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Net-Zero Carbon Communities: A Systematic Bibliometric Review of Research Trends, Structural Gaps, and Future Directions

Jia Xin Chai[1], Ru Guo[1,2,3,4,*]

[1]College of Environmental Science and Engineering, Institute of Environmental Planning and Management, Tongji University, Shanghai 200092, China;
[2]Institute of Carbon Neutrality, Tongji University, Shanghai 200092, China;
[3]Key Laboratory of Cities Mitigation and Adaptation to Climate Change, Shanghai 200092, China
[4]Shanghai Institute of Pollution Control and Ecological Security, Shanghai 200092, China
**Correspondence Author*

Abstract: ***As cities account for over 70% of global energy-related carbon emissions, the community scale has emerged as a critical but undertheorized site for urban decarbonisation. Translating city-level net-zero commitments into verifiable outcomes requires disaggregation to the neighbourhood level, where energy use, mobility, governance, and social practice intersect most directly. Yet no systematic bibliometric mapping of the net-zero carbon community (NZCC) field currently exists. This review analyses 1,292 Scopus-indexed publications from 2001 to 2026, applying keyword co-occurrence network analysis, burst detection, geographic mapping, and spatial scale cross-tabulation to characterise the field's structure and identify persistent gaps. Annual output has grown from fewer than 30 papers through 2019 to 375 in 2025, coinciding with the EU Green Deal and China's dual-carbon pledge. Three structural deficits are found through the analysis, including marginalisation of governance studies, the unlinking of carbon assessment and governance literatures and the underrepresentation of developing countries. Advancing the field requires integrating institutional analysis with carbon assessment, building feedback loops between monitoring evidence and governance design, and developing context-sensitive frameworks for the Global South.***

Keywords: Net-zero carbon communities, Bibliometric review, Decarbonisation, Urban governance, Carbon monitoring, Community-scale transition**.**

1. Introduction

Cities account for over 70% of global energy-related carbon emissions [1], and the concept of net-zero carbon cities has gained substantial traction in international policy discourse [2]. Cities and nations around the world have set carbon reduction goals following the enactment of the Paris Agreement, aiming to mitigate challenges from climate change [3]. However, translating city-wide ambitions into actionable, verifiable outcomes requires disaggregation to the community scale, where energy consumption, mobility, governance, and social practice intersect most tangibly [3,4]. Moreover, micro-scales such as communities and neighbourhoods are the smallest unit where policy interventions are designed, implemented, and experienced by residents [5,6]. Despite this recognition, the community scale remains undertheorised as a unit of socio-technical transition, and no current systematic bibliometric mapping of this rapidly expanding field exists.

"Community" denotes any sub-city spatial unit sharing common characteristics, encompassing all buildings, supporting infrastructure, public spaces, green areas, and the people who live, work, or visit within it. "Neighbourhood" and "community" are the 2 main terms used by researchers. Brozosky et al. [5] defined neighbourhoods as a cluster of buildings. Hamiduddin [7], Sharifi et al. [8], and Ruiz-Valero et al. [9] have expanded the boundary to include buildings, mobility, open spaces and networks. Hamiduddin [7] and Chastenet et al. [10] further added social, economic, and environmental dimensions, conceptualising the neighbourhood as an urban area where sustainability principles and planning are enacted. Conversely, Hamdan et al. [11] conceptualise community as the collective of citizens and local organisations actively engaged in project governance. Zhu et al. [12] and Xu et al. [13] have a similar take as the neighbourhood definition, taking communities as an urban spatial structure that could be transformed through socio-technical designs. Despite the interchanging usage in the field, this review adopts "community" as an umbrella term for any sub-city spatial unit encompassing buildings, infrastructure, public spaces, and the people within it, following the Global Protocol for Community-Scale Greenhouse Gas Emission Inventories definition of "community", any "geographically discernible sub-national entity" within the urban context [14].

