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Unraveling the Drivers of Urban Carbon-Neutral Systems: A Bibliometric Analysis, Systematic Review, and Future Research Directions

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ABSTRACT

Climate change has intensified the need for integrated urban carbon-neutral systems as cities account for a substantial share of global energy consumption and greenhouse gas emissions. However, existing studies remain fragmented across technological, governance, spatial, environmental, and socio-economic perspectives, limiting a comprehensive understanding of the key drivers underpinning urban carbon-neutral transitions. This study aims to identify and synthesize the principal drivers of urban carbon-neutral systems by integrating bibliometric analysis with a systematic literature review. A two-stage review design was employed using 661 Scopus-indexed publications published between 2017 and 2025. Bibliometric analysis was first conducted to examine publication trends, influential journals, authors, countries, collaboration networks, and thematic evolution, followed by a PRISMA 2020-guided systematic literature review that identified 51 high- and moderate-quality studies for qualitative synthesis. The findings reveal seven interrelated drivers of urban carbon-neutral systems, namely technological innovation, urban green spaces, energy systems and infrastructure, policy and governance, socio-economic factors, urban form and design, and climate and environmental factors. China emerged as the most productive country in the bibliometric analysis, while the systematic literature review demonstrated that these drivers operate as interconnected components of an integrated urban system rather than independent determinants, leading to the development of a conceptual framework for urban carbon-neutral transitions. The findings provide practical guidance for policymakers and urban planners in developing integrated technological, governance, spatial, and environmental strategies to accelerate urban carbon-neutral transitions, while offering a conceptual foundation for future empirical research.

1. INTRODUCTION

Climate change continues to pose one of the most significant challenges to global sustainability. Urban areas account for approximately 70% of global energy-related carbon dioxide (CO_2) emissions while simultaneously serving as centres of economic activity, technological innovation, and population growth [1, 2]. Consequently, cities have become critical arenas for achieving carbon neutrality through integrated technological, institutional, spatial, and socio-economic transformations. Owing to their relatively flexible governance structures, innovation capacity, and proximity to local stakeholders, cities are well positioned to design, implement, and evaluate carbon-neutral transition strategies [3].

Urban carbon-neutral systems refer to integrated technological, institutional, spatial, socio-economic, and environmental arrangements designed to facilitate long-term decarbonization while maintaining sustainable urban development [4, 5]. Realizing such systems calls for a systemic view that encompasses the interplay among energy infrastructure, governance frameworks, land-use planning, and social dynamics [6-8]. Theoretically, it contributes to sustainability science by expanding the scope of research on urban transformation from an isolated focus on patterns of built form toward system-level interactions [8, 9], while implementing changing policies to improve environmental quality and build resilient cities.

Academics have studied various aspects of urban decarbonization. According to previous studies, mitigation strategies should consider low-carbon technologies, with prominent examples being renewable energy integration, energy-efficient buildings, and smart energy systems [10, 11]. However, more studies highlight sustainable transportation, eco-infrastructure, and land-utilization designs to minimize emissions and promote carbon sinks [11, 12]. Governance-related studies have investigated policy instruments and extant regulatory frameworks that enable urban decarbonization [9].

However, existing studies remain fragmented across technological, spatial, environmental, and governance perspectives, with limited attention given to the interrelationships among these dimensions within urban carbon-neutral systems [8]. This fragmentation constrains the development of a comprehensive understanding of how multiple drivers collectively influence urban carbon-neutral transitions, thereby limiting the formulation of integrated and effective decarbonization strategies. Furthermore, existing review studies are predominantly narrative or thematic in nature, while relatively few have combined bibliometric analysis with systematic literature review to comprehensively examine the intellectual structure and evolving research themes in this field [13].

This study employs a holistic approach that combines bibliometric analysis and systematic literature review to mitigate these limitations. Bibliometric analysis identifies publication trends, dominant authors, and thematic structures based on citation patterns and networks [8, 13, 14]. A systematic literature review offers comprehensive conceptual insights and synthesis of the theme [10, 15, 16]. Together, these complementary methods provide a comprehensive approach to mapping knowledge structures and identifying the principal drivers of urban carbon-neutral systems.

This study adds to the literature in three key aspects. First and foremost, by identifying and synthesizing key interlinked drivers, it promotes a system-level understanding of urban carbon-neutral systems. It bridges fragmented research streams by proposing an integrative conceptual framework. It is a valuable resource for policymakers and urban planners seeking practical guidance on developing integrated and flexible approaches to carbon-neutral urban development.

This study systematically analyzes the evolution, landmarks, and driving forces of research on urban carbon-neutral systems. The analysis considers peer-reviewed journal articles indexed in the Scopus database to maintain academic rigor and global relevance [17, 18]. A global perspective can capture the bird's-eye view of global research trends. Based on the identified gaps and goals, this study answers the following research questions:

RQ1: Which articles, journals, countries, and authors hold the most significant influence in the field of urban carbon-neutral systems?

RQ2: What research contexts and thematic determinants related to urban carbon-neutral systems have been explored over the past decade?

RQ3: What are the potential future research directions for advancing research on urban carbon-neutral systems?

The remainder of this paper is organized as follows. Section 2 describes the research methodology. Section 3 presents the results of the bibliometric analysis and systematic literature review, followed by the discussion of the findings. Section 4 outlines future research directions. Section 5 discusses the theoretical and practical implications of the study, its limitations, and recommendations for future research. Finally, Section 6 concludes the study.

2. METHODS

2.1 Research design

This study adopted a two-stage research design integrating bibliometric analysis and a systematic literature review to provide a comprehensive understanding of urban carbon-neutral systems research. The integration of these two complementary approaches enabled both a quantitative mapping of the intellectual structure of the research field and a qualitative synthesis of the underlying drivers and future research directions. While bibliometric analysis objectively identifies publication trends, influential contributors, collaboration networks, and thematic structures, the systematic literature review facilitates an in-depth interpretation of the evidence reported in the selected studies. This integrated review design combines quantitative science mapping with qualitative evidence synthesis, thereby providing a comprehensive understanding of the intellectual development, key drivers, and future research directions of urban carbon-neutral systems [13, 18].

In the first stage, bibliometric analysis was conducted using the complete dataset retrieved from the Scopus database. A total of 661 publications published between 2017 and 2025 were retrieved from the Scopus database using the predefined search strategy. The complete dataset was retained for bibliometric mapping to examine annual publication trends, leading journals, productive countries, influential authors, keyword co-occurrence networks, and thematic evolution. Using the entire dataset ensured a comprehensive representation of the intellectual landscape and research evolution of urban carbon-neutral systems.

In the second stage, the same initial dataset underwent a systematic screening process following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020) guidelines [19]. Eligibility screening and quality assessment were subsequently performed to identify studies suitable for qualitative synthesis. After applying the predefined inclusion criteria and quality assessment, 51 high- and moderate-quality studies were retained for the systematic literature review. These selected studies formed the basis for identifying the principal drivers of urban carbon-neutral systems and establishing a robust conceptual foundation for the proposed research framework.

Figure 1 illustrates the overall research design and study selection process. Although both analytical stages originated from the same Scopus search strategy, they were conducted using different datasets for distinct analytical purposes. Specifically, the bibliometric analysis was performed using the complete dataset of 661 Scopus-indexed publications to examine publication trends, collaboration networks, thematic evolution, and the intellectual structure of urban carbon-neutral systems research. In contrast, the systematic literature review synthesized evidence from the final 51 studies that satisfied all predefined eligibility and quality assessment criteria following the PRISMA 2020 guidelines. Accordingly, the bibliometric analysis and the systematic literature review should be regarded as complementary analytical components rather than analyses conducted on an identical dataset. The procedures adopted in each stage are described in the following sections.

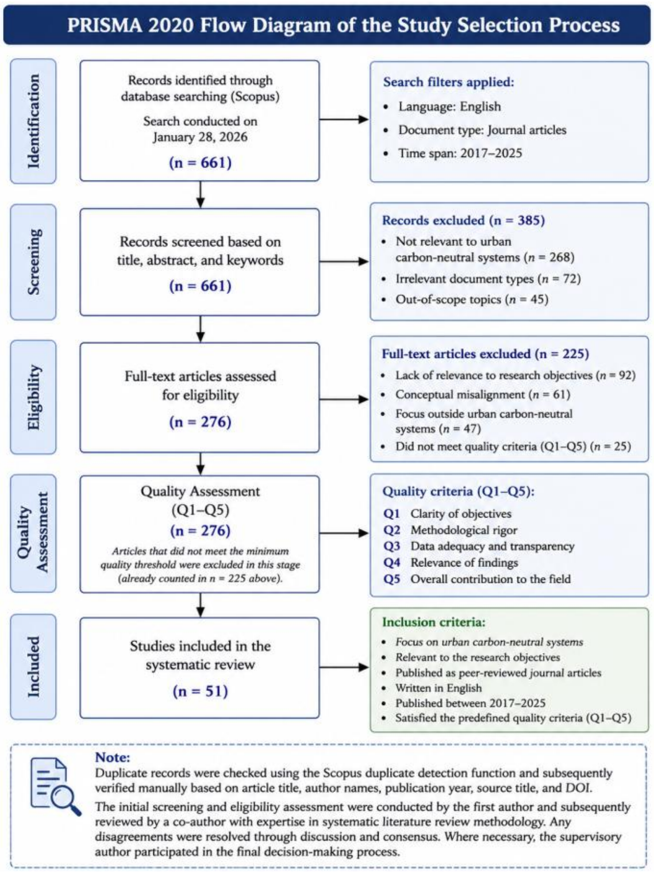

Figure 1. Study selection process following the PRISMA 2020 guidelines
Source(s): created by the authors.

2.2 Study selection process

The study selection process was conducted systematically following the PRISMA 2020 guidelines to ensure a transparent, rigorous, and reproducible identification of relevant studies [19]. The Scopus database was selected as the primary data source because of its broad multidisciplinary coverage, standardized bibliographic metadata, and extensive indexing of high-quality peer-reviewed journals, making it particularly suitable for bibliometric analysis and systematic literature reviews [13, 18].

