | Country     | JIF (2020) | Citations | OA |
|------|----------------------------------------------|----------|-------------|-------------|------------|-----------|----|
| 1    | *Journal of Cleaner Production*              | 135      | 1.937 (Q1)  | USA         | 9.297      | 4012      | No |
| 2    | *Renewable & Sustainable Energy Reviews*    | 124      | 3.522 (Q1)  | USA         | 14.982     | 7737      | No |
| 3    | *Sustainability*                             | 103      | 0.612 (Q2)  | Switzerland | 3.251      | 1108      | Yes|
| 4    | *Energies*                                   | 92       | 0.598 (Q3)  | Switzerland | 3.004      | 969       | Yes|
| 5    | *Energy*                                     | 70       | 1.961 (Q1)  | England     | 7.147      | 2599      | No |
| 6    | *Applied Energy*                             | 69       | 3.035 (Q1)  | England     | 9.746      | 3900      | No |
| 7    | *Renewable Energy*                           | 68       | 1.825 (Q1)  | England     | 8.001      | 2350      | No |
| 8    | *Energy Policy*                              | 54       | 2.093 (Q1)  | England     | 6.142      | 2079      | No |
| 9    | *Sustainable Cities and Society*             | 48       | 1.645 (Q1)  | England     | 7.587      | 877       | No |
| 10   | *Energy Conversion and Management*           | 47       | 2.743 (Q1)  | England     | 9.709      | 1967      | No |

3.7. Research Hotspots in SDEC Research

To identify the research hotspots of SDEC, we conducted a keyword co-occurrence network analysis using VOSviewer, and the results are shown in Figure 7. In Figure 7, a total of 331 out of 8331 keywords appearing in publications between 1990 and 2021 are included, and each keyword was used at least 10 times, with the term “renewable energy” being the largest node and the most frequent. In addition, nodes with the same color belong to the same cluster. The high-frequency keywords based on symbiotic relationships around the research theme of urban microclimate presented the following five major research clusters, which can be used to analyze the main SDEC research contents, perspectives, and hotspots.

Figure 7. Keyword co-occurrence network map.
Cluster 1 (red) includes “performance”, “system”, “optimization”, “wind energy”, and “generation”. This represents SDEC’s focus on cleaner production and energy. In essence, cleaner production is a production model that adopts a holistic and preventive environmental strategy for production processes and products to reduce or eliminate their potential harm to human beings and the environment while fully satisfying human needs and maximizing socioeconomic benefits [48]. In the face of increasing adverse factors such as resource scarcity, population explosion, and environmental degradation, cleaner production and cleaner energy provide a valuable solution for cities to cope with the negative effects of these adverse factors from a sustainability perspective. It not only effectively reconciles economic and environmental benefits but also contributes to the construction and development of ecological cities [49,50].

Cluster 2 (green) illustrates the importance of sustainable urban buildings for sustainable development through high-frequency words such as “sustainability”, “consumption”, “cities”, “buildings”, and “energy efficiency”. According to the United Nations Environment Programme (UNEP), the building sector accounts for 40% of total energy consumption. In European countries, 36% of total greenhouse gas emissions are attributed to buildings [51]. Developing a greener and smarter built environment is one of the trends for the future development of eco-cities [52]. On the other hand, green buildings have sparked interest in this field of research because they are healthier and more sustainable. Determining and developing efficient energy solutions associated with green buildings to address future energy needs remains critical. In addition, the design process for green buildings must consider the fundamental parameters of cost, maintenance, and operation to maximize economic and social benefits based on low carbon emissions and energy efficiency [53,54].

Cluster 3 (blue) includes the high-frequency words “management”, “life-cycle assessment”, “biogas”, “anaerobic-digestion”, “municipal solid-waste”, and so on. This shows the correlation between solid waste management, anaerobic digestion technology, life cycle assessment, and SDEC. These keywords show that scholars’ research on municipal solid waste disposal and life cycle assessment is significant for the sustainable development of ecological cities. Since the oil crisis in the 1970s, life cycle assessment methods have been gradually adopted internationally for environmental impact assessment of solid waste problems [55]. With the increased awareness of the hazards of municipal solid waste to the environment and human health, research on municipal solid waste has been of great interest to scholars for the past three decades [56]. Meanwhile, based on the concept of sustainable development, anaerobic digestion technology has attracted academic interest because of its ability to convert the energy of solid organic matter into biogas for combustion or power generation to achieve resource and energy recovery treatment.

