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Review

Smart City and Energy: A Bibliometric Review of the Smart City and Smart Energy Concept from the Perspective of the Bioclimatic Approach

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Smart City and Energy: A Bibliometric Review of the Smart City and Smart Energy Concept from the Perspective of the Bioclimatic Approach

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Abstract: Smart Cities have emerged as a promising approach for transforming urban living into more sustainable and resilient systems through technology-driven innovations and data-driven governance. Despite its growing implementation and diffusion around the globe, many questions surrounding this topic have emerged. Many critics have emerged since its first conceptualization in the first decade of the current century. Smart Cities have been criticized for their utopian objectives and the security, safety, people's freedom, and privacy within these systems. There are also capitalistic and neoliberalism-related critiques. Other critiques also highlight the current climate cost of Smart City initiatives. In the context of those critiques, bioclimatic and passive strategies might provide an interesting evolution of the concept but seem to be left in the background. This paper aims to contribute to the understanding of the linkages between environmental design approaches and the Smart City discourse. The contribution will explore to which extent bioclimatic and environmental design principles are present in the Smart City discourse and what the patterns are inside the current literature. The methodology of the research included a quali-quantitative analysis of the body of literature in Scopus and a bibliometric analysis using the VOS Viewer tool.

Keywords: Smart City; smart districts; bioclimatic; environmental design

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1. Introduction

The conceptualization of Smart Cities has evolved into a visionary paradigm, offering a glimpse into the trajectory of urban life over the past two decades [1–3]. Since its inception at the onset of the preceding century, cities have undergone diverse transformations, most of them aligning with the Smart City vision, especially within big cities and metropolis [1,4]. Numerous urban centers have embraced this paradigm by implementing pioneering services across many domains, such as mobility, governance, healthcare, and education. The energy sector, in particular, has been strongly hit by the Smart City paradigm, developing approaches in many different paths, such as the energy regeneration of entire districts and cities through smart grids [5–9], the increase of clean energy production [10,11], and the involvement of communities in energy production in the form of energy communities or energy citizenship [12–15]. In all these approaches, ICT and data have a central role, constituting the underlying digital infrastructure that seems to enable many innovative approaches.

Within the realm of Smart Cities, a pronounced attention to digital integration is evident, particularly in the service sector, where many innovative solutions, tools, and connectivity modalities are emerging. At the same time, novel concepts such as the "digital twin" [16], the "15-minute city" [17–19], and the "metaverse city"[20] are surfacing. These concepts reveal a current tendency for continuous evolutions, especially in city-related definitions, supported by digitalization and, in general, by a technocratic approach.

Contemporary challenges, exemplified by the COVID-19 pandemic and energy crises, accentuate the pressing need for substantive, systemic changes rather than isolated innovations. The consensus prevails that Smart Cities can serve as a viable approach to address these challenges, leveraging technology to support policies and urban management across diverse domains, including climate change mitigation efforts [21]. Nevertheless, a universal strategy for transforming a city into a smart entity remains puzzling. On one hand, each city exhibits unique requirements, while on the other, shared impediments and challenges are discernible. The quest for a collective trajectory is propelled by the shared aspirations of cities to enhance efficiency, address societal issues, embrace ecological sustainability, and fortify resilience, among other objectives such as economic ones.

Inside this framework, critics of the Smart City paradigm have surfaced and continue to do so, highlighting its potential drawbacks in areas such as security, personal privacy, and economic disparities. Scholars raise concerns about the paradigm's alignment with a capitalist society, accentuating the widening gap between socioeconomic classes due to these approaches [22–28]. This critical discourse sheds light on the potential side effects of current city strategies, necessitating reflective adjustments. Within the energy field, in fact, these considerations are even more advanced if considering, for example, the phenomenon of energy poverty [29–32]. However, it is important to note that the correlations between the Smart City concept and energy poverty have been scarcely investigated; some first reflections are shown in [33,34]. How can cities plan their sustainable strategies, taking advantage of the possibilities that are given by the new technologies, but at the same time taking into consideration the possible side effects and backlashes? This is a key question that scholars around the world will need to address in the future.

Moreover, critics underscore the capital-intensive nature of the paradigm, emphasizing the pervasive reliance on costly technologies for concrete transformation into a Smart City. Drawing parallels to historical moments in architectural and building science, where the widespread availability of cooling and heating supplies led to standardized construction overlooking local climates, this critique advocates for a shift in approach. Similarly, the field of bioclimatic design arose from addressing the oversight, delineating energy into active and passive components. Active energy encompasses energy produced using equipment like heating systems, while passive energy exploits local climates via strategies such as natural ventilation and indirect heating systems, forming the core of environmental or bioclimatic design approaches [35–41]. In addition, some scholars are also highlighting the sustainable costs (e.g., land use) of energy generation from renewables [11].

This critique prompts a question: can a similar correlation between the Smart City paradigm and environmentally conscious bioclimatic design emerge? This paper aims to explore this question in the context of the energy sector, investigating the potential links between the Smart City discourse and environmentally friendly bioclimatic approaches.

Two hypotheses underscore this contribution. The first one is that the current trajectory of Smart City development relies excessively on costly technocratic approaches, not considering or including the passive methodologies provided by the bioclimatic approach. The second one is that there are potentialities of applying bioclimatic design concepts from architecture to the Smart City discourse.

In the next sections, these hypotheses are explored by performing a bibliometric analysis of the Scopus database. To provide a comprehensive analysis, the paper will use both a quantitative and qualitative approach, as deepened in Section 3.

The paper is structured into five sections. Section 1 provides an introduction to the topics and highlights the research hypothesis. Section 2 deepens a background qualitative review of the key aspects of Smart Energy, bioclimatic approaches in architecture, and Smart City's main critics, suggesting potential gaps to be covered. Section 3 highlights the main methodology used in this contribution both for the qualitative and quantitative parts. Section 4 will show the results and Section 5 will provide their discussion. Finally, Section 6 will provide a conclusion and future potential paths of research.

2. Background Qualitative Literature Review, Objectives, and Research Questions

The discourse surrounding Smart Cities has significantly escalated, especially post-2015, owing to influential global agendas and reports [42,43]. This attention stimulated different interdisciplinary contributions, revealing cities' nature as multi-layered systems [44–46]. Nonetheless, a prevailing challenge persists in the absence of a cohesive definition, resulting in fragmented viewpoints very linked within specific domains [28,42,44,47–52].

Sectors like the smart economy, governance, mobility, and environment have notably framed scholarly conversations around the Smart City, expanding to emergent areas like security, education, health, energy, and performance [53–80]. Despite this diversity, the literature predominantly centers on highlighting and dissecting technological innovations, which remains one of the main aspects of the Smart City discourse. At the same time, there is an increasing trend in exploring future trajectories and potential developments [42,44,50,75,81–93], especially with methodologies such as scenarios, forecasting, roadmaps, and pathways [94,95]. In addition, the advent of COVID-19 accelerated the adoption of digital applications, spotlighting the potential of Smart City solutions in fortifying urban resilience [96,97].