A comprehensive search strategy was developed using a combination of keywords representing three major components: (1) carbon-neutral concepts, (2) urban contexts, and (3) determinant-related terms. Boolean operators ("AND" and "OR") were employed to combine the search terms and maximize retrieval accuracy. The search was conducted on January 28, 2026, using the following search query:

TITLE-ABS-KEY
("carbon neutral*" OR "net zero" OR "low carbon city" OR "urban decarbonization")
AND ("urban system*" OR "city" OR "urban area")
AND ("determinant*" OR "driver*" OR "factor*" OR "influence*")

The inclusion criteria comprised studies that (1) were published as peer-reviewed journal articles, (2) were written in English, (3) were published between 2017 and 2025, and (4) explicitly addressed urban carbon-neutral systems or closely related topics. Conversely, conference papers, book chapters, editorials, notes, non-English publications, and studies outside the scope of urban carbon-neutral systems were excluded from the review [19].

The search strategy identified 661 publications. Prior to the screening process, duplicate records were checked using the duplicate detection function available in Scopus and subsequently verified manually by comparing article titles, author names, publication year, source title, and DOI to ensure dataset consistency. The remaining records were screened based on their titles, abstracts, and keywords to assess their relevance to the objectives of this study. During this stage, 385 records were excluded because they were unrelated to urban carbon-neutral systems, represented document types outside the predefined inclusion criteria, or addressed research topics beyond the scope of this review. Consequently, 276 publications proceeded to the full-text eligibility assessment.

The full-text screening involved a detailed evaluation of each publication to determine its conceptual relevance, methodological suitability, and contribution to understanding the drivers of urban carbon-neutral systems. Studies were excluded if they did not adequately address the research objectives, demonstrated conceptual misalignment with the scope of this review, focused primarily on application domains unrelated to urban carbon-neutral systems, or did not satisfy the predefined quality assessment criteria. Following the eligibility assessment, 51 studies fulfilled all inclusion requirements and were retained for the subsequent systematic literature review. The complete study selection process is illustrated in Figure 1.

To enhance the transparency and reliability of the study selection process, the initial screening and eligibility assessment were conducted by the first author. The screening results were subsequently reviewed and validated by a co-author with expertise in SLR methodology to verify the consistency of study selection decisions. Any discrepancies regarding study eligibility were resolved through discussion until consensus was achieved. Where necessary, the supervisory author provided methodological guidance and participated in the final decision-making process to ensure consistency with the predefined inclusion and exclusion criteria. This collaborative review process minimized potential selection bias and enhanced the credibility, transparency, and reproducibility of the systematic literature review.

2.3 Quality assessment

To ensure the methodological rigor and reliability of the systematic literature review, a structured quality assessment was conducted after the full-text eligibility screening [18, 19]. The quality assessment aimed to evaluate the relevance, methodological soundness, and overall contribution of each eligible study before its inclusion in the final qualitative synthesis. Consistent with established systematic literature review practices, only studies demonstrating adequate methodological quality were retained for subsequent qualitative synthesis [13].

The quality assessment was performed using five predefined evaluation criteria adapted from established systematic literature review guidelines. Each eligible study was independently assessed against the following questions:

Q1. Does the study explicitly focus on urban carbon-neutral systems?

Q2. Is the research content presented clearly and comprehensively?

Q3. Is the research methodology appropriate and rigorously implemented?

Q4. Are the findings logically interpreted and adequately discussed?

Q5. Does the study provide sufficient evidence relevant to the objectives of this review?

Each criterion was scored using a three-point evaluation scale, where 1 indicated full compliance with the assessment criterion, 0.5 indicated partial compliance, and 0 indicated non-compliance. The initial assessment was conducted by the first author and subsequently reviewed by a co-author with expertise in systematic literature review methodology. Any differences in quality assessment were resolved through discussion until consensus was achieved. Where necessary, the supervisory author provided methodological guidance to ensure the consistent application of the predefined evaluation criteria.

Studies with a final quality score of 3.0 or above were classified as high quality; studies scoring between 1.5 and 3.0 were classified as moderate quality, whereas studies scoring below 1.5 were considered low quality. Only studies classified as high or moderate quality were retained for the final systematic literature review. Following this assessment, 51 studies satisfied all quality requirements and were included in the qualitative synthesis. This quality assessment procedure enhanced the methodological rigor, transparency, and reproducibility of the review by ensuring that all included studies satisfied predefined evaluation standards before qualitative synthesis.

2.4 Bibliometric data analysis

Bibliometric analysis was conducted using the bibliometrix package through the Biblioshiny interface in RStudio, which provides comprehensive tools for science mapping and quantitative analysis of bibliographic data [13, 19]. The complete bibliometric dataset consisting of 661 Scopus-indexed publications was used to identify publication trends, leading journals, productive countries, influential authors, collaboration networks, keyword co-occurrence, thematic evolution, and the intellectual structure of urban carbon-neutral systems research. Unlike the systematic literature review, which synthesized evidence from the final 51 eligible studies, the bibliometric analysis retained the complete dataset to provide a comprehensive overview of the research landscape.

The bibliometric analysis included performance analysis and science mapping techniques. Performance analysis was used to evaluate publication productivity, citation impact, influential authors, journals, institutions, and countries, whereas science mapping explored the intellectual structure of the research field through co-authorship, keyword co-occurrence, thematic evolution, and conceptual structure analyses. Network visualizations and thematic maps were generated using Biblioshiny to facilitate the interpretation of research trends and knowledge development within the field.

Before constructing the bibliometric networks, the metadata exported from Scopus underwent additional preprocessing to improve data consistency and analytical reliability. Duplicate records had already been removed during the PRISMA screening process and were further verified prior to bibliometric analysis. Variations in author names, institutional affiliations, and country information were manually reviewed using the available Scopus metadata. Particular attention was given to common author names that could potentially represent different researchers, such as *Jing Liu* and *Wei Liu*. Where ambiguity was identified, author identities were cross-checked using institutional affiliations, publication records, research topics, and Scopus author metadata where available. Considering the manageable size of the bibliometric dataset, ambiguous cases were resolved through manual validation rather than automated algorithmic disambiguation to improve the reliability of author productivity, collaboration, and country-level analyses.

For network construction, full counting was applied to preserve all co-authorship and keyword relationships contained in the bibliographic records. Keyword co-occurrence networks were generated using authors' keywords, with edge weights representing the frequency of co-occurrence between keyword pairs. Biblioshiny's default association-strength normalization was applied to reduce the influence of highly frequent keywords and to improve comparability across network nodes. Cluster identification was performed using the Louvain community detection algorithm implemented in Bibliometrix, whereas network visualization employed the default layout optimization provided by Biblioshiny. To improve network readability and reduce visual noise, isolated nodes and extremely weak connections were excluded from graphical visualizations where appropriate, while all bibliometric calculations were performed using the complete dataset.

The bibliometric findings were subsequently integrated with the systematic literature review to support the qualitative synthesis of the seven principal drivers of urban carbon-neutral systems and the development of the proposed conceptual framework.

3. RESULTS AND DISCUSSION

3.1 Bibliometric analysis

3.1.1 Trend of publication

The annual trends of published research papers on the factors influencing urban carbon-neutral systems are illustrated in Figure 2, which illustrates the annual publication trend in urban carbon-neutral systems research between 2017 and 2025. In general, the publication pattern is shown to be non-monotonic and reveals different scholarly interests. Initially, only one article was published in 2017, and the same number in 2019. Thereafter, an overall upward trend was observed over the period 2022–2025, although with fluctuations. Although the number of publications remains relatively small, a clear upward trend is observed, indicating growing academic interest in urban carbon-neutral systems.

3.1.2 Most globally cited articles

An assortment of the most impactful papers related to determinants that influence urban carbon-neutral systems is displayed in Table 1. These papers exhibit strong academic influence, as indicated by their citation numbers, bearing evidence of their place in scientific literature. One highly cited study is *"How effective has the low-carbon city pilot policy* *been as an environmental intervention in curbing pollution? Evidence from Chinese industrial enterprises,"* which was published in Energy Economics in 2023. This study remains the most highly cited publication on these research questions. This study received 267 citations in total, demonstrating its strong academic impact with an annual citation rate of 89.

Table 1. Top 10 most globally cited articles on factors influencing urban carbon-neutral systems research

Rank	Title	Ref.	DOI	Source	Total Citations	Total Citations per Year
1	How effective has the low-carbon city pilot policy been as an environmental intervention in curbing pollution? Evidence from Chinese industrial enterprises	[20]	doi.org/10.1016/j.eneco.2023.106523	Energy Economics	267	89
2	Carbon-neutral cities: Critical review of theory and practice	[3]	doi.org/10.1016/j.jclepro.2022.130912	Journal of Cleaner Production	205	51.25
3	Carbon emissions in China's urban residential building sector through 2060: A dynamic scenario simulation	[21]	doi.org/10.1016/j.energy.2022.124395	Energy	129	32.25
4	District heating in cities as a part of low-carbon energy system	[22]	doi.org/10.1016/j.energy.2018.03.156	Energy	85	10.63
5	Analyzing national and local pathways to carbon-neutrality from technology, emissions, and resilience perspectives—Case of Finland	[7]	doi.org/10.3390/en12050949	Energies	69	9.86
6	Environmental policies for GHG emissions reduction and energy transition in the medieval historic centre of Siena (Italy): the role of solar energy	[23]	doi.org/10.1016/j.jclepro.2018.03.068	Journal of Cleaner Production	59	7.38
7	China's Green Economy Performance: Evidence from Dynamic Thresholds and System GMM Panel Data Approaches	[24]	doi.org/10.3390/ en15030884	Energies	55	13.75
8	Transition from traditional historic urban block to positive energy block	[25]	doi.org/10.1016/j.energy.2020.117485	Energy	44	7.33
9	A carbon-neutral scenario simulation of an urban land–energy–water coupling system: A case study of Shenzhen, China	[5]	doi.org/10.1016/j.jclepro.2022.135534	Journal of Cleaner Production	36	12
10	Optimal pathway to urban carbon neutrality based on scenario simulation: A case study of Shanghai, China	[26]	doi.org/10.1016/j.jclepro.2023.137901	Journal of Cleaner Production	31	10.33

Source(s): Created by the authors.

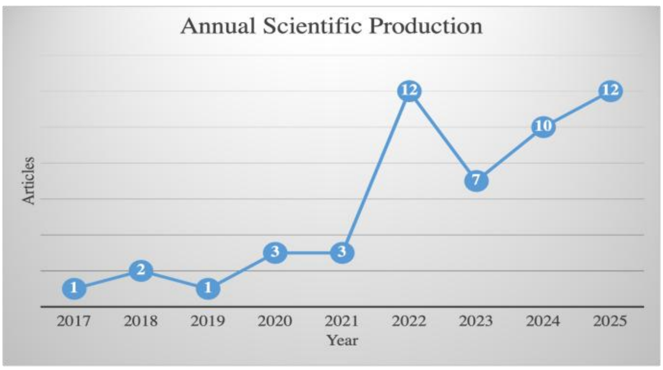

Figure 2. Trend of publication
Note: This figure is based on the 51 SLR studies.
Source(s): Created by the authors.