Cluster 4 (yellow) focuses on energy policies for cities that address the challenges of climate change, including “renewable energy”, “climate change”, “cities”, “energy efficiency”, “energy policy”, “future”, and other high-frequency words. Cities are more vulnerable to climate change due to their more concentrated infrastructure, population, and resource allocation. In addition, cities consume vast amounts of non-renewable resources, and many cities have had to develop energy policies to facilitate the disadvantages of energy depletion [57]. However, it is worth noting that only a few cities have energy policies that consider climate change and sustainable development measures [58]. Therefore, achieving renewable energy to manage adaptation effectively and attain a genuinely sustainable urban ecology remains challenging. Moreover, climate change as part of the global political agenda also urgently requires harmonizing international sustainability goals in energy policy.

Cluster 5 (purple) focuses on China’s carbon emissions and economic development, and it includes the following high-frequency words: “China”, “impact”, “CO2 emission”, “economic growth”, and “energy consumption”. China implemented the reform and opening-up policy in 1978, and in the following 30 years of development, China has gradually become one of the fastest growing economies in the world [59,60]. However, China’s economic development cannot be separated from its energy consumption, and
according to statistics, nearly 90% of China’s carbon emissions come from the energy sector. This has led to a growing situation of carbon emissions [61]. According to the United Nations Environment Programme’s Emissions Gap Report 2019, China is the world’s largest carbon emitter, accounting for more than a quarter of global carbon emissions in 2018. At the 76th session of the UN General Assembly, China proposed that it will strive to achieve carbon peaking by 2030 and carbon neutrality by 2060. Carbon emissions are important quantitative information in sustainable development, and China, as the world’s most populous country, cannot achieve global urban ecological sustainability without its presence [62].

The co-citation statistics can show the articles that are highly cited and represent specific works on SDEC research. Table 6 lists the 10 most cited papers in this area. The most cited article is titled “Modelling solar potential in the urban environment: a state-of-the-art review”, with 29 citations. In this article, Kasman et al. reviewed concepts and models for estimating and representing solar potential in complex landscapes. They suggest a new trend in using multiple GIS tools for energy analysis in urban environments [63]. The work of these 10 articles can be found to focus on new energy utilization, green infrastructure development, and modeling and urban transformation strategies for sustainable development of eco-cities.

Table 6. Top 10 most cited articles.

| Rank | Title                                                                 | Year | Citations |
|------|----------------------------------------------------------------------|------|-----------|
| 1    | Modelling solar potential in the urban environment: State-of-the-art review | 2015 | 29        |
| 2    | Environmental Accounting: EMERGY and Environmental Decision Making   | 1996 | 29        |
| 3    | 4th Generation District Heating (4GDH) Integrating smart thermal grids into future sustainable energy systems | 2014 | 28        |
| 4    | City-integrated renewable energy for urban sustainability             | 2016 | 24        |
| 5    | Geographies of energy transition: Space, place and the low-carbon economy | 2013 | 23        |
| 6    | Social perceptions about a technological innovation for fuelwood cooking: Case study in rural Mexico | 2007 | 23        |
| 7    | 2006. Environmental management—Life cycle assessment—Principles and framework | 2006 | 22        |
| 8    | CO₂ emissions, economic growth, energy consumption, trade and urbanization in new EU member and candidate countries: A panel data analysis | 2015 | 21        |
| 9    | A review on buildings energy consumption information                   | 2008 | 21        |
| 10   | Solar energy and urban morphology: Scenarios for increasing the renewable energy potential of neighbourhoods in London | 2015 | 20        |