Scholars identify three primary drivers as the ones framing the Smart City concept—community, technology, and policy—emphasizing outcomes such as productivity, sustainability, accessibility, well-being, livability, and governance [93]. Notably, there has been a significant shift from exclusively conceptual discussions toward an approach focusing more on the interrelations with climate change and sustainability, showcasing an evolving connection between Smart City concepts and sustainable practices [42,92]. Proposals advocating for the new concept of Smart Sustainable Cities show the need for technological integration, adherence to sustainability principles, and respect for environmental constraints [92].

Despite this attention to the topic, several critiques have emerged for the Smart City concept. Among these, the most frequent critiques consider the actual development of the Smart City discourse as a reflection of neoliberal, capitalistic, and, thus, political and economic approaches more than place-based necessities of evolution.

In 2013, Vanolo [22] conducted a critical analysis of the Smart City concept, with a particular focus on its implications for power dynamics and knowledge within the contemporary urban environment. The author argued that the Smart City is not just a technological innovation but also a disciplinary strategy that shapes and governs urban spaces. He highlighted how the Smart City discourse is embedded in neoliberal ideologies, reinforcing social inequalities. Similarly, in 2014, Hollands [27,98] intervened critically in the dominance of the corporate Smart City model, highlighting the need for a critical perspective on this approach. The article argued that the corporate Smart City model is driven by profit motives and corporate interests, often neglecting the needs and voices of urban residents. Already at the time, he called for a more inclusive and participatory approach to Smart City development, emphasizing the importance of addressing social justice and equity concerns.

Kitchin's articles [23,24] identified present shortcomings in critical scholarship on Smart Cities, emphasizing the need for detailed genealogies, empirical case studies, and collaborative engagement with stakeholders. The author argued that existing critical perspectives on Smart Cities often lack in-depth empirical research and comprehensive analysis of specific Smart City initiatives. He called for a more nuanced and context-specific understanding of Smart Cities, highlighting the importance of engaging with diverse stakeholders to address the complex social, political, and ethical dimensions of urban technology. His articles provided a comprehensive overview of the limitations of current critical scholarship on Smart Cities and offered recommendations for future research and practice.

More recently, in 2021, Struver et al. [25] emphasized the absence of a critical and emancipatory debate on the right to a Smart City, calling for socially smart, just, and sustainable ideas and strategies. The article critically examined the corporate storytelling and narratives surrounding the smart urbanism concept, highlighting the need to question and challenge the dominant discourses that often prioritize technological solutions over social and environmental concerns. In line with Kitchin's approach, the authors advocated for a more inclusive and participatory approach to urban development, emphasizing the importance of empowering communities and promoting equitable access to urban resources. Finally, Lynch's article [26], in 2019, explored the values, beliefs, and practices of the movement for technological freedom in Barcelona, engaging in a critical conversation with work on urban political movements and alternative economies. The author examined how grassroots movements in Barcelona are contesting the dominant narratives of digital futures and Smart City development. He highlighted the importance of alternative economies and community-driven initiatives in shaping urban technology and governance. The article provides valuable insights into the potential for grassroots movements to challenge the top-down approaches to Smart City development and advocate for more democratic and inclusive urban futures.

Despite the presence of multiple critics also in more recent years, Smart City applications and evolutions are predominant. A lot of attention has been paid to the energy theme as a key component of the Smart City topic and as a sector able to provide substantial impacts, especially within the climate transition and the decarbonization of cities. Smart Energy is included in the principal subdivision of the topic [53]. The concept of Smart Energy has evolved over time, but there is still no widely accepted formal definition, as there is for the broader Smart City concept [99]. The term "Smart Energy" encompasses various aspects, including energy flexibility, intelligent building clusters, and the integration of small-scale energy sources within the structures of virtual power plants [100,101]. Smart Energy involves the application of advanced technologies and innovative approaches to improve energy performance, occupant comfort, and sustainability in buildings [102,103]. It also encompasses the management, coordination, and control of multiple energy subsystems, including renewable energy sources, to enhance energy efficiency and address the challenges of electrification [104,105]. Within the broader context of Smart City, Smart Energy can be clustered into various subdivisions, each addressing specific aspects of energy management and sustainability. These subdivisions include—but are not limited to—intelligent building clusters, energy flexibility, virtual power plants, and smart grid technologies. The concept of intelligent building involves electrically interconnected smart buildings within the same microgrid, aiming to optimize energy usage and enhance sustainability [100,106]. Energy flexibility, on the other hand, focuses on the adaptive and responsive energy management strategies within buildings, contributing to the overall concept of Smart Energy [100,106]. Virtual power plants represent an innovative approach to integrating small-scale energy sources and managing energy distribution in a decentralized manner, contributing to the resilience and reliability of energy systems [101,105]. Additionally, smart grid technologies play a crucial role in enabling the integration of renewable energy sources, demand response mechanisms, and advanced energy management solutions within the urban energy infrastructure [5,107].

As it is possible to see from this synthetic overview, the Smart Energy concept is devoted to "positive" forms of energy aiming to support climate transition, mainly renewable sources of energy and, within these, electricity. The "passive" aspects are completely left in the Smart City discourse. To understand the difference between "passive" and "active" energy, it is essential to consider the concepts of energy transfer and production. Passive systems do not produce energy internally, and strictly passive systems do not consume or dissipate input energy [108]. On the other hand, active systems involve generating or consuming energy [109]. Generally, the distinction between passive and active energy lies in the generation, consumption, and transfer of energy within a system. Passive systems do not produce energy internally and have limitations on energy extraction, while active systems involve energy generation, consumption, and fluctuations. In the context of sustainable building design and the urban dimension, the role of passive and active energy transitions has been recognized, emphasizing the interdependence between urban processes and energy transitions [110]. Furthermore, the study of passive design and alternative energy in building energy optimization has demonstrated that passive measures in building envelope design can significantly reduce overall energy consumption without compromising occupants' comfort [111]. Moreover, the optimal combination of passive design strategies has been identified as crucial for improving building energy performance while ensuring indoor thermal comfort [112]. The integration of passive and active technology packages has been proposed as a means to improve building energy efficiency, particularly in the context of zero-energy buildings [113]. Within this context, the bioclimatic approach is relevant. The bioclimatic approach in architecture involves integrating the natural climate conditions of a specific location into the architectural design process. This approach focuses on creating buildings that harmonize with their environment, utilizing passive design strategies to enhance energy efficiency and occupant comfort. By considering factors such as solar orientation, natural ventilation, thermal mass, and shading, architects can design buildings that effectively respond to the local climate, leading to reduced energy consumption and improved indoor environmental quality. Bioclimatic architecture aims to optimize the use of natural resources like sunlight, wind, and vegetation to minimize reliance on mechanical systems for heating, cooling, and lighting [37,114,115]. By exploring the seamless integration of bioclimatic principles from individual buildings to urban planning, the bioclimatic approach not only enhances the sustainability of structures but also extends its impact on entire urban environments. Some authors have recently started to investigate the potentialities of extending the bioclimatic approach of buildings to cities. By incorporating these principles into urban design, cities can strategically address challenges such as the urban heat island effect, elevate air quality, and cultivate inviting outdoor spaces that prioritize the well-being and comfort of residents [116,117].