3.1.3 Leading journal

Table 2 shows the main results in terms of referenced journals worldwide in relation to urban carbon-neutral systems. The top five most cited journals are Journal of Cleaner Production (370 citations), Energies (255 citations), Energy (264 citations), Environment, Development and Sustainability (11 citations), and Qinghua Daxue Xuebao/Journal of Tsinghua University (11 citations). The most influential journal of the selected publications is Journal of Cleaner Production. This reflects its pivotal position within the field for both communicating research and influencing impact, as evidenced by an h-index of 7 and a g-index of 8.

3.1.4 Most productive countries

Table 3 presents the ten most productive countries based on the bibliometric dataset comprising 661 publications retrieved from the Scopus database. Unlike the systematic literature review, which was conducted using the final 51 eligible studies after the PRISMA screening process, this bibliometric analysis utilized the complete bibliographic dataset to examine global research productivity and collaboration patterns. Consequently, the publication counts reported in Table 3 refer to the full bibliometric dataset rather than the 51 studies included in the systematic literature review.

China produced the largest number of publications (65 articles), demonstrating its leading contribution to research on urban carbon-neutral systems. The United Kingdom ranked second with five publications, followed by Japan and Italy with four publications each. Finland contributed three publications, whereas Latvia and Norway each produced two publications. Poland, Korea, and France each contributed one publication. These findings demonstrate that research on urban carbon-neutral systems has expanded internationally, although research productivity remains concentrated in a limited number of countries.

Table 2. Top 5 most globally cited journals

Journals	Publisher	h_index	g_index	m_index	Total Citations	Number of Publications	PY_start
Journal of Cleaner Production	Elsevier	7	8	0.778	370	8	2018
Energies	MDPI	4	4	0.500	255	4	2019
Energy	Elsevier	3	6	0.333	264	6	2018
Environment, Development and Sustainability	Springer	3	3	0.600	11	4	2022
Qinghua Daxue Xuebao/Journal of Tsinghua University	Tsinghua University Press	2	2	0.400	11	2	2022

Source(s): Created by the authors.

Table 3. Top 10 most productive countries

Countries	Number of Articles	Total Citations	Average Articles Citations
China	65	596	25.90
United Kingdom	5	15	15.00
Japan	4	7	7.00
Italy	4	70	23.30
Finland	3	359	119.70
Latvia	2	44	44.00
Norway	2	24	24.00
Poland	1	7	7.00
Korea	1	3	3.00
France	1	0	0.00

Source(s): Created by the authors.

3.1.5 Most influential authors

Table 4 presents key authors contributing to the study of urban carbon-neutral systems. The author with the highest productivity is Jing Liu, with an h-index of 3, g-index of 3, and 27 citations. Yaling Wu is at number two (h-index 3, g-index 3, total citations 23), and Mingyang Cong comes next at position three (h-index 2, g-index 2, total citations 20). Haoran Wu is at the bottom of the top ten authors with an h-index of 2, g-index 2, and citation count of 9. The results in this paper reflect that the research on urban carbon-neutral systems is becoming more and more popular and should be expected to receive additional contributions in the future.

3.1.6 Author's keywords analysis

Table 5 presents the co-occurrence network of authors' keywords, illustrating the conceptual relationships among research themes associated with urban carbon-neutral systems. In this network, nodes represent individual keywords, whereas edges indicate that two keywords co-occur within the same publication. The detected clusters represent groups of conceptually related research topics. For example, Cluster 1 primarily comprises broad concepts associated with urban carbon-neutral systems, whereas Cluster 2 contains more specialized themes related to emission control, urban transportation, and associated environmental issues.

Betweenness centrality was primarily used to identify keywords acting as bridges between different thematic clusters. Keywords such as carbon, carbon neutral, urban transportation, and carbon dioxide exhibit comparatively higher betweenness values, indicating their important role in connecting otherwise distinct research themes within the knowledge network. These keywords therefore contribute substantially to the integration of different research domains.

Although closeness centrality values appear numerically similar across most nodes (approximately 0.000–0.001), this pattern reflects the structural characteristics of the relatively compact keyword co-occurrence network generated by Biblioshiny rather than indicating identical conceptual importance among keywords. Consequently, closeness centrality was not used as the primary indicator for interpreting keyword influence. Instead, greater emphasis was placed on betweenness centrality and PageRank because these measures more effectively capture the bridging role and overall influence of keywords within the bibliometric network.

PageRank analysis further confirms the prominence of several keywords within the overall network. Carbon, carbon neutrality, emission control, carbon dioxide, and energy efficiency exhibit comparatively higher PageRank values, indicating that these concepts occupy influential positions within the overall knowledge structure. Collectively, the network metrics demonstrate that carbon-related concepts continue to form the intellectual core of urban carbon-neutral systems research while simultaneously linking emerging themes concerning transportation, energy transition, and climate change.

Table 4. Top 10 most influential authors

Authors	h_index	g_index	m_index	Total Citations	Number of Publications	PY_start
Jing Liu	3	3	0.750	27	3	2023
Yaling Wu	3	3	0.600	23	3	2022
Mingyang Cong	2	2	0.500	20	2	2023
Yizhou Jiang	2	2	0.500	12	2	2023
Silan Li	2	2	0.667	5	2	2024
Wei Liu	2	2	0.400	57	2	2022
Liu Xiaohua	2	3	0.400	15	3	2022
Xinyao Wang	2	3	0.400	47	3	2022
Cun Wei	2	2	0.500	20	2	2023
Haoran Wu	2	2	0.667	9	2	2024

Source(s): Created by the authors.

Table 5. Network centrality measures of the authors' keyword co-occurrence network

Node	Cluster	Betweenness	Closeness	PageRank
carbon	1	24057.620	0.001	0.020
carbon neutrals	1	11719.915	0.001	0.013
carbon neutralities	1	8061.496	0.001	0.010
carbon emissions	1	4282.442	0.001	0.009
buildings sector	1	101.788	0.000	0.002
carbon accounting	1	521.797	0.000	0.001
energy intensity	1	5.166	0.000	0.000
multi agent systems	1	316.036	0.000	0.002
simulation	1	55.976	0.000	0.001
emission control	2	7214.239	0.001	0.010
urban transportation	2	11897.412	0.001	0.008
low carbon	2	2255.076	0.000	0.004
greenhouse gases	2	935.623	0.000	0.003
cost reduction	2	574.647	0.000	0.003
carbon dioxide	3	10129.357	0.001	0.010
energy efficiency	3	8078.250	0.001	0.009
energy utilization	3	7187.506	0.001	0.009
renewable energies	3	956.369	0.000	0.005
urban area	3	3527.534	0.000	0.004
climate change	4	6624.686	0.001	0.008
smart city	4	8412.590	0.000	0.006
energy transitions	4	1719.694	0.000	0.003
sustainable cities	4	1528.518	0.000	0.003
energy planning	4	1024.135	0.000	0.002

Source(s): Created by the authors.

Note: Owing to the relatively compact keyword network, closeness centrality values show limited numerical variation and are therefore interpreted cautiously. Greater emphasis is placed on betweenness centrality and PageRank when identifying influential research themes.

3.1.7 Thematic map analysis

Figure 3 presents a strategic thematic map illustrating the conceptual structure of urban carbon-neutral systems research based on Callon's centrality-density framework [27]. The thematic map provides an overview of the principal research themes and their stage of development, thereby identifying both established research domains and potential future research directions. The map classifies research themes into four quadrants according to two complementary dimensions: centrality and density. Centrality reflects the degree of interaction between a thematic cluster and other research themes, indicating its importance within the overall knowledge network, whereas density measures the internal cohesion and developmental maturity of each thematic cluster. Consequently, themes with higher density are generally considered more mature and conceptually well developed.

The upper-right quadrant, referred to as the Motor Themes, represents research topics characterized by both high centrality and high density. These themes are conceptually mature, well developed, and strongly connected to the broader research field, making them the principal drivers of knowledge development. The dominant themes identified in this quadrant include carbon sequestration, optimization, carbon capture and utilization (CCU), carbon dioxide (CO_2), energy efficiency, energy utilization, emission control, climate change, and decarbonization. Their prominent position indicates that technological innovation and carbon mitigation strategies remain the primary focus of urban carbon-neutral systems research.

The upper-left quadrant represents the Niche Themes, which exhibit relatively high density but lower centrality. These themes are generally well developed internally but remain less connected to the broader research landscape, reflecting specialized areas of investigation. In contrast, the lower-right quadrant comprises the Basic Themes, characterized by high centrality but comparatively lower density. Themes such as carbon emissions, China, and the boundary term carbon neutrals occupy this quadrant, indicating that they constitute fundamental concepts underpinning urban carbon-neutral systems research while continuing to evolve conceptually. Given that the term carbon neutrals represents a linguistic variation of the more widely adopted concept of carbon neutrality, it was interpreted cautiously during the thematic analysis as a closely related conceptual expression rather than as an entirely distinct research theme.

The lower-left quadrant represents the Emerging or Declining Themes, which are characterized by relatively low density and low centrality. These themes may indicate either newly emerging research topics that have not yet reached conceptual maturity or areas receiving decreasing scholarly attention. The principal themes identified in this quadrant include carbon neutrality, urban transportation, economic and social effects, and energy transition. During the interpretation of the thematic map, semantically related expressions, such as energy transition and energy transitions, were discussed collectively because they represent the same underlying research concept. Likewise, closely related terms associated with carbon neutrality were interpreted collectively to improve conceptual clarity while preserving the original bibliometric output generated by Biblioshiny. Monitoring these emerging themes remains important because they are likely to shape future research on urban carbon-neutral systems.

3.2 Systematic literature review

An extensive search of the vast literature collected from the Scopus database was performed to gain insights into previous studies. Indeed, at its core, this study sought to identify the necessary ingredients that make up Urban Carbon-Neutral Futures. This study identifies seven key drivers that would influence the process of Urban Carbon-Neutral Systems. To improve the transparency of the synthesis process, Table 6 summarizes the recurring concepts identified across the reviewed studies and their synthesis into the seven conceptual drivers of urban carbon-neutral systems.