3.7.1. Sustainable Development of Eco-Cities and New Energy Utilization

According to statistics, total global energy consumption has increased twofold in the last 50 years, with the proportion of traditional energy sources declining and the proportion of new energy sources in final energy consumption continuing to grow. The development and research technology of new energy use has not yet been able to promote the large-scale use of new energy. Still, the conditions for small-scale development and use in local areas of cities are already available, especially in eco-cities, where new energy should be considered in the urban energy system at the early stage of urban construction. In recent years, solar energy utilization technology has received widespread attention. Many countries have begun to study solar energy utilization at the urban scale, closely integrating solar energy with urban spatial structure, building forms, public space utilization, etc. [64,65]. Nasrollahi et al. pointed out that widening streets has an increasing impact on the amount of radiation reaching urban canyons and reduces energy consumption. The results of their study show the parameters affecting the amount of radiation reaching urban neighborhoods, visual comfort, and energy consumption reduction, which are listed in order of their
priority: urban canyon geometry, surface reflectance, external shading devices, roof shape, street orientation, and sky view factor (SVF) [66]. Huide Fu et al. presented validated simulation models for solar thermal (ST), photovoltaic (PV), and photovoltaic/thermal (PV/T) systems, and an energy comparison was performed for three solar systems adopted in Hong Kong, Lhasa, Shanghai, and Beijing, respectively. The results of their study show that for urban residential buildings with limited available installation space, hybrid PV/T systems may have the greatest energy savings potential among solar thermal, PV, and hybrid PV/T systems [67]. Mohajeri et al. studied the impact of urban compactness on solar potential. They found an increase in annual solar radiation of up to 30–40% from compact to decentralized neighborhoods [68]. It can be seen that urban compactness can strongly influence the use of urban solar energy. Therefore, it is a topic that needs to be strengthened to establish relevant models to accurately predict and evaluate the impact of the urban spatial structure as well as energy systems on solar energy utilization and to provide a scientific basis for urban spatial planning, building design, and energy systems in recent years.

3.7.2. Sustainable Development of Eco-Cities and Green Infrastructure

Green infrastructure (GI) is a network of interconnected green spaces consisting of various open spaces and natural areas such as parks, green roofs, bio walls, street trees, permeable pavers, and community gardens [69,70]. Green infrastructure can connect ecological islands into ecological networks, thereby maintaining ecological balance and biological populations, promoting urban ecology, and preserving natural biodiversity [71]. Green infrastructure practices are widely used as source control measures to treat stormwater. Resident behaviors and perceptions can significantly influence the implementation and maintenance management of green infrastructure and provide relevant recommendations for its construction [72]. Through an extensive social survey of stakeholders in New York City, Miller et al. found that while stormwater management is a major driver of GI investment in New York City, a focus on multifunctional green facilities and design to provide simultaneous multiple ecosystem service (ES) sites may increase public support for green facilities and provide additional local value [73]. In addition, as the value and function of GI in preserving ecosystems begins to be widely recognized with the increased focus on ES issues, urban planners and policymakers are seeking the most appropriate configuration of green infrastructure tools, such as geographic information systems (GIS), spatial planning, and climate strategies [74,75]. Attention is now focused on the potential of building green infrastructure to solve various urban problems. Wendy Y. Chen examined how urban green infrastructure contributes to the carbon balance of 35 major cities in China. Her study showed that the total amount of carbon stored in urban green infrastructure vegetation in the 35 cities was estimated to be 18.7 million tons [76]. Abdulateef et al. assessed the effectiveness of green infrastructure in reducing the surface heat island effect in Baghdad. They used a computer program to simulate regional surface temperatures and found that green infrastructure effectively reduced the intensity of the surface heat island effect by 4–22 °C [77]. Green infrastructure has gradually become a scientific tool to guide the method of land use. Meanwhile, green infrastructure, as an important form of urban ecological infrastructure implementation, has been included by many researchers and government agencies in the consideration for eco-city construction and planning.

3.7.3. Sustainable Development of Eco-Cities and Urban Transformation

Rapid urbanization is taking place, but it also brings serious demographic and environmental problems. Resource-based cities in particular are facing challenges from resource depletion and environmental issues, and urban change is imminent. Ecological and sustainable development perspectives are receiving increasing attention in promoting urban transformation, and the feasibility of the eco-city concept, including integrated management systems, has been successfully demonstrated in many cities and regions. Mei-Chih Hu et al. conducted a comparative case study of three Asian cities (Penghu (Taiwan), Seoul
(Korea), and Tianjin (China)). They found that the eco-urban transformation process in Asian cities was based on different development models but similar in terms of the use of national capacity [78]. By coordinating with national development systems and resources, each city developed its renewable energy portfolio to transform itself into an environmentally specific and sustainable low-carbon city. In addition to scientific decisions, appropriate assessment methods and models for planners and decision makers are essential to facilitate the eco-city transition [79]. However, due to the complexity of urban development, no single method can provide a perfect evaluation of a city’s overall development. Therefore, various evaluation methods need to be integrated to meet the different needs from the economic, environmental, and social perspectives. In addition, different cities face different dominant factors in ecological transformation, and further research is needed on achieving urban transformation with maximum efficiency.