The long history of inclusion of passive and bioclimatic design in the context of building and urban design makes the absence of this concept in the mainstream Smart City discourse surprising. It seems that the Smart City topic only revolves around active forms of energy (mainly in the realm of energy generation from renewables and smart distribution), as supported by the most common definitions of Smart Energy.

This is the main objective of the present contribution: to verify if passive design and bioclimatic approaches are present in the framework of Smart City in the current literature. An additional objective is to verify the presence of evolutionary trends in this direction. The paper aims to fill this gap by verifying the hypothesis through a bibliometric review of the Smart City topic concerning two specific elements:

- the understanding of the concept of Smart Energy and passive and bioclimatic design applied to the district dimension and, in particular, their relations and clusterization
- the understanding of potential trends and future research paths for a more passive-oriented and bioclimatic Smart City evolution.

This paper seeks to explore recent literature and provide thoughtful considerations for advancing research on Smart Cities. As such, the hypothesis that the paper aims to verify is the following:

- Passive and bioclimatic design strategies seem not to be included in the current debate about Smart Cities.

Based on this hypothesis, the two underlying research questions for this review are as follows:

- RQ1: Are there existing or potential correlations between the Smart City concept and passive and bioclimatic strategies, and what are those correlations?
- RQ2: Is it possible to foresee a potential future development of the Smart City discourse into more passive-oriented and bioclimatic approaches, or is this development completely outside this research field?

3. Materials and Methods

This review paper uses the methodology of bibliometric research with the intention of identifying patterns and trends through bibliometric analysis. To perform this analysis a systematic literature review was performed in the Scopus database. Data were analyzed with the VOS Viewer tool, an open-source tool able to create clusterization from bibliographic data [118].

The Scopus database was chosen for its reputation for indexing high-standard and peer-reviewed papers and for the substantial presence of the Smart City topic in the collections. Additionally, Scopus allows downloading formats which are compatible with VOSviewer, and it also provides some analysis of citations and results that are useful to direct the search and immediately have insights on emerging aspects. As referred to in Section 6, the inclusion of other databases, such as Web of Science, will be considered in further publications. In order to include all the relevant contributions and to answer the research questions, several entries have been considered in Scopus, as detailed in Table 1. The literature search was conducted between August 2023 and February 2024, with a final check in April 2024.

Table 1. Detail of the literature search on Scopus.

Query Wording	Details	No. of Appearances
"Smart city" OR "Smart cities" AND "energy"	In abstract, keywords, and title	8615 total 5043 after refinement
"Smart Energy"	In abstract, keywords, and title	4924 total 3590 after refinement
"Bioclimatic" AND "design" OR "architecture"	In abstract, keywords, and title	1170 941 after refinement
"Smart city" OR "Smart cities" AND "energy" AND "bioclimatic"	In abstract, keywords, and title	20

The literature search had different phases. The first one was a search in the general Smart City and energy framework. It included the wordings of "smart city" and "energy" in the topic. This was important to understand the general response of the database and check the big picture of the topic. This first search resulted in 8615 papers that were refined to a final number of 5043. The filtering included the exclusion of research fields not in line with the research question (e.g., mathematics, medicine), the type of contribution (excluded editorials, collections of papers), and the limitation to papers written in English. The second search aimed to better identify the keywords inside the specific Smart Energy sector. The identification of clusters has been derived from this search. The query included the wording "Smart Energy", and it resulted in 4924 papers, which became 3590 papers after refinement.

To understand the role of bioclimatic approaches, a two-step approach was then taken. The first one aimed at identifying the main keywords and clustering in the topic of bioclimatic. This query included the wording of "bioclimatic" and "design" or "architecture". This search resulted in 1170 papers, which became 941 papers after refinement. In this case, the refinement also regarded the exclusion of research fields not in line with the research question (e.g., mathematics, medicine, nursing) and the type of contribution (excluded editorials, collections of papers) and was limited to papers written in English.

A last step was carried out to check the presence of direct relationships between the Smart City topic and the bioclimatic one. The search included the query "smart city" with "energy" and "bioclimatic". However, only 20 papers emerged, and the results were not necessarily relevant. For this reason, this part has only been used for the literature background and the qualitative part of the research.

The first, second, and third searches were used to perform a clustering analysis with the VOS Viewer tool. In contrast, the last search was used qualitatively. Table 1 shows the details of the literature search on Scopus, while Figure 1 shows the flow chart of the methodology.

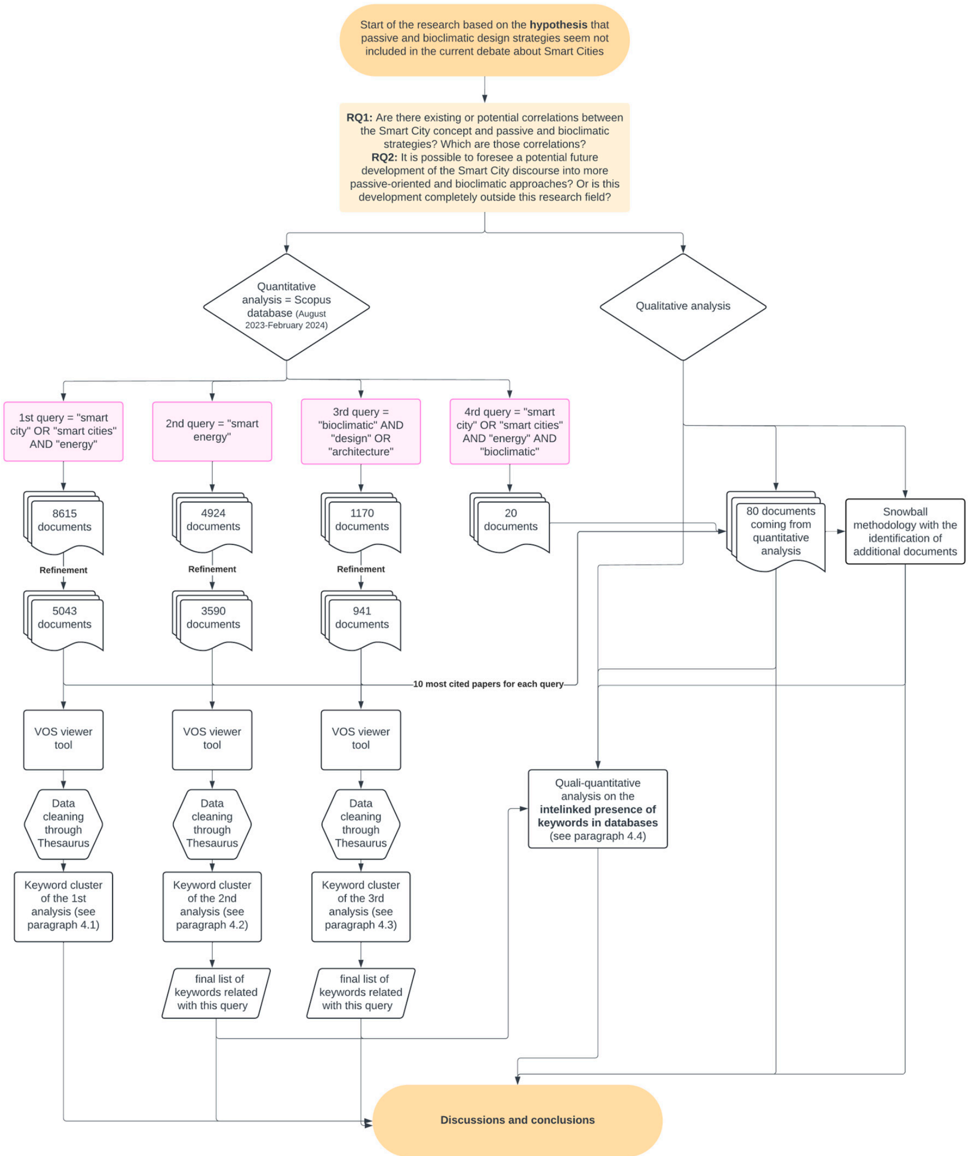

Figure 1. Flowchart of the methodology used, created by the author.