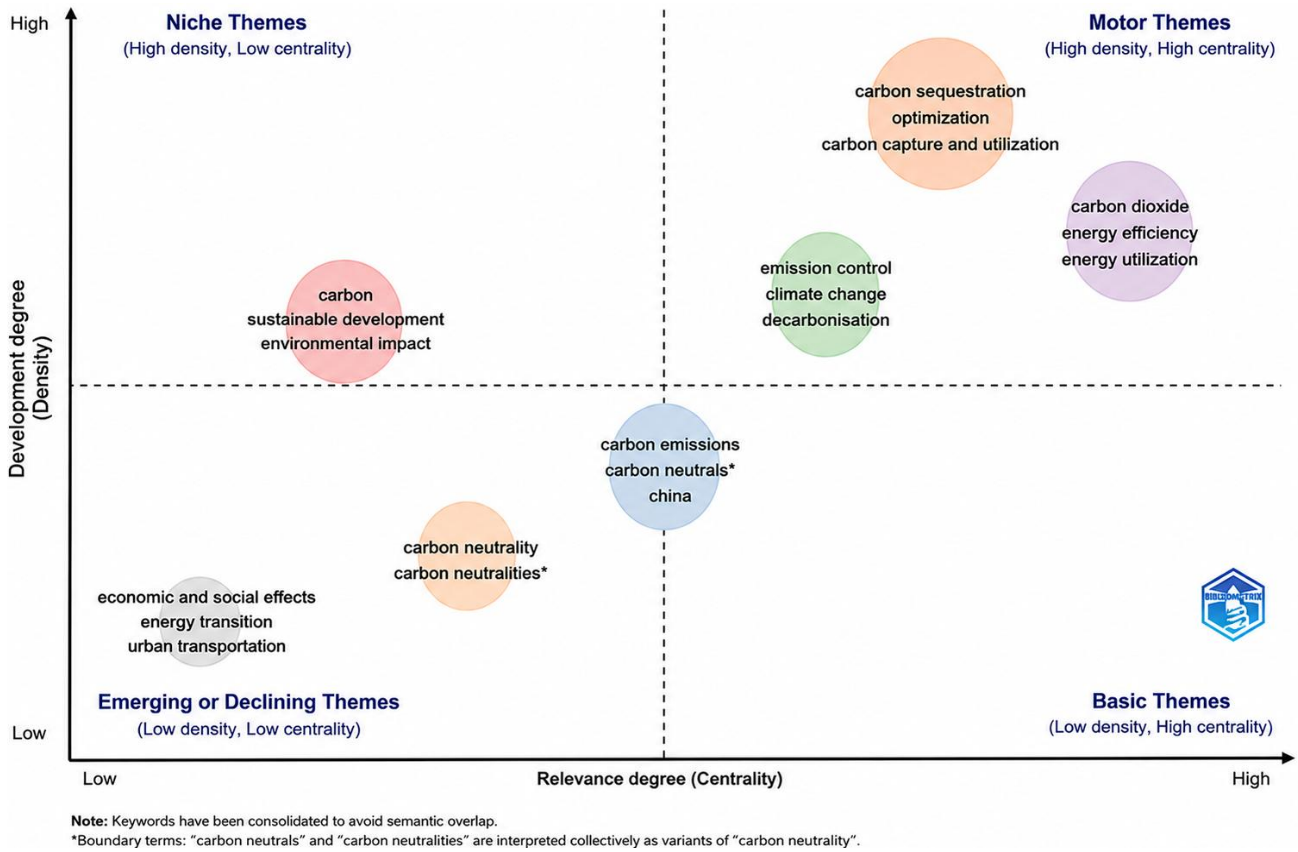

Figure 3. Strategic thematic map of research themes in urban carbon-neutral systems
Source: Created by the authors using the Biblioshiny-bibliometrix package.

Table 6. Evidence mapping of the seven drivers synthesized from the systematic literature review

Driver	Representative Concepts Synthesized from the Reviewed Studies	Synthesis Rationale	Related Section
Technological innovation	Artificial intelligence (AI), digital twins, carbon capture and utilization (CCU), renewable energy technologies, smart technologies, low-carbon innovation	These concepts consistently describe technological solutions that improve carbon reduction, enhance energy efficiency, and accelerate urban carbon-neutral transitions. They were therefore synthesized into the broader driver of Technological Innovation.	Section 3.2.1
Urban green spaces	Urban parks, green infrastructure, green corridors, biodiversity conservation, ecological restoration, carbon sequestration	These concepts emphasize the ecological functions of urban green spaces in carbon storage, climate regulation, and ecosystem resilience. Their recurring appearance across the reviewed studies justified their synthesis as Urban Green Spaces.	Section 3.2.2
Energy systems and infrastructure	Renewable energy systems, smart grids, low-carbon infrastructure, energy-efficient buildings, electrification, sustainable energy supply	These concepts collectively represent the technological and physical infrastructure supporting urban decarbonization and energy transition. They were synthesized into Energy Systems and Infrastructure.	Section 3.2.3
Policy and governance	Environmental regulation, carbon policies, governance mechanisms, institutional coordination, policy incentives, carbon accounting	These concepts consistently highlight the institutional and regulatory mechanisms required to facilitate and coordinate urban carbon-neutral implementation. Accordingly, they were grouped under Policy and Governance.	Section 3.2.4
Socio-economic factors	Public participation, stakeholder engagement, behavioral change, economic development, green investment, community awareness	These concepts explain how social acceptance, economic capacity, and stakeholder involvement influence the adoption and long-term success of carbon-neutral initiatives. They were therefore synthesized as Socio-economic Factors.	Section 3.2.5
Urban form and design	Compact city, mixed land use, transit-oriented development (TOD), sustainable urban planning, walkability, land-use efficiency	These concepts consistently describe urban spatial characteristics affecting transportation demand, land-use efficiency, and energy consumption. They were synthesized into Urban Form and Design.	Section 3.2.6
Climate and environmental factors	Climate resilience, ecosystem services, carbon sinks, land-use change, environmental carrying capacity, ecological sustainability	These concepts represent environmental conditions that influence both the feasibility and effectiveness of urban carbon-neutral systems. They therefore form the broader driver of Climate and Environmental Factors.	Section 3.2.7

Source(s): Synthesized by the authors from the 51 eligible studies included in the systematic literature review.

3.2.1 Technological innovation

As noted, technological innovation is the key actor of current urban carbon-neutral systems by allowing cities to systematically decrease emissions based on resource efficiency with data-driven and low-carbon solutions. Low-carbon technologies, that is, energy-efficient building systems, the integration of renewable energy and carbon capture, storage, and utilization technology deployment, offer a technical basis for long-term decarbonization pathways in urban areas [2]. Developments in the field of artificial intelligence have also solidified this paradigm shift and support predictive modeling, real-time monitoring, and adaptive planning inputs to enhance urban energy performance [2, 10]. At the same time, urban digital twins enable policymakers and planners to model intricate inter-urban systems, assess intervention scenarios, and expedite evidence-based decision-making towards emission-free targets [28]. As an integrated innovation ecosystem, these technologies work together to improve the resilience of urban systems and deliver more efficient operations alongside reduced structural carbon dependency. Their merger marks the transition from reactive environmental management to proactive technology-generated urban sustainability approaches.

This suggests that technological innovation acts as a primary enabler of urban carbon-neutral systems by facilitating the development and deployment of low-carbon solutions. However, its effectiveness is highly dependent on the readiness of energy systems and infrastructure, as well as the presence of supportive policy and governance frameworks. Without proper integration with these elements, technological advancements alone may not lead to significant carbon reduction outcomes.

3.2.2 Urban green spaces

Urban green spaces are an essential ecological infrastructure in modern urban carbon-neutral systems, as they not only act as natural sinks for carbon but also mitigate the challenges posed by climate change through microclimate improvement within cities. Vegetation found in urban parks, green corridors, and rooftop ecosystems not only directly reduces carbon dioxide emissions by sequestering atmospheric carbon but also indirectly reduces cooling energy demand owing to plant-thermal mitigation effects [29, 30]. The potential of urban green spaces to optimize carbon neutrality is a result of strategic spatial planning, biodiversity-minded design, and ecologically coherent environmental management practices [30]. Consequently, well-managed green spaces can function as active elements of urban climate regulation rather than passive land-use features. In addition to their biophysical functions, urban green spaces reinforce the resistance of urban ecosystems by stabilizing environmental quality and contributing to sustainable urban metabolism. With the intensifying global threat of climate change, the development of lush green infrastructures based on scientifically sound principles is crucial for maintaining carbon balance and ecological efficacy.

This suggests that urban green spaces contribute to carbon sequestration and environmental sustainability within urban systems. However, their effectiveness depends on how well they are integrated with urban form and design strategies, indicating that green infrastructure must be planned holistically rather than implemented as isolated interventions.

3.2.3 Energy systems and infrastructure

Energy systems and infrastructure are the structural substratum of low-carbon transitions in urban areas; they structure how energy is generated, distributed and used within the city. The transition away from fossil-fuel reliance to an electrified system fueled by renewables is needed to meaningfully lower urban carbon intensity at scale [31]. Zero-carbon vehicles, intelligent grids and energy-efficient building stock contribute to an integrated decarbonization of the transport and building sectors-two of the biggest urban emitters. Other renewable-based urban technologies make possible decentralized and more resilient energy networks with fewer transmission losses and enhanced system flexibility [32]. Today's infrastructure planning begins to focus on the socio-technical framework and interfaces between energy, mobility and digital channels for efficient urban performance. There is great potential if cities can design energy infrastructure with low-carbon principles, achieving multiple objectives simultaneously (energy security, operational efficiency and long-term sustainability) with one stone.

This suggests that energy systems and infrastructure serve as the operational backbone of urban carbon-neutral transitions. However, their effectiveness is closely linked to technological innovation and policy support, indicating that infrastructure development must align with technological advancements and regulatory frameworks to achieve optimal outcomes.