3.8. Frontier Trending in SDEC Research

To attain a clearer understanding of the development process and research trends of SDEC, the burst word analysis function of CiteSpace software can be further utilized, and the results are shown in Table 7. “Year” indicates the year of the start of the burst detection. A higher strength indicates that the mutation term is receiving more short-term attention in its research field.

| Keywords                  | Year | Strength | Beginning | End   | 1990–2021                      |
|---------------------------|------|----------|-----------|-------|-------------------------------|
| Sustainable development   | 1990 | 3.37     | 1996      | 2007  |                               |
| Sustainability           | 1990 | 5.60     | 2009      | 2014  |                               |
| Renewable energy         | 1990 | 4.89     | 2009      | 2012  |                               |
| Energy                   | 1990 | 6.35     | 2011      | 2013  |                               |
| Future                   | 1990 | 3.95     | 2011      | 2012  |                               |
| Policy                   | 1990 | 3.65     | 2011      | 2018  |                               |
| Land use                 | 1990 | 3.85     | 2012      | 2015  |                               |
| Bioenergy                | 1990 | 3.35     | 2012      | 2018  |                               |
| Urban metabolism         | 1990 | 3.89     | 2014      | 2017  |                               |
| Emission                 | 1990 | 4.51     | 2016      | 2017  |                               |
| Tool                     | 1990 | 3.6      | 2016      | 2019  |                               |
| Urban planning           | 1990 | 3.48     | 2018      | 2019  |                               |
| Ecosystem service        | 1990 | 3.39     | 2018      | 2019  |                               |
| Performance analysis     | 1990 | 5.09     | 2019      | 2021  |                               |
| Solar radiation          | 1990 | 3.27     | 2019      | 2021  |                               |

Note: Each blue line represents a year. The year in which the keyword bursts is replaced by a red line.

Table 7 shows the evolution process of SDEC research topics over time. Based on the temporal distribution of key nodes, we summarize the development trends in the SDEC research field as follows. (1) Sustainability has been an essential topic in the SDEC research field, and the keywords of sustainability appeared in the area as early as 1996.
(2) From 2009 to 2012, there were several key nodes related to the topic of energy, including renewable energy and bioenergy, which indicates that the topic has gradually received the attention of scholars. During this period, topics such as land use and policy also appeared together, which indicates that the research on SDEC was in the exploratory stage, and scholars have discussed different topics and researched them extensively [80]. (3) Since 2014, with the increasing prominence of sustainable development requirements and the increasingly stringent standards for carbon emissions, urban green planning and urban ecosystem services have become the main research directions of SDEC. In addition, scholars’ research on the performance analysis of urban ecosystems and the impact of solar radiation on urban ecology has gradually become a mainstream trend in the field [81,82].

4. Discussion

Low-carbon, ecological, and green development of cities is an important way to solve the resource and energy crisis, mitigate ecological and environmental degradation, and cope with climate change. Many cities and regions worldwide have set short- and long-term development goals, such as Waitakere (New Zealand), Copenhagen (Denmark), and Cleveland (USA). They have produced detailed sustainable development plans around one or several aspects of urban ecological construction to address many of the issues faced during the urban ecological transition well [83,84]. At the same time, there has been a significant increase in academic studies on the topic of sustainable development of ecological cities in the past three decades, and there are significant positive trends. The results of this paper show that the first research article on the sustainable development of eco-cities was published in 1992. Since then, the number of published articles has shown a continuous growth trend. To analyze in depth the evolution of the field of urban ecological sustainability, this paper divided the research period into four periods of 8 years each. The first period was the initial phase of the study (1990–1997), during which the number of articles published was relatively small, with only 11 publications on SDEC, a relatively singular focus for its research theme, and slow overall research progress. However, in the last period (2014–2020), there were 1556 publications, and the number of authors, countries, and journals involved in the study doubled. This changing trend is related to the growing societal interest in sustainable urban development. The impacts of climate change have led to an increasing number of scholars focusing on research in this field. Furthermore, by fitting the curve with $R^2 = 0.9856$, we predict that the number of annual publications of SDEC research is expected to exceed 1000 by 2027.