A total of 80 papers (including the 10 most cited papers for each query and the 20 papers for the final search) underwent a detailed qualitative analysis, while 9574 papers were included in the general quantitative analysis. The initial screening involved reviewing the titles and abstracts of the 80 papers, and a more thorough examination was conducted for the most important ones (included in the background literature review and in Section 5). These in-depth readings were crucial to ensure that key aspects of the topic were not missed in the co-occurrence maps and to avoid overlooking essential details in the analyses. Additionally, other contributions were identified through a qualitative approach during the database scan and were incorporated for further qualitative reviews.

For the bibliometric analysis, both Scopus's embedded tools and VOS Viewer were utilized. VOS Viewer, an open-source software available for all operating systems [118], has been widely adopted in recent papers across various research fields [42,119–121]. This software facilitates the correlation of terms found in literature, including those in titles, abstracts, authors, and journals. Moreover, VOS Viewer allows for a cleaning process involving the incorporation of thesaurus files created for each analysis. This step is crucial to prevent duplications, double counting, and normalization of abbreviations. After obtaining initial results, adjustments were made to clusterization parameters to generate a meaningful number of clusters, resulting in a more relevant map. Details regarding this procedure are delineated at the beginning of every subsection in Section 4. By default, all VOS Viewer analyses were conducted using textual data to showcase the co-occurrence of terms found in titles and abstracts. The input files utilized were bibliographic database files obtained from Scopus. A binary counting methodology was chosen to prevent duplicate counting within individual papers, with a minimum occurrence threshold of five documents set to exclude terms occurring in fewer than five documents.

However, as emphasized by Zheng et al. [87], drawing on the insights of numerous authors [122,123], hybrid techniques were employed in the analysis, integrating both qualitative and quantitative approaches. For the qualitative approach, a selection of 80 papers was meticulously reviewed and carefully read, starting with the top 10 most cited papers for each analysis. This selection has then been enlarged using a snowball methodology [124,125]. The findings from this qualitative reading are incorporated into Sections 2, 5 and 6.

4. Results

This section provides a comprehensive yet concise overview of the primary findings from the analysis. It is segmented into sub-paragraphs, with each subsection detailing the outcomes of a specific query.

4.1. The Smart City Concept in the Energy Context

This analysis aimed to provide an updated insight into the Smart City topic within the energy sector. The complete collection of papers was entered into the VOS Viewer software 1.6.18 using a suitable format, emphasizing word co-occurrence in both titles and abstracts. Subsequently, binary counting was employed, with a minimum threshold of five term co-occurrences set to be depicted on the map. The normalization process involved utilizing the association strength method.

A cleaning phase was executed, scrutinizing all considered words and incorporating a thesaurus file. This file guided the system to exclude non-relevant terms, preventing duplications (e.g., singular and plural words) and averting double counting (e.g., abbreviations), as elaborated in Section 2. Further optimizations were carried out in the number of clusters, aiming for the most optimal configuration. Each cluster comprised a minimum of 100 words. The outcomes are presented in Figure 2.

The map illustrated in Figure 2 highlights the emergence of four primary clusters concerning the Smart City topic within the energy framework. The largest cluster, denoted by the color red, comprises 315 items. This cluster encompasses keywords associated with various energy aspects intertwined with the Internet of Things, sensors, power management, and computing. Notably, the two principal keywords, "energy utilization" and "energy efficiency", demonstrate a robust connection to the query itself ("smart city" AND "energy"), establishing a strong link with all other branches. Within the red cluster, noteworthy connections stem from these two keywords. Firstly, the "Internet of Things" node leads to interconnected branches, including security-related keywords, sensor-related terms, energy computing, and, ultimately, power management and resource allocation.

Of significance within the red cluster are keywords associated with sensors, which manifest in multiple forms with substantial frequency. Additionally, the keyword related to "blockchain" surfaces prominently, affirming the growing significance of this topic within the field, as previously highlighted in 2022 [97].

The second cluster, containing 287 items, is identified by the color green. It encompasses keywords related to sustainability, covering various perspectives such as environmental sustainability and protection, sustainable cities, urban planning, climate change, decision-making, population-related aspects, and, lastly, buildings and architectural design. In this preliminary analysis, it appears that this cluster is more linked with architectural and sustainable approaches. Interestingly, even though the precise term is absent, bioclimatic design seems to have some elements in common with this cluster. Within this green cluster, the principal keywords include "sustainable development", "sustainability", "decision-making", "urban planning", "buildings", "artificial intelligence", and "information management". In contrast to the preceding cluster, this one seems to include more parallel keywords, hinting at a more varied and interconnected thematic landscape.