3.2.4 Policy and governance

Rooted in the urban context, policy and governance are regarded as an institutional driver of carbon-neutral systems: They define regulatory orientation, bring stakeholders together, and convert climate targets into enforceable action. Robust environmental governance, especially with policies that operate in unison, has been found to minimize urban carbon emissions by harmonizing regulatory incentives and sustainability outcomes [4, 33]. Initiatives such as third-party disclosure of environmental information serve to improve data transparency and drive low-carbon technology R&D by creating accountability pressure toward cities or industries [4]. At the city-level operation, carbon accounting and management systems enable measurable targets for planning, monitoring, and corrective action that manage climate change [34]. Strong governance structures therefore help reduce the 'implementation deficit' between climate ambition and real-world impact. Data-centric, institutionally coordinated and stable policy instruments provide a predictable environment that drives progress along long-term decarbonization paths.

This suggests that policy and governance play a critical role in shaping the direction and effectiveness of urban carbon-neutral initiatives. However, their impact depends on how well they support technological adoption and coordinate with socio-economic conditions, highlighting the importance of integrated and adaptive policy frameworks.

3.2.5 Socio-economic factors

There are social drivers of carbon-neutral transitions in cities, as well, such as socio-economic factors that specify the ability of communities and institutions to engage with and sustain low-carbon transitions. The public's involvement in the process is crucial, however, given that when citizens are involved, policies are more likely to be accepted, and this leads to behavioral changes conducive to reductions in a carbon footprint [6, 35]. There is empirical evidence that community-based climate change mitigation is more effective when social consciousness and local contributions become an integral part of urban environmental strategies [35]. At the meso level, economic growth realizes carbon neutrality by creating financing, for example, for the production of green innovation and technology upgrading [4, 36]. Cities with better socio-economic capacity mobilize resources more easily and maintain decarbonization programmes in the long run. As such, socio-economic processes are an enabling condition and reinforcing factor for effective carbon-neutral metabolism governance.

This suggests that socio-economic factors influence the adoption and diffusion of carbon-neutral practices within urban systems. However, their effectiveness varies depending on public awareness, economic capacity, and stakeholder engagement, indicating that social readiness is essential for translating policy and technological solutions into real-world outcomes.

3.2.6 Urban form and design

The design and form of the city drive carbon outcomes by organizing where people move, live, and use energy within it. High-density development, mixed land use, and accessibility networks that facilitate reduction of travel demand and energy intensity have potential to decrease per capita greenhouse gas (GHG) emissions [37]. Urban designs that facilitate walking, public transit use, and energy-efficient buildings make low-carbon behavior part of the material structure of daily life. Designing new urban districts for carbon neutrality shows the potential of spatial design as long-term emissions control rather than short-term policy intervention [12]. Over and above the question of efficiency, urban design constructs norms and expectations regarding sustainable futures; it also mediates how communities think about, envision, and adapt to living in decarbonized environments [38]. When environmental performance is central to the spatial planning process, the shape of the city becomes a tool in itself – part of the solution rather than merely a canvas for one.

This suggests that urban form and design act as structural enablers that determine the efficiency and feasibility of implementing carbon-neutral strategies. However, their effectiveness depends on alignment with energy systems, transportation networks, and land-use planning, emphasizing the need for integrated urban development approaches.

3.2.7 Climate and environmental factors

The capacity of the urban system is its natural ability to fix carbon and eventually maintain ecological balance through climate and the environment. Urban ecosystems can store carbon, and this capacity is driven by a coupling of plants, soil quality, land use, and human disturbance that determines the extent to which cities remain carbon sinks [39, 40]. Resilient climatic stressors also create favorable conditions that promote carbon-neutral strategies [40]. These ecological patterns indicate that these technological and policy strategies should be implemented within the ecological limits and not outside their context. This is reflected, among other things, by the fact that climate justice and energy democratization are increasingly being debated as important environmental challenges in their own right; both illustrate the necessary social inclusiveness of environmentally induced transitions in the long term [41]. Integrating ecological science into urban planning anchors carbon-neutral aspirations to biophysical realities in cities.

This suggests that climate and environmental factors serve as boundary conditions that shape the feasibility and effectiveness of urban carbon-neutral strategies. However, their influence varies across geographic and environmental contexts, indicating that localized and context-specific approaches are necessary for successful implementation.

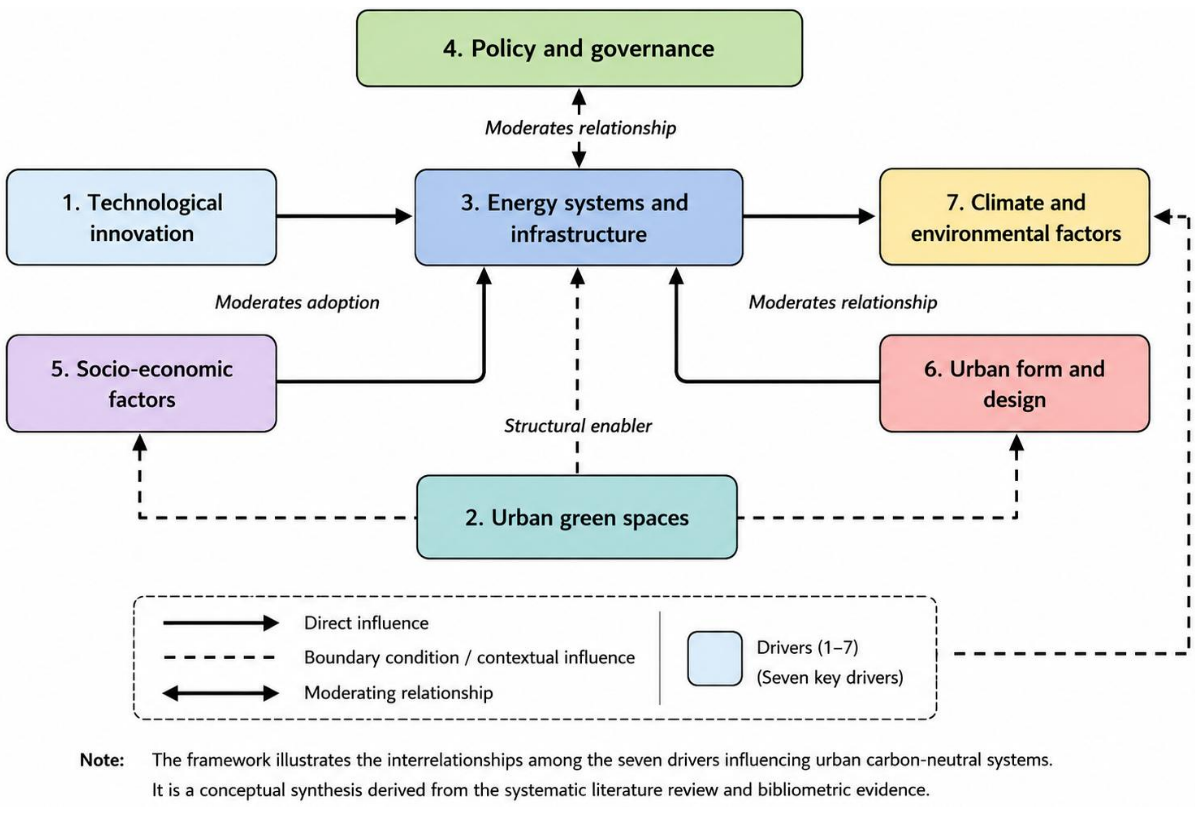

Figure 4. Conceptual framework of urban carbon-neutral systems based on seven key drivers

3.2.8 Conceptual framework of urban carbon-neutral systems

This study proposes a conceptual framework illustrating the relationships among the seven drivers of urban carbon-neutral systems synthesized from the systematic literature review. Rather than representing independently isolated determinants, the framework integrates these seven drivers into a holistic conceptual structure to explain how technological, institutional, socio-economic, spatial, and environmental dimensions collectively contribute to urban carbon-neutral performance. The framework is intended to synthesize the current body of knowledge identified through the reviewed literature and to provide a theoretical foundation for understanding the interrelationships among these drivers. Technological innovation and energy systems and infrastructure constitute the primary operational drivers supporting urban carbon-neutral transitions, whereas policy and governance provide the institutional mechanisms necessary to facilitate their implementation.

Socio-economic factors influence the adoption and long-term implementation of carbon-neutral practices through public participation, stakeholder engagement, and economic capacity. Urban form and design together with urban green spaces function as structural enablers by shaping the spatial and ecological characteristics of urban systems, whereas climate and environmental factors provide the contextual boundary conditions influencing the feasibility and effectiveness of carbon-neutral strategies. Accordingly, the proposed framework should be interpreted as a conceptual synthesis derived from bibliometric evidence and systematic literature review findings rather than as an empirically tested causal model. The relationships illustrated in Figure 4 represent theoretically synthesized interactions among the identified drivers and are intended to guide future empirical validation rather than establish confirmed causal relationships.

3.3 Discussions

This study provides a comprehensive synthesis of the intellectual development and principal drivers of urban carbon-neutral systems by integrating bibliometric analysis with a systematic literature review. The bibliometric analysis, conducted using the complete dataset of 661 Scopus-indexed publications, revealed a clear upward trend in research output between 2017 and 2025, indicating growing global academic interest in urban carbon-neutral systems. This increasing publication trajectory reflects the rising importance of urban decarbonization in response to international sustainability agendas, climate change mitigation targets, and the transition toward carbon-neutral cities. Collectively, these findings demonstrate that urban carbon-neutral systems have evolved into an increasingly important multidisciplinary research field with a rapidly expanding knowledge base.

To address RQ1, bibliometric analysis was conducted using the complete dataset of 661 Scopus-indexed publications to identify the most influential articles, journals, countries, and authors in the field of urban carbon-neutral systems. The results indicate that the *Journal of Cleaner Production* received the highest number of global citations (370), highlighting its leading role in disseminating research on urban carbon neutrality. The most highly cited publication was Yang et al. [20], "How Effective Has the Low-Carbon City Pilot Policy Been as an Environmental Intervention in Curbing Pollution? Evidence from Chinese Industrial Enterprises," published in *Energy Economics*. Furthermore, the author analysis identified Jing Liu as one of the most influential contributors to this research field, reflecting the substantial scholarly contribution of Chinese researchers to urban carbon-neutral systems.

The geographical distribution of publications further demonstrates the growing international interest in urban carbon-neutral systems. Increasing concerns regarding climate change, carbon emissions, and sustainable urban development have encouraged research activities across both developed and developing countries. As presented in Table 3, China emerged as the most productive country, followed by contributions from the United Kingdom, Japan, Italy, and several other countries. It should be noted that the country analysis presented in Table 3 was derived from the complete bibliometric dataset of 661 publications rather than the 51 studies included in the systematic literature review. Therefore, these findings should be interpreted as indicators of global research productivity rather than evidence synthesized from the qualitative review.