At present, the research topics in this field mainly focus on complex practical problems such as ecological city construction and sustainable development, and the research content is becoming more and more organized and systematic. Based on the clustering results, we can extract five frontier hotspots in this field: clean production, green and sustainable urban architecture, urban solid waste treatment, energy policy, and carbon emission and economic development in China. These results show a trend of cross-fertilization with environmental science, green sustainable science and technology, thermodynamics, public policy, political science, geography, economics, and other disciplines, and they indicate expanding research in the field. At the same time, it is worth noting that although the theme of eco-city construction and sustainable development has become very popular in recent years, scholars’ research perspectives are not limited to directly analyzing the influencing factors of eco-city construction and sustainable development; they also consider the geographic environment, socioeconomic development, public finance, and other related aspects. In terms of research methods, the field has developed a research system of GIS, theoretical models, survey interviews, and other methods. Analyzing and summarizing the co-cited literature, we found that the main hot issues scholars focused on included new energy utilization, green infrastructure, and urban transformation, and they pay more attention to the combination of new energy and environment, the social and ecological benefits of green infrastructure, and the strategy and evaluation of urban transformation to meet the challenges of climate change, dramatic population growth, environmental
pollution, and energy depletion on ecological city construction. In addition, by analyzing and summarizing the highlighted terms, we found that urban green planning and urban ecosystem services have become the main research directions. Future development trends include performance analysis and whole life cycle assessment of urban ecosystems.

Although this paper has contributions, it still has limitations and needs future development. It is worth noting that we only selected the WOS database for the bibliometric analysis, and the results of this study may not fully reflect the complete research on the sustainable development of ecological cities. There are other databases, such as Scopus, that were not considered. However, the WOS database, as one of the most comprehensive databases in the world, contains many high-quality publications that can represent the research hotspots and frontiers in the field.

In the future, we can strengthen the research areas of sustainable development of ecological cities in the following aspects. (1) We should strengthen technological innovation. The current research in this field mainly conducts environmental simulation or technology assessment by establishing relevant models, and it lacks practical technological innovation. The research perspective can also be innovative in two aspects: efficient energy conversion technology and renewable energy management system. (2) We should strengthen the research on the concerns of stakeholders in ecological city construction. The target of urban public services is the public, and public opinion and acceptance play an important role in effectively implementing relevant policies and plans. The eco-city construction plans of different cities and regions should be in line with the development status and conditions of the region as well as the needs of the public. Copying from other regions is obviously out of touch with reality, especially in underdeveloped areas. (3) Further research can focus on the social, economic, and environmental issues facing the ecological transformation of cities. With the accelerated urbanization process, how to effectively promote ecological urban transformation while considering economic development, social progress, and environmental management is still an urgent issue.

5. Conclusions

In this paper, a sample of 1864 articles between 1990 and 2021 was analyzed using a combination of CiteSpace and VOSviewer software to present the current status and development of ecological urban sustainability research over three decades. To achieve this goal, an in-depth analysis of the nature of publications, research hotspots, the most relevant research trends, and future directions on the subject was conducted.

The results show that over the past 30 years, more and more scholars have focused on SDEC due to climate change, the research literature on SDEC has grown, and research has become more diverse and global. Worldwide, scholars from China, the United States, Italy, and England are the most important contributors to the literature on SDEC. Although a core group of authors was initially formed, the overall collaborative network remains relatively fragmented. Analysis of relevant journals revealed that open-source journals have strongly contributed to the development of SDEC research. In addition, keywords, co-citation analysis, and highlighted words indicate that SDEC research mainly focuses on clean production, sustainable buildings, municipal solid waste management, energy policies, and carbon emissions in China. The most advanced studies are related to three areas: new energy use, green infrastructure, and urban transformation. With the emergence of climate change, carbon emission limits, and sustainability requirements, future research by scholars targeting performance analysis and whole life cycle assessment of urban ecosystems will gradually become a mainstream trend.

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