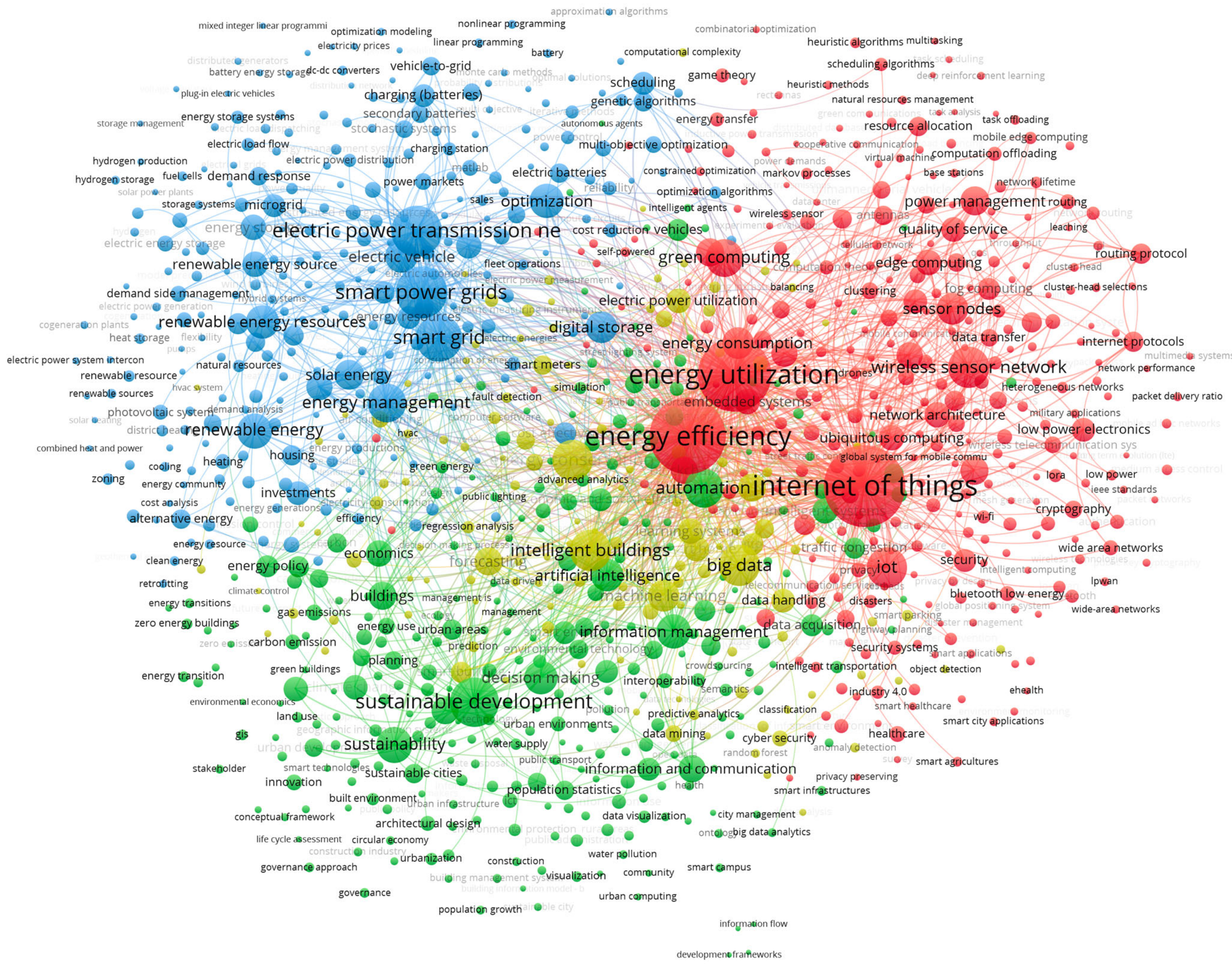

Figure 2. The output of the co-occurrence analysis of terms for the Smart City topic in the energy framework performed with VOS Viewer. The figure shows the physical distances among terms present in titles and abstracts of the literature analyzed, providing clusters of networks of co-occurring terms.

The third cluster, encompassing 264 items and characterized by the color blue, primarily revolves around topics related to the smart grid, storage, and renewable energies. This cluster includes several essential keywords, exploring various facets of the energy sector. However, a prevalent focus within this cluster is on the role of renewable energy sources and their management, emphasizing innovative distribution methods like the smart grid.

Concluding the analysis, the fourth cluster, represented by the color yellow and comprising 134 items, encompasses a diverse array of keywords. These range from "energy conservation" to "big data", "intelligent buildings", "machine learning", "smart homes", and "deep learning". Despite the higher diversity observed in this cluster compared to others, it appears that these clusters converge around the data aspects of the Smart City concept. This involves both methodologies, such as "forecasting", "learning systems", and "monitoring", and specific objects like "smart home" and "intelligent building".

4.2. Smart Energy Keywords Clusters

This analysis aims to provide an overview of the keyword clusters around the specific term of Smart Energy. As defined in the introduction, Smart Energy is intended to be one of the recognized components of a Smart City. Figure 3 shows the results of the cluster analysis.

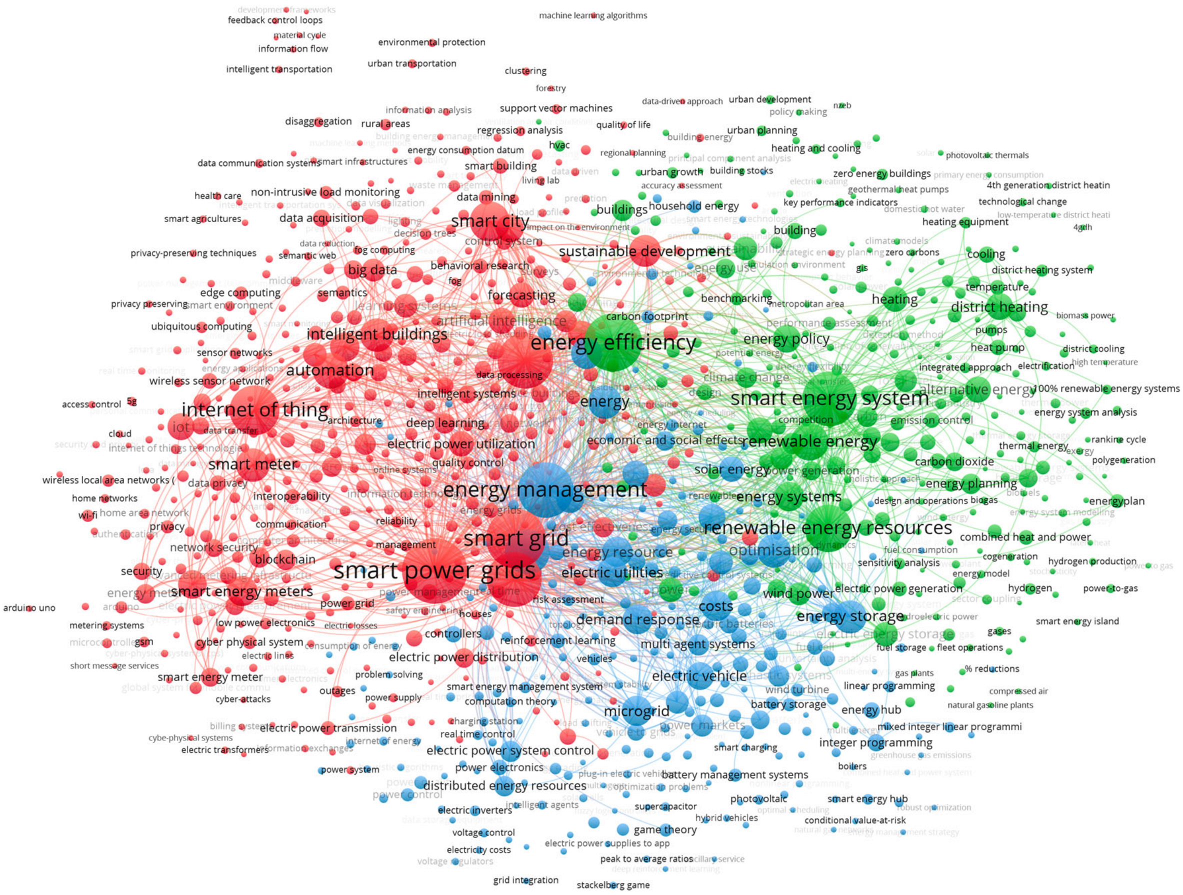

Figure 3. The output of the co-occurrence analysis of terms for the Smart Energy topic performed with VOS Viewer. The figure shows the physical distances among terms present in titles and abstracts of the literature analyzed, providing clusters of networks of co-occurring terms.

The image reveals three main clusters, each seemingly originating from a core keyword. Specifically, the red cluster is shaped by “energy utilization”, the green cluster is shaped by “energy efficiency”, and the blue cluster is shaped by “energy management”.