China's leading contribution to research on urban carbon-neutral systems can be attributed to its rapid urbanization, strong economic growth, and increasing commitment to achieving national carbon neutrality targets. These conditions have stimulated extensive academic research alongside substantial investments in low-carbon technologies, renewable energy, and sustainable urban infrastructure. Moreover, national initiatives, including carbon peaking strategies, green urban development programmes, low-carbon infrastructure investment, and carbon emissions trading mechanisms, have provided a supportive policy environment that has accelerated both research and practical implementation of urban carbon-neutral systems.

To address RQ2, the findings from bibliometric keyword co-occurrence analysis were integrated with evidence synthesized through the systematic literature review. The bibliometric analysis identified four dominant thematic clusters centred on carbon, carbon neutrality, urban transportation, and carbon dioxide, reflecting the core intellectual structure of the research field. Building upon these findings, the systematic literature review synthesized evidence from 51 high- and moderate-quality studies and identified seven interrelated drivers of urban carbon-neutral systems: technological innovation, urban green spaces, energy systems and infrastructure, policy and governance, socio-economic factors, urban form and design, and climate and environmental factors. Together, these drivers provide a comprehensive conceptual understanding of how multiple dimensions interact to facilitate urban carbon-neutral transitions.

Technological innovation and energy systems and infrastructure constitute the fundamental pillars of urban carbon-neutral systems because they determine a city's capacity to transition toward a low-carbon economy. Technological innovation accelerates the adoption of low-emission technologies, improves energy efficiency, and enhances the resilience and competitiveness of urban systems over the long term [42, 43]. Likewise, energy systems and infrastructure facilitate large-scale emission reductions through renewable energy deployment, electrification, and the development of energy-efficient urban infrastructure [44, 45]. Without supportive energy infrastructure, technological innovations are often implemented in isolation and remain difficult to scale across urban environments. Therefore, integrating technological innovation with energy system transformation is essential for achieving effective and sustainable urban carbon-neutral transitions. These findings suggest that technological innovation and energy systems should be viewed as complementary components of an integrated urban carbon-neutral system rather than as independent technological interventions.

Urban green spaces and climate and environmental factors provide the ecological foundation for urban carbon-neutral systems by complementing technological interventions with nature-based solutions. Urban green spaces contribute to carbon sequestration, improve urban microclimates, and reduce energy demand through ecosystem services [29, 30]. Their importance extends beyond emission reduction by strengthening environmental resilience and supporting the long-term sustainability of urban carbon-neutral strategies. Furthermore, local climatic and environmental conditions influence the effectiveness of low-carbon interventions by affecting energy consumption patterns, ecosystem performance, and carbon sequestration potential [46]. Consequently, urban carbon-neutral strategies that overlook ecological conditions may face substantial implementation challenges. Integrating nature-based solutions with technological and infrastructural innovations is therefore essential for developing resilient and sustainable urban carbon-neutral systems.

Policy and governance serve as the institutional foundation of urban carbon-neutral systems by coordinating diverse stakeholders, resources, and policy instruments. Effective governance frameworks facilitate the implementation of carbon-neutral strategies through regulatory mechanisms, economic incentives, and cross-sector collaboration [4, 36]. In addition to promoting the adoption of green technologies, well-designed policy frameworks provide the institutional stability required to support long-term investments in sustainable urban development. Conversely, fragmented governance structures and limited coordination among stakeholders often constrain the effectiveness of urban decarbonization initiatives. Therefore, transparent, adaptive, and evidence-based governance is essential to ensure that urban carbon-neutral transitions are implemented effectively, monitored systematically, and sustained over the long term.

Socio-economic factors together with urban form and design shape behavioral patterns, spatial development, and long-term urban sustainability, thereby supporting the successful implementation of urban carbon-neutral systems. Socio-economic conditions influence adaptive capacity, public acceptance of climate policies, investment decisions, and the continuity of low-carbon behavioral change [46, 47]. At the same time, urban form and design directly affect mobility patterns, energy consumption, and land-use efficiency, making them critical long-term determinants of carbon emissions [48, 49]. Compact, mixed-use, and transit-oriented urban forms can substantially reduce carbon emissions while improving overall urban sustainability. These findings demonstrate that urban carbon neutrality extends beyond technological solutions and should be understood as a comprehensive socio-technical and spatial transformation. Accordingly, achieving urban carbon-neutral systems requires integrated strategies that simultaneously address technological, institutional, socio-economic, and spatial dimensions.

Collectively, these findings demonstrate that urban carbon-neutral transitions should not be interpreted as the outcome of isolated technological interventions. Rather, successful transitions emerge from continuous interactions among technological innovation, governance, socio-economic conditions, urban planning, environmental systems, and supporting infrastructure. Consequently, integrated policy design is likely to generate more sustainable and resilient urban decarbonization pathways than sector-specific interventions.

4. FUTURE RESEARCH DIRECTIONS

Findings from the systematic literature review were visualized using a thematic map to inform about central research desiderata and future work potential of urban carbon-neutral systems (RQ3). Based on Figure 3, the results are elaborated to understand what each thematic cluster means and how it will impact future research areas. Apparently, topics located in the Motor Themes quadrant, such as carbon dioxide, energy efficiency, energy integration, and carbon capture and CO_2, have strong centrality and density values. This implies that the current literature largely focuses on technical and operational measures for CO_2 abatement. While these tropes of technology are rather sophomorically framed, here is a potential area for future research: how to better embed technological solutions into urban policy-making and multi-level governance in ways that bolster longer-term implementation on the ground (especially in ever-growing cities in developing and emerging economies).

Moreover, themes like emission control, climate change and decarbonization, which cover moderate positions in centrality, seem to act as a linking theme between the technical intervention and the wider sustainable purposes. Subsequent research should explore linkages between emission control plans and urban planning, energy systems, and sustainable transportation policies. Meanwhile, the themes including carbon neutrality, urban transport, and carbon emissions (especially those in China) still have low thematic density, denoting that empirical studies integrating these areas are still few. This opens comparative perspectives between one country or city and other countries and cities in order to shed light on how diverse the pathways might be towards carbon neutrality under different institutional and socio-economic conditions. On the other hand, declining themes such as energy transition and socio-economic impacts stress the necessity to further revamp research on this area of social and economic consequences of energy transitions. A number of potential policy, social, and economic pathways to such urban carbon-neutral systems have been described below, which need to be taken into account in this research.

Future research on urban carbon-neutral systems should move beyond isolated technological solutions and adopt a more integrated, systemic, and interdisciplinary perspective. Based on recent thematic developments in the literature, several promising research directions can be identified to advance both theoretical understanding and practical implementation.

a) Transition of urban infrastructure and low-carbon transport

There is a continued embodiment of the potential of urban infrastructure as a pathway to carbon-neutral cities. Future research should focus on the construction of zero-carbon and carbon-sink-integrated buildings, especially by incorporating methods for captured CO_2 to be stored in or sequestered with the built environment [50, 51]. Concurrently, low-carbon mobility systems deserve far more scholarly attention, particularly with respect to electric mobility and the integration of public transport as well as transit-oriented urban design. It is also necessary to explore how urban form, land-use planning, and transport systems complement each other to structurally diminish the reliance on fossil fuels and long-term carbon intensity [52].

b) Policy instruments and systemic reform

Policy contexts are critical in determining pathways for decarbonizing the urban sector. More research is needed to investigate how adaptive and flexible policy instruments, such as carbon intensity targets, carbon sink incentives, and energy efficiency standards, can be integrated to meet varying urban conditions [41, 50]. Further, governance-focused research should be conducted to explore multi-level and cross-sector collaboration arrangements for cooperative action among governmental agencies, utilities, private actors (market actors), and civil society. Cross-regional and governance model comparisons would enrich understanding of the effectiveness of institutions and of policy transferability [8, 53].

c) Digitization and urban smartness

Applying digital technologies to urban carbon management creates new potentials. It is further suggested that future research could examine the synergistic coupling of urban digital twins with zero energy buildings, and employ artificial intelligence, internet of things and cyber-physical systems to maximise urban energy flows and emission reductions [54]. Moreover, the use of data-driven urban intelligence methods could facilitate real-time monitoring, modeling and visualization of carbon dynamics in different urban subsystems. Areas that warrant investigation include how these media platforms can enable coordinated climate action and decision-making at the city scale [55].

d) Multidisciplinary/interdisciplinary approaches

The road to urban carbon neutrality is a transdisciplinary effort. Future work needs to combine the fields of environmental science, urban planning, engineering, public health, and social science to take into account the complex and relevant characteristics in the relationships among urban carbon systems [56, 57]. Notably, advanced life-cycle assessment method frameworks such as dynamic life-cycle assessment with the integration of multi-origin and multi-level data enable more realistic estimates of urban carbon footprints. Research is still much needed to harmonize such methodologies so that they can be compared and are policy relevant [51].

e) Social involvement and civic engagement

Social aspects are also increasingly recognized as crucial factors of the success of urban decarbonization. Further investigations are recommended to pursue the mechanisms that can improve citizen engagement, community involvement, and social acceptance toward carbon-neutral actions. Studies on behavioral change, social norms, and citizen-led climate action have potential for useful knowledge about reducing home energy consumption and the quality of the introduced habits [6]. The dynamic relationship between public engagement, policy design, and technology uptake is an important but under-researched area.

f) Technological innovation and development in green energy

Technological development continues to be the key driver of urban carbon-neutral systems. Areas of research may include but are not limited to maximizing the performance of renewable energy technologies, advanced energy storage systems, and new materials for enhanced system performance in densely urbanized environments [58]. Furthermore, the practicalities and efficiency of implementing carbon capture and storage and carbon capture and utilization in urban areas still need to be studied empirically, including how they can be integrated with existing infrastructure at an acceptable cost relative to benefit [41].

g) Evaluation, monitoring and performance measurement

Strong evaluation and monitoring frameworks are necessary to monitor how much progress carbon-neutral cities make. For the future, we recommend standardizing methods used to specify boundaries for emissions, accounting practices, and management of urban systems [59]. Elaborating transparent key performance indicators to evaluate policy effectiveness and technological performance can assist evidence-based decision-making, as well as steer long-term urban sustainability strategies [60].