At present, there is no single, universally accepted definition of a net-zero carbon community (NZCC). The terminology is far from unified, reflecting the field's rapid evolution and the diversity of technical, regulatory, and spatial contexts in which decarbonisation is pursued. At the most fundamental level, a distinction exists between energy-focused, carbon-focused, and performance-focused frameworks [5]. Terms such as Zero Energy District (ZED) and Zero Energy Neighbourhood (ZEN) target annual energy balance through on-site renewables but do not necessarily account for embodied carbon or upstream emissions [15]. A development could qualify as "zero energy" while still carrying a significant carbon footprint. Carbon-themed frameworks such as Zero Carbon District or Net Zero Carbon Emission District apply full life-cycle greenhouse gas accounting across Scope 1–3 emissions [12]. Performance ambition also varies. Nearly Zero Energy Neighbourhood (nZEN) aligns with EU

regulatory minimums [16], while Positive Energy District (PED) and Energy Positive Neighbourhood (EPN) go further by exporting surplus renewable energy to the grid [17]. Despite their terminological differences, all of these frameworks address distinct but interconnected dimensions of urban decarbonisation. Given that "net zero" is widely used in international agreements and standards, encompassing all CO2-equivalent emissions, this review adopts "net-zero carbon community" (NZCC) as an umbrella term for all relevant efforts.

Bibliometric evidence demonstrates that NZCC research has grown near-exponentially since 2020, with annual output having doubled between 2022 and 2025. This surge coincides with major policy commitments at the landscape level. Yet the technological solutions have gained more focus in the field, while underweighting governance and social dynamics. The absence of studies focusing on transition analysis of community-scale needs to be better studied for better governance. Therefore, this review aims to map, quantify, and critically assess these gaps through systematic bibliometric analysis of 2,238 Scopus-indexed publications from 2001 to 2026, providing an evidence-based foundation for future research and policy.

2. Methodology

2.1 Data Collection and Preparation

The bibliographic dataset was retrieved from the Scopus database using a Boolean search string designed to capture research addressing carbon neutrality at the community and neighbourhood scale: TITLE-ABS-KEY((“net zero carbon” OR “net-zero carbon” OR “carbon neutral” OR “zero carbon”) AND (communit* OR neighborhood* OR district* OR “urban area” OR “built environment”) AND NOT (“net zero energy” OR “net-zero energy” OR “net zero water” OR “net-zero water” OR “net zero waste” OR “net-zero waste”)). The NOT operator excluded energy-balance, water, and waste frameworks that do not directly address carbon outcomes. The search was restricted to articles and reviews published in English between 2001 and 2026, yielding 1,530 documents after document-type filtering.

The systematic screening followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework across seven sequential stages (Figure 1). An initial Scopus Boolean search retrieved 2,238 records. Document type filtering retained only articles and reviews, excluding 708 conference papers, book chapters, editorials, and other document types (n = 1,530). Language filtering removed 61 non-English records (n = 1,469). Duplicate DOI screening identified no duplicates, and a keyword availability filter removed 28 records lacking both author and index keywords, yielding a deduplicated dataset of 1,441 records. A relevance check is done manually, excluding non-relevant papers. Papers whose primary subject concerned biological or biochemical processes (n = 127), chemical catalysis (n = 12), marine transport decarbonisation (n = 4), agricultural carbon farming (n = 6), or food-product lifecycle studies (n = 0). To prevent false exclusions, any record containing explicit community-scale urban anchors, such as “community-scale,” “neighbourhood,” “zero-carbon”) was retained regardless of rule matches. This procedure removed 149 records, producing a final analytical sample of 1,292 publications comprising 1,118 original articles and 174 reviews across 517 unique journals.

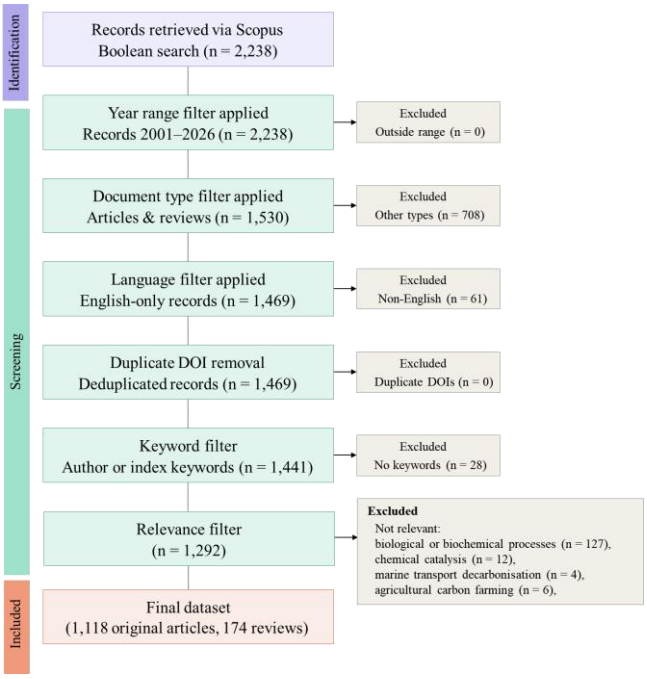

Figure 1: PRISMA-style screening flowchart.