The largest cluster, depicted in red and containing 461 items, revolves around keywords associated with the smart aspect of energy. It emphasizes terms like “smart grid”, “internet of things”, and “smart meters”. Additionally, it incorporates specific keywords related to big data, smart monitoring, automation, and smart buildings. Two notable subtopics emerge within this cluster, visible as substantial nodes in the image. The first, located in the lower part, revolves around smart grids and electric power, showcasing strong connections with nearly all other keywords. This underscores the pivotal role of this aspect in the Smart City, particularly within the Smart Energy domain. The second subtopic, linked to the Internet of Things node, extends to smart metering, measuring aspects, smart buildings, and the broader Smart City theme.

The green cluster, with 280 items, is the second cluster, incorporating keywords linked with “energy efficiency”. However, the nodes within this cluster extend beyond the “energy efficiency” theme, covering keywords related to energy generation, especially through renewable resources. The cluster appears divided into two core sub-groups. The first centers around the general term "smart energy systems", connecting keywords such as "heating", "cooling", "district heating", and "buildings". The second sub-group, intrinsically linked with the overarching "smart energy system", emphasizes "renewable energy resources", interconnecting with various types of renewable resources. In contrast to the red cluster, which seems like the juxtaposition of two parallel sub-groups, the green one appears more interconnected, resembling a matryoshka where each main keyword contains the subsequent one.

The final cluster, depicted in blue and comprising 259 items, is initiated by the keyword "energy management". This keyword establishes links with numerous smaller nodes, differing from the more concentrated links in the red and green clusters. Despite the presence of the management keyword, the other words within this cluster seem more aligned with a range of subtopics, spanning vehicles, microgrids, distributed energy resources (proximate to the red cluster), storage-related terms, and economic-related words.

In contrast to the prior analysis, which focused on locating the energy topic within the Smart City context, this analysis reveals a broader array of keywords outside the robust connections. These peripheral keywords, visible at the edges of the image, exhibit minimal or no connections with the main network. This suggests that the topic remains dynamic, encompassing various subtopics and specifications that delve into significant specialization and detail.

4.3. Environmental Design and Bioclimatic Keyword Clusters

This analysis aims to provide an overview of the keyword clusters around the specific terms of bioclimatic design and architecture. As recalled in Section 3, the objective of this analysis is to better understand which main keywords are included in this research field in order to detect their position within the Smart City and Smart Energy topic. The results of the VOS Viewer analysis are synthetized in Figure 4.

Figure 4 shows the presence of three core clusters. The first one is the red one, with 131 items. It collects keywords pertaining to the theoretical concept around bioclimatic design and bioclimatic architecture. In particular, it is possible to see words such as "sustainable development", "architectural design", "energy efficiency", and "housing" but also "environmental impact", "sustainable buildings", "intelligent buildings", "environmental performance", "climate control", and "zero energy buildings". The cluster includes many synonyms linked with more sustainable and passive types of architectural practice, together with keywords related to the generic concepts of sustainability.

Three main keywords seem to create relative subgroups. The first one is "sustainable development", which is mainly linked with the broad topic of sustainability. The second one is "architectural design", strongly linked with the "housing" keywords. Both words refer to the more practical aspects of bioclimatic implementation in the architectural field, which are also linked with the building dimension (embodied by the green cluster). Links to this subgroup are, for example, keywords such as "sustainable construction", "intelligent buildings", "participatory design", "economic and social effects", "energy", and "building envelope". It is interesting to note that this cluster also contains the words "energy" and "energy efficiency", highlighting the presence of a clear connection between the two topics. The third subgroup is related to the keyword "energy efficiency", which is linked with "zero energy buildings" and the literature sector devoted to environmental and energy performance analysis ("life cycle", "environmental comfort", "environmental performance", and "environmental impact").

The second cluster is the green one, and it contains 82 items. It mainly contains keywords related to the building dimension and passive energy. It is interesting to see that the main keywords in this cluster are "buildings" and "energy utilization". The first one is linked with both the design part of the bioclimatic approach ("structural design", and design strategy") and the energy one ("heating", "cooling", and "bioclimatic chart"). The second one, "energy utilization", is connected with all the energy-related words such as "energy management", "energy performance", "passive design", "passive solar", "energy use", "energy savings", "energy consumption", and "energy conservation". The second cluster seems very linked with the energy sector, especially within the building dimension.

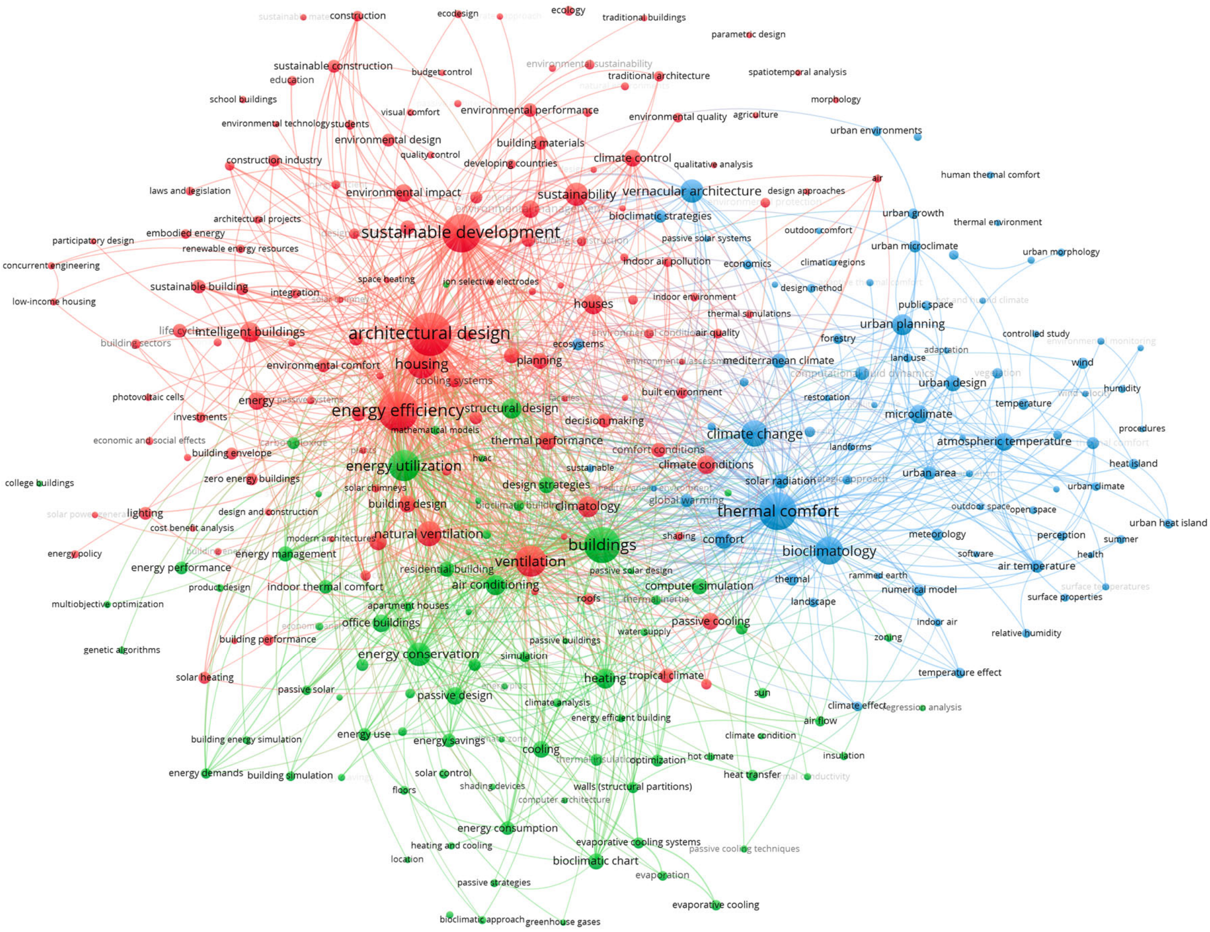

Figure 4. The output of the co-occurrence analysis of terms for the bioclimatic design and bioclimatic architecture field performed with VOS Viewer. The figure shows the physical distances among terms present in titles and abstracts of the literature analyzed, providing clusters of networks of co-occurring terms.