5. IMPLICATIONS, LIMITATIONS, AND RECOMMENDATIONS

This study has important theoretical and practical aspects to promote research on carbon-neutral urban systems. This study contributes to the literature on carbon-neutral cities by systematically synthesizing disparate knowledge and identifying key drivers for developing carbon-neutral urban systems. We integrated the existing literature using a bibliometric analysis and systematic review to develop a conceptual framework comprising seven dimensions (technological innovation, urban green spaces, energy systems and infrastructure, policy and governance, socio-economic factors, urban form and design, and climate and environmental factors). This wider view affords a richer theoretical framework, turning attention from specific technologies or policy measures aimed at urban carbon neutrality to interactions among technological, institutional, spatial, socio-economic, and ecological systems that collectively contribute to urban carbon-neutral systems. Thus, this study not only provides a theoretical framework for research on urban carbon-neutral systems but also serves as a guideline for further theory development.

From a methodological perspective, the study also indicates how well bibliometric analysis can be combined with systematic literature reviews to explore high-potential and multi-disciplinary research areas. The co-occurrence of network analysis and thematic mapping using the PRISMA-based screening is a review process that identifies dominant themes, research gaps, and emerging topic trends on urban carbon-neutral systems. This study explains how thematic maps can be used to interpret research themes with respect to their maturity and centrality, offering a methodological roadmap to future researchers pursuing enquiry on dynamic sustainability topics. This mixed-methods approach also illustrates how quantitative, bibliometric measures, and qualitative synthesis can be successfully used in synergy to provide insights that neither of the approaches would reach alone. This work represents a methodological contribution by providing reproducible methods for use in other sustainability and urban studies contexts.

This research has practical implications; therefore, the findings will be extremely beneficial for decision-makers, urban planners, and city managers who are investigating the carbon-neutral transition. The key drivers emphasize the need to develop policies using a holistic framework that includes questions about technology deployment, infrastructure change, spatial planning, and social engagement. Policymakers can use these lessons to focus on integrated governance mechanisms that align energy systems, land-use planning, and climate policies along decarbonization multidecadal pathways. For urban practitioners, important lessons include that investments in low-carbon technologies and green infrastructure should be accompanied by adaptive governance mechanisms—as well as inclusive socio-economic strategies—to sustain these transformations. This study provides data-driven advice for the development of integrated urban carbon-neutral system pathways that balance environmental effectiveness with economics and social acceptance.

This work highlights that gaining urban carbon-neutral systems requires not discrete action but a systemic and lasting task. This study makes a contribution by elucidating the theoretical framework, proposing an elaborated research approach, and delivering practical implications for academics as well as practitioners. These consequences contribute to the design of more robust and inclusive urban carbon-neutral systems and create a platform for further empirical and policy-related research in this domain.

This study is subject to several limitations that warrant consideration. There are several limitations to this analysis. We want to acknowledge that our analysis is based on the Scopus database only, which, although it has wide and high-quality coverage of scientific literature, does not cover all relevant publications in the field of urban carbon-neutral systems, for example, those indexed by other databases. This choice was made to enhance the reliability and consistency in data acquisition and analysis; nonetheless, future investigations should consider integrating several databases for a complementary view. Second, this analysis is based solely on journal articles and not conference proceedings/books/book chapters that may contribute new insights or novel directions for urban carbon-neutral systems. Third, there is a potential for relevant studies to be missed using this systematic keyword search strategy because of terminological and conceptual framing differences. Further, the interpretation and thematic categorization of literature via bibliometric and systematic review approaches may introduce some subjectivity, although these risks were mitigated by ensuring analytical consistency. Thus, future research needs to integrate more data sources and search strategies as well as synthesis methods that mix quantitative and qualitative perspectives to fully capture the dynamic development process for urban carbon-neutral systems.

6. CONCLUSION

This study aimed to identify and synthesize the intellectual development and principal drivers of urban carbon-neutral systems by integrating bibliometric analysis with a systematic literature review. The findings demonstrate that urban carbon-neutral systems have evolved into an increasingly important multidisciplinary research field shaped by seven interrelated drivers: technological innovation, urban green spaces, energy systems and infrastructure, policy and governance, socio-economic factors, urban form and design, and climate and environmental factors. Rather than operating independently, these drivers interact dynamically to support integrated urban carbon-neutral transitions through the combined influence of technological innovation, institutional capacity, spatial planning, and socio-ecological processes.

This study contributes to the literature by combining quantitative science mapping with qualitative evidence synthesis to develop a conceptual framework that integrates fragmented knowledge on urban carbon-neutral systems and provides a theoretical foundation for future empirical research. From a practical perspective, the findings offer valuable guidance for policymakers, urban planners, and other stakeholders in designing coordinated technological, governance, spatial, and environmental strategies that support sustainable and resilient urban development. Future research is encouraged to empirically validate the proposed conceptual framework across different urban contexts and geographical settings to further strengthen the evidence base for urban carbon-neutral transitions.

Despite its contributions, this study has several limitations. First, the analysis relied exclusively on the Scopus database and English-language publications, which may have excluded relevant studies indexed elsewhere. Second, the proposed framework represents a conceptual synthesis derived from existing literature rather than an empirically validated causal model. Future studies may validate the proposed framework using empirical methods such as Structural Equation Modeling (SEM), Fuzzy-set Qualitative Comparative Analysis (fsQCA), or longitudinal case studies.

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REFERENCES

[1] UN-HABITAT. (2022). World cities report 2022: Envisaging the future of cities. United Nations Human Settlements Programme. https://unhabitat.org/sites/default/files/2022/06/wcr_2022.pdf.

[2] Shang, W.L., Lv, Z. (2023). Low carbon technology for carbon neutrality in sustainable cities: A survey. Sustainable Cities and Society, 92: 104489. https://doi.org/10.1016/j.scs.2023.104489

[3] Huovila, A., Siikavirta, H., Antuña Rozado, C., et al. (2022). Carbon-neutral cities: Critical review of theory and practice. Journal of Cleaner Production, 341: 130912. https://doi.org/10.1016/j.jclepro.2022.130912

[4] He, X., Zhou, J., Xu, H. (2024). The impact of third-party environmental information disclosure on urban carbon-neutrality technology innovation. Polish Journal of Environmental Studies, 34(6): 7609-7624. https://doi.org/10.15244/pjoes/193904

[5] Lin, G., Jiang, D., Yin, Y., Fu, J. (2023). A carbon-neutral scenario simulation of an urban land–energy–water coupling system: A case study of Shenzhen, China. Journal of Cleaner Production, 383: 135534. https://doi.org/10.1016/j.jclepro.2022.135534

[6] Lima, N.M., Nygård, M., Heris, M.P. (2023). Towards

carbon-neutral cities: The crucial role of social participation. In 2023 International Conference on Future Energy Solutions (FES), Vaasa, Finland, pp. 1-6. https://doi.org/10.1109/fes57669.2023.10182857
[7] Pilpola, S., Arabzadeh, V., Mikkola, J., Lund, P.D. (2019). Analyzing national and local pathways to carbon-neutrality from technology, emissions, and resilience perspectives—Case of Finland. Energies, 12(5): 949. https://doi.org/10.3390/en12050949
[8] Tozer, L., Klenk, N. (2018). Urban configurations of carbon neutrality: Insights from the Carbon Neutral Cities Alliance. Environment and Planning C: Politics and Space, 37(3): 539-557. https://doi.org/10.1177/2399654418784949
[9] Sharifi, A. (2021). Urban sustainability assessment: An overview and bibliometric analysis. Ecological Indicators, 121: 107102. https://doi.org/10.1016/j.ecolind.2020.107102
[10] Yan, F., Qi, X. (2024). Application and prospect of artificial intelligence technology in low-carbon cities—From the perspective of urban planning content and process. Land, 13(11): 1834. https://doi.org/10.3390/land13111834
[11] Jiang, X., Zhai, J. (2026). From microclimate response to systemic adaptation: A temporal framework for socioecological urban greening under compound climate risks. Urban Forestry & Urban Greening, 116: 129210. https://doi.org/10.1016/j.ufug.2025.129210
[12] Tuan, P.N., Ha, T.T.V., Ngoc, L.T.B. (2024). Developing new urban areas in Ho Chi Minh City towards carbon neutrality. In Lecture Notes in Civil Engineering, pp. 1062-1072. https://doi.org/10.1007/978-981-97-1972-3_118
[13] Donthu, N., Kumar, S., Mukherjee, D., Pandey, N., Lim, W.M. (2021). How to conduct a bibliometric analysis: An overview and guidelines. Journal of Business Research, 133: 285-296. https://doi.org/10.1016/j.jbusres.2021.04.070
[14] van Eck, N.J., Waltman, L. (2009). Software survey: VOSviewer, a computer program for bibliometric mapping. Scientometrics, 84(2): 523-538. https://doi.org/10.1007/s11192-009-0146-3
[15] Khanra, S., Dhir, A., Kaur, P., Mäntymäki, M. (2021). Bibliometric analysis and literature review of ecotourism: Toward sustainable development. Tourism Management Perspectives, 37: 100777. https://doi.org/10.1016/j.tmp.2020.100777
[16] Mongeon, P., Paul-Hus, A. (2015). The journal coverage of Web of Science and Scopus: A comparative analysis. Scientometrics, 106(1): 213-228. https://doi.org/10.1007/s11192-015-1765-5
[17] Badakhshan, E., Mustafee, N., Bahadori, R. (2024). Application of simulation and machine learning in supply chain management: A synthesis of the literature using the Sim-ML literature classification framework. Computers & Industrial Engineering, 198: 110649. https://doi.org/10.1016/j.cie.2024.110649
[18] Aria, M., Cuccurullo, C. (2017). Bibliometrix: An R-tool for comprehensive science mapping analysis. Journal of Informetrics, 11(4): 959-975. https://doi.org/10.1016/j.joi.2017.08.007
[19] Page, M.J., McKenzie, J.E., Bossuyt, P.M., et al. (2021). The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. BMJ, 372: n71. https://doi.org/10.1136/bmj.n71
[20] Yang, S., Jahanger, A., Hossain, M.R. (2023). How effective has the low-carbon city pilot policy been as an environmental intervention in curbing pollution? Evidence from Chinese industrial enterprises. Energy Economics, 118: 106523. https://doi.org/10.1016/j.eneco.2023.106523
[21] Huo, T., Ma, Y., Xu, L., Feng, W., Cai, W. (2022). Carbon emissions in China's urban residential building sector through 2060: A dynamic scenario simulation. Energy, 254: 124395. https://doi.org/10.1016/j.energy.2022.124395
[22] Hast, A., Syri, S., Lekavičius, V., Galinis, A. (2018). District heating in cities as a part of low-carbon energy system. Energy, 152: 627-639. https://doi.org/10.1016/j.energy.2018.03.156
[23] Marchi, M., Niccolucci, V., Pulselli, R.M., Marchettini, N. (2018). Environmental policies for GHG emissions reduction and energy transition in the medieval historic centre of Siena (Italy): The role of solar energy. Journal of Cleaner Production, 185: 829-840. https://doi.org/10.1016/j.jclepro.2018.03.068
[24] Jia, L., Hu, X., Zhao, Z., He, B., Liu, W. (2022). How environmental regulation, digital development and technological innovation affect China's green economy performance: Evidence from dynamic thresholds and system GMM panel data approaches. Energies, 15(3): 884. https://doi.org/10.3390/en15030884
[25] Blumberga, A., Vanaga, R., Freimanis, R., et al. (2020). Transition from traditional historic urban block to positive energy block. Energy, 202: 117485. https://doi.org/10.1016/j.energy.2020.117485
[26] Li, L., Li, J.F., Peng, L., Wang, X.L., Sun, S.J. (2023). Optimal pathway to urban carbon neutrality based on scenario simulation: A case study of Shanghai, China. Journal of Cleaner Production, 416: 137901. https://doi.org/10.1016/j.jclepro.2023.137901
[27] Bagdi, T., Ghosh, S., Sarkar, A., Hazra, A.K., Balachandran, S., Chaudhury, S. (2023). Evaluation of research progress and trends on gender and renewable energy: A bibliometric analysis. Journal of Cleaner Production, 423: 138654. https://doi.org/10.1016/j.jclepro.2023.138654
[28] Ramnarine, I.D., Sherif, T.A., Alorabi, A.H., et al. (2025). Urban revitalization pathways toward zero carbon emissions through systems architecting of urban digital twins. Environment and Planning B: Urban Analytics and City Science, 52(8): 1920-1948. https://doi.org/10.1177/23998083251318142
[29] Fang, Y., Zhang, X., Cao, Y. (2025). Digital technologies framework and future trends of carbon sequestration research in urban green spaces: A review. International Journal of Environmental Science and Technology, 22(13): 13277-13296. https://doi.org/10.1007/s13762-025-06607-x
[30] Feng, Y., Fang, C., Jia, X., et al. (2025). Dual pathways of carbon neutrality in urban green spaces: Assessment and regulatory strategies. Sustainable Cities and Society, 125: 106311. https://doi.org/10.1016/j.scs.2025.106311
[31] Liu, Y., Chen, S., Jiang, K., Kaghembega, W.S.H. (2022). The gaps and pathways to carbon neutrality for different type cities in China. Energy, 244: 122596. https://doi.org/10.1016/j.energy.2021.122596
[32] To, K., Fernández, J.E. (2013). Alternative urban