The third cluster is the blue one, and it contains 82 items as well. It has different subgroups mainly related to bioclimatology and climate. Strong keywords are "thermal comfort" with "bioclimatology" as a first sub-group, "climate change" with "urban planning" as a second sub-group, and "vernacular architecture" as a last small one.

Specific attention can be paid to the links of the "energy" word. This map clearly shows a link between the topic of the bioclimatic approach and the energy sector. As shown in Figure 5, the "energy" keyword seems to be mainly linked with "sustainable building" and "intelligent building" for the building-related part of the red cluster, then to the three core keywords of the same cluster ("sustainable development", "architectural design", and "energy efficiency"), and then to the words "planning" and ventilation for what concern the red cluster. It is then linked with the green cluster and, in particular, with "energy utilization", "buildings", "air conditioning", and "energy conservation". A final link is also present with the blue cluster, with the words "climate change", "thermal comfort", and "comfort".

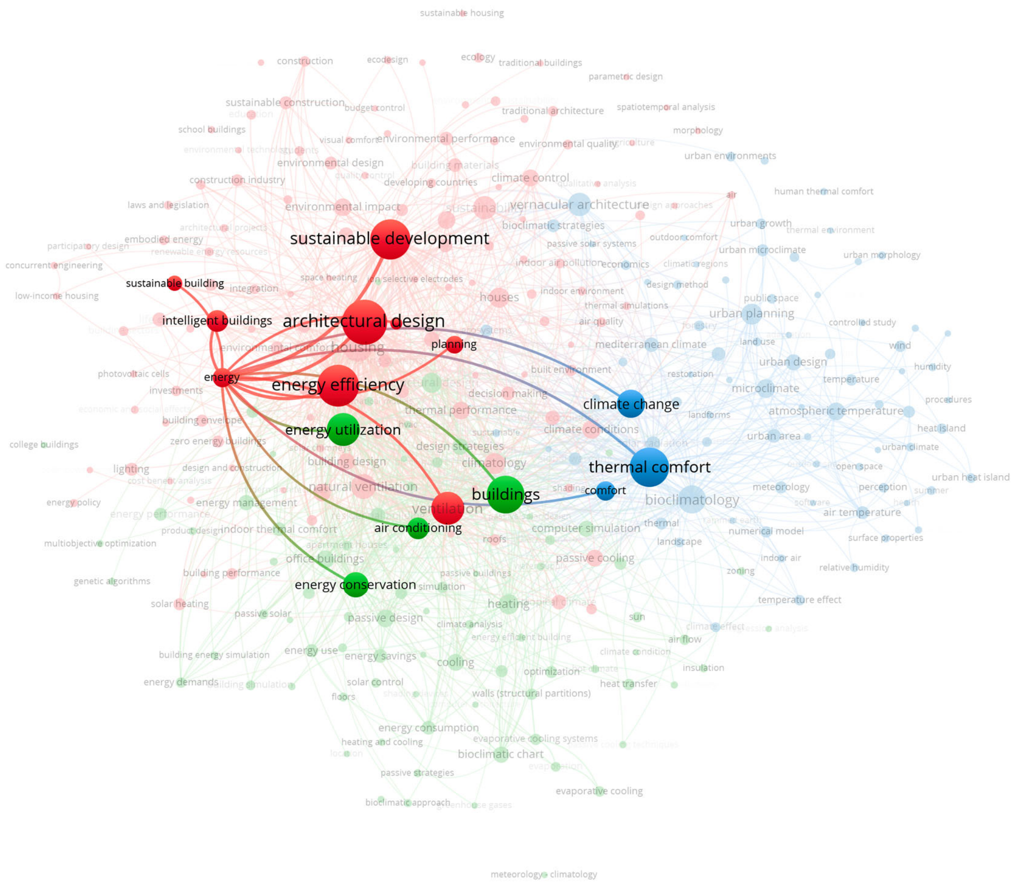

Figure 5. The output of the co-occurrence analysis of terms for the bioclimatic design and bioclimatic architecture field. The image shows, in particular, the connections of the word "energy" with other keywords. The figure shows the physical distances among terms present in titles and abstracts of the literature analyzed, providing clusters of networks of co-occurring terms.

For the objective of the paper, it is also crucial to note that the words linked with the Smart City or Smart Energy fields are not present in the results of this analysis, showing the absence of a strict connection between the topics of bioclimatic design and the Smart City discourse.

4.4. Interlinks between Environmental Design Keywords and the Smart Energy and Smart City Fields

This section aims to detect the interlinked presence of the most recurrent keywords in the three searches. The analysis was done in two steps: the first was searching the keywords of the bioclimatic network (see Section 4.3) into the Smart City and Smart Energy ones (Table 2), and the second was searching the keywords of the Smart City and Smart Energy sectors into the bioclimatic one (Table 3). Both analyses are intended to qualitatively verify the results detected within the background literature review and the VOS Viewer-based analyses. The selection of the keywords is made qualitatively and quantitatively considering the following: (1) the qualitative relevance in the field (selected based on the background literature review) and (2) their dimension in the correspondent energy map (the ten most recurrent keywords in the database).

The verification analysis strongly supports the outcomes from the VOS Viewer analysis. Specifically, it appears that all themes fall within the same broad framework of studies, which is sustainability. However, there's currently no clear link between the bioclimatic approach and the realms of Smart Cities or Smart Energy. Notably, the ten most frequently used keywords in the bioclimatic sector are largely mirrored in the Smart City and Smart Energy domains, emphasizing the commonality of the overall framework.

Table 2. Interlinks among keywords (k. in the table) in the three searches performed with VOS Viewer (n.m. stands for "network map").

Keywords from the Bioclimatic Network	Selection Methodology	Smart City n. m.	Smart Energy n. m.
Bioclimatic design	Main topic	No	No
Bioclimatic architecture	Main topic	No	No
Architectural design	Ten most recurrent k.	Yes	Yes
Energy efficiency	Ten most recurrent k.	Yes	Yes
Sustainable development	Ten most recurrent k.	Yes	Yes
Thermal comfort	Ten most recurrent k.	Yes	Yes
Buildings	Ten most recurrent k.	Yes	Yes
Ventilation	Ten most recurrent k.	Yes	Yes
Energy utilization	Ten most recurrent k.	Yes	Yes
Housing	Ten most recurrent k.	Yes	Yes
Bioclimatology	Ten most recurrent k.	No	no
Climate change	Ten most recurrent k.	Yes	Yes
Ecodesign	Qualitative	No	No
Zero-energy buildings	Qualitative	Yes	Yes
Comfort	Qualitative	No	No
Bioclimatic building	Qualitative	No	No
Environmental quality	Qualitative	No	No
Sustainable building	Qualitative	No	No
Passive energy	Qualitative	No	No
Embodied energy	Qualitative	No	No
Climate control	Qualitative	Yes	Yes
Microclimate	Qualitative	No	No

Table 3. Interlinks among keywords (k. in the table) in the three searches performed with VOS Viewer. n.m. stands for "network map", SC stands for "smart city", and SE stands for "smart energy".

Keywords from the Smart City and Smart Energy Networks	Selection Methodology	Bioclimatic n. m.
Internet of things	Ten most recurrent k. (SC + SE)	No
Energy efficiency	Ten most recurrent k. (SC + SE)	Yes
Energy utilization	Ten most recurrent k. (SC + SE)	Yes
Smart power grids	Ten most recurrent k. (SC + SE)	No
Electric power transmission networks	Ten most recurrent k. (SC + SE)	No
Sustainable development	Ten most recurrent k. (SC)	Yes
Smart grid	Ten most recurrent k. (SC + SE)	No
Intelligent buildings	Ten most recurrent k. (SC)	Yes
Wireless sensor network	Ten most recurrent k. (SC)	No
Big data	Ten most recurrent k. (SC)	No
Energy management	Ten most recurrent k. (SE)	Yes
Smart energy system	Ten most recurrent k. (SE)	No
Renewable energy resources	Ten most recurrent k. (SE)	Yes
Energy management system	Ten most recurrent k. (SE)	No

This alignment is also evident in Table 3, where the most general keywords from the Smart City and Smart Energy searches overlap with those in the bioclimatic domain. Nevertheless, the unique, qualitatively selected keywords in the bioclimatic field are mostly absent in the Smart City and Smart Energy sectors. Similarly, the most precise keywords associated with the smart discourse are not evident in the bioclimatic field.

5. Discussion

This paper aims to contribute to the study of the Smart City concept, making some small progress in its connection to the Smart Energy sector and, specifically, the bioclimatic approach. The focus is on exploring a specific aspect of literature, particularly contributions related to integrating passive and bioclimatic approaches into the Smart City field. A range of search terms was used on Scopus to map out different identified domains. Both qualitative and bibliometric analyses were conducted using the Scopus database and VOS Viewer tools. The results reveal some interesting points, which will be discussed in relation to the research questions.

Research Question 1: Are there any existing or potential correlations between the Smart City concept and passive and bioclimatic strategies, and what are they?

According to the analysis, the answer is twofold. On the negative side, the findings indicate that direct connections between the Smart City and the bioclimatic approach are not emerging. The Smart City discourse primarily focuses on active forms of energy rather than incorporating considerations about the passive use of natural resources, as seen in the bioclimatic debate (e.g., passive solar gains, natural ventilation, and passive cooling). This is also quite evident in some new publications that show some potential future trends in the Smart City discourse in the direction of artificial intelligence and blockchain [126,127]. However, both domains fall under the broader framework of sustainable design and the broader field of climate change-related studies, suggesting a potential correlation in the future, given the increasing costs, including land use, associated with generating new energy, even from renewables. This aspect has been widely observed and analyzed by Ahveniemmi et al. [128] in 2017 in a highly cited paper. The authors, in particular, observe the presence of an overlapping of the two concepts, proposing a new definition of "smart sustainable cities", to underline the importance of including sustainability in the Smart City discourse, also from a monitoring perspective. Furthermore, the approach taken by Kylili et al. [129] shows some interesting approaches to the link between the Smart City and sustainable building design. In their contribution, they see this link mainly through the BIM (Building Information Modeling) technologies and the life-cycle approach. As it is possible to see, in this case, the relationship is not direct between Smart City and bioclimatic but between Smart City and more nuanced approaches linked with the more general sustainable design.

Finally, both fields involve two main scales of analysis: the city (including the intermediate dimension of districts/neighborhoods) and the building. However, it is possible to note how the few papers trying to create a link between Smart Cities and the bioclimatic approach are mainly looking at the outdoor dimension, especially at the district scale [130], and linking the topic to resilience strategies [131,132].

Even if, quantitatively, the interlink is not evident, from a qualitative perspective, some specific publications are investigating this potentiality. In particular, Serghides et al. [116] focus on the bioclimatic approach in developing sustainable cities, particularly within the EU ERANET project "Smart bioclimatic low-carbon urban areas as innovative energy isles in the sustainable city" (SUI). The main objective of the project is to develop sustainable cities by balancing energy systems at a local level, with a focus on urban energy and CO_2 reduction. The bioclimatic approach is one of the three cornerstone procedures of the project, alongside Smart Grids and Management Platform. Even if the Smart City is not directly cited, it is clear that the project's direction is aligned with the Smart City approach.

Research Question 2: Can we foresee a potential future development of the Smart City discourse toward more passive-oriented and bioclimatic approaches, or is this development beyond this research field?

Based on the analysis, there are no clear existing overlaps, and no elements (quantitative or qualitative) support an evolution of the Smart City discourse toward more passive-oriented approaches. However, considering the shared general framework of both fields, it is plausible to suggest that future interrelations may emerge. Some studies reflect on the cost of energy generation, even from renewables, and the bioclimatic approach has long considered this, especially at the building scale. This potential future development is not entirely beyond the research field but is not yet present.

6. Conclusions

In summary, the review has shed light on aspects of the Smart City concept and proposed potential lines of further research. The methodology utilized has involved two main aspects: firstly, conducting a qualitative review of recent contributions on the Smart City topic, with a specific focus on their connections with both active and passive forms of energy—highlighting the significance of bioclimatic approaches; and secondly, performing a bibliometric analysis utilizing the VOS Viewer tool. This analysis has identified some literature gaps that could be addressed in future research and has raised questions that could guide future reviews. The key findings are as follows:

1. There is a lack of substantial emphasis on bioclimatic approaches or more nuanced and passive forms of energy within the discourse surrounding Smart Cities and Smart Energy. However, both fields share the overarching goal of sustainable cities and sustainability, suggesting the potential for future connections to emerge.
2. Even if there are no contributions creating a direct link between the two concepts, some reflections on the costs (e.g., in land use) of active forms of energy are arising, poising doubt on the long-term sustainability of these technologies and paving the way for the inclusion of different approaches.

The consequences of this study mainly revolve around affirming and spotlighting prevailing trends in Smart City development, especially considering the connection between two important fields of investigation such as the Smart City and the Bioclimatic one, while also putting forward new hypotheses for further exploration. However, a notable limitation of this study is the scarcity of actual contributions that recognize a connection between these two fields of inquiry. Future research will focus on expanding the literature base, including querying the Web of Science database using similar search terms, to determine whether there is a larger body of literature that either supports or modifies the findings presented in this study.

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