technology for future low-carbon cities: A demonstration project review and discussion. In Topics in Safety, Risk, Reliability and Quality, pp. 165-193. https://doi.org/10.1007/978-3-319-02493-6_12
[33] Lu, J., Wang, T., Liu, X. (2023). Can environmental governance policy synergy reduce carbon emissions? Economic Analysis and Policy, 80: 570-585. https://doi.org/10.1016/j.eap.2023.09.003
[34] Gao, P., Zhu, C., Zhang, Y., Chen, B. (2023). An approach for analyzing urban carbon emissions using machine learning models. Indoor and Built Environment, 32(8): 1657-1667. https://doi.org/10.1177/1420326x231162253
[35] Leknoi, U., Yiengthaisong, A., Likitlersuang, S. (2022). Community engagement initiative amid climate change crisis: Empirical evidence from a survey across Bangkok Metropolis of Thailand. Cities, 131: 103995. https://doi.org/10.1016/j.cities.2022.103995
[36] Pan, Y., Zhou, Y. (2025). Can carbon neutrality promote green and sustainable urban development from an environmental sociology perspective? Evidence from China. Sustainability, 17(9): 4209. https://doi.org/10.3390/su17094209
[37] Guo, R., Leng, H., Yuan, Q., Song, S. (2024). Impact of urban form on carbon emissions of residents in counties: Evidence from Yangtze River Delta, China. Environmental Science and Pollution Research, 31(44): 56332-56349. https://doi.org/10.1007/s11356-024-34836-z
[38] Tozer, L., Klenk, N. (2018). Discourses of carbon neutrality and imaginaries of urban futures. Energy Research & Social Science, 35: 174-181. https://doi.org/10.1016/j.erss.2017.10.017
[39] Shi, T.M., Wang, D., Tang, Y., Li, P.Y., Chu, Y. (2023). Research progress on calculation method and impact factors of carbon sequestration capacity in urban ecosystems. Chinese Journal of Applied Ecology, 34(2): 555-565. https://doi.org/10.13287/j.1001-9332.202302.002
[40] Zhao, X., Ouyang, X., Chen, J., Zhang, T. (2025). Research on evaluation and influencing mechanism of ecosystem health in China's urban agglomerations. Ecological Indicators, 178: 114091. https://doi.org/10.1016/j.ecolind.2025.114091
[41] Sessa, E., Guarino, F., Cellura, M., Riva Sanseverino, E. (2025). Climate neutral cities in the landscape of sustainability, climate justice, and decarbonization: A literature review. Energy Reports, 14: 3657-3672. https://doi.org/10.1016/j.egyr.2025.10.025
[42] Tian, J., Huang, W., Peng, J., Fu, S., Wang, J. (2023). How technological innovation influences carbon neutrality? The perspective of spatial spillover effect and attenuation boundary. Journal of Environmental Planning and Management, 68(3): 612-639. https://doi.org/10.1080/09640568.2023.2268267
[43] Jia, Z., Yang, X., Shi, F., Xing, Y. (2024). Pathways to innovation: How city pilots leverage digital technology to reduce carbon emissions. Energy Strategy Reviews, 56: 101578. https://doi.org/10.1016/j.esr.2024.101578
[44] Song, S., Li, T., Liu, P., Li, Z. (2022). The transition pathway of energy supply systems towards carbon neutrality based on a multi-regional energy infrastructure planning approach: A case study of China. Energy, 238: 122037. https://doi.org/10.1016/j.energy.2021.122037
[45] Moon, H., Lee, H., Kim, B., Kim, Y. (2022). Urban hydrogen production model using environmental infrastructures to achieve the net zero goal. Energies, 15(24): 9293. https://doi.org/10.3390/en15249293
[46] Huang, H., Liao, F., Liu, Z., Cao, S., Zhang, C., Yao, P. (2025). Peak assessment and driving factor analysis of residential building carbon emissions in China's urban agglomerations. Buildings, 15(3): 333. https://doi.org/10.3390/buildings15030333
[47] Khalifa, J. (2024). Investigating the implications of technological innovations and clean energy in carbon neutrality in Tunisia. International Journal of Energy Economics and Policy, 15(1): 407-416. https://doi.org/10.32479/ijeep.17850
[48] Jareemit, D., Srivanit, M., Tanapant, S., Limeechokchai, B. (2025). Role of urban morphology integrated building envelope materials in achieving zero emissions: A simulation-based study in complex-shaped urban blocks. Energy Reports, 13: 27-39. https://doi.org/10.1016/j.egyr.2024.11.088
[49] Liu, Y. (2025). Explaining and overcoming barriers to urban carbon neutrality: Historical institutionalism in transport-land use coordination. In Sustainable Development Goals Series, pp. 33-43. https://doi.org/10.1007/978-981-96-8951-4_4
[50] Duan, Z., Kim, S. (2023). Progress in research on net-zero-carbon cities: A literature review and knowledge framework. Energies, 16(17): 6279. https://doi.org/10.3390/en16176279
[51] Liu, T., Zhou, C. (2025). Urban building carbon sinks under the carbon neutrality goal: Research hotspots, measurement frameworks, and optimization strategies. Buildings, 15(24): 4445. https://doi.org/10.3390/buildings15244445
[52] Monteiro, J., Sousa, N., Coutinho-Rodrigues, J., Natividade-Jesus, E. (2024). Challenges ahead for sustainable cities: An urban form and transport system review. Energies, 17(2): 409. https://doi.org/10.3390/en17020409
[53] Lam, K.L., Liu, G., Motelica-Wagenaar, A.M., van der Hoek, J.P. (2022). Toward carbon-neutral water systems: Insights from global cities. Engineering, 14: 77-85. https://doi.org/10.1016/j.eng.2022.04.012
[54] Bibri, S.E., Huang, J., Omar, O., Kenawy, I. (2025). Synergistic integration of digital twins and zero energy buildings for climate change mitigation in sustainable smart cities: A systematic review and novel framework. Energy and Buildings, 333: 115484. https://doi.org/10.1016/j.enbuild.2025.115484
[55] Lai, Y. (2022). Urban intelligence for carbon neutral cities: Creating synergy among data, analytics, and climate actions. Sustainability, 14(12): 7286. https://doi.org/10.3390/su14127286
[56] Yao, Q., An, N., Ci, H. (2024). The dynamics and trends of international research on urban carbon risk. Sustainability, 17(1): 7. https://doi.org/10.3390/su17010007
[57] Zhu, H., Jiang, M., Zhang, D., et al. (2023). Carbon neutrality pathways exploration—A state-of-the-art study: Key technological advancements, current challenges, and potential opportunities. Sustainable Energy Technologies and Assessments, 60: 103489. https://doi.org/10.1016/j.seta.2023.103489
[58] Woon, K.S., Phuang, Z.X., Taler, J., et al. (2023). Recent

advances in urban green energy development towards carbon emissions neutrality. Energy, 267: 126502. https://doi.org/10.1016/j.energy.2022.126502

[59] Chen, J., Wang, H., Yin, W., Wang, Y., Lv, J., Wang, A. (2024). Deciphering carbon emissions in urban sewer networks: Bridging urban sewer networks with city-wide environmental dynamics. Water Research, 256: 121576. https://doi.org/10.1016/j.watres.2024.121576

[60] Suppa, A.R., Cavana, G., Binda, T. (2022). Supporting the EU Mission "100 Climate-Neutral Cities by 2030": A review of tools to support decision-making for the built environment at district or city scale. In Lecture Notes in Computer Science, pp. 151-168. https://doi.org/10.1007/978-3-031-10542-5_11