2.2 Bibliometric Analysis

Four complementary analyses were conducted using Python (v3.12) with the pandas, NetworkX, and matplotlib libraries [18]. Descriptive profiling and Geographic tagging are first performed on the dataset. Next, keyword co-occurrence network analysis was performed on the 60 most frequent author keywords after normalisation of variant spellings. The keyword burst detection then identifies terms exhibiting statistically significant temporal surges by computing year-specific z-scores of keyword proportions against their historical baselines, with a threshold of 1.5 standard deviations defining burst periods. Lastly, a research gap analysis cross-tabulated spatial scale and the geographic context to quantify underrepresented intersections.

3. Results

3.1 Publication Landscape and Growth Trajectory

Figure 2 shows that the annual output in the NZCC field rose sharply from 30 publications through 2019, to 132 in 2022, and reached 375 in 2025. The 2026 count of 96 represents a partial year that, if annualised, projects to approximately 260, indicating sustained momentum. This inflexion coincides with the EU Green Deal’s announcement in late 2019 and China’s dual-carbon pledge of September 2020, suggesting that high-level landscape pressures triggered a cascading research response [19,20]. There are 1,118 original articles (86.5%) and 174 reviews (13.5%), indicating a field with sufficient primary research to support systematic synthesis.

The journal distribution reveals a pronounced disciplinary concentration (Figure 3). Sustainability (51 papers), Energies (48), Energy (38), Journal of Cleaner Production (37), and

Sustainable Cities and Society (37) lead the rankings. These venues are oriented toward energy systems, building science, and broad sustainability rather than institutional or social analysis. Notably, no governance, urban planning, or social science journal appears in the top 15. Journals such as Environmental Policy and Governance, Urban Studies, and Research Policy, which would be expected outlets for governance-oriented NZCC research, are absent from the dataset entirely.

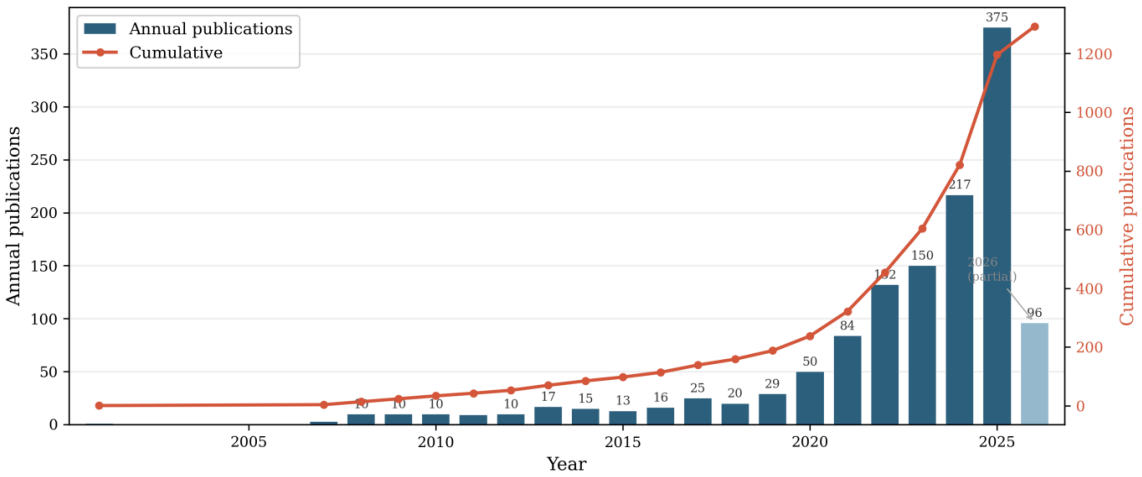

Figure 2: Annual publication trend of NZCC-related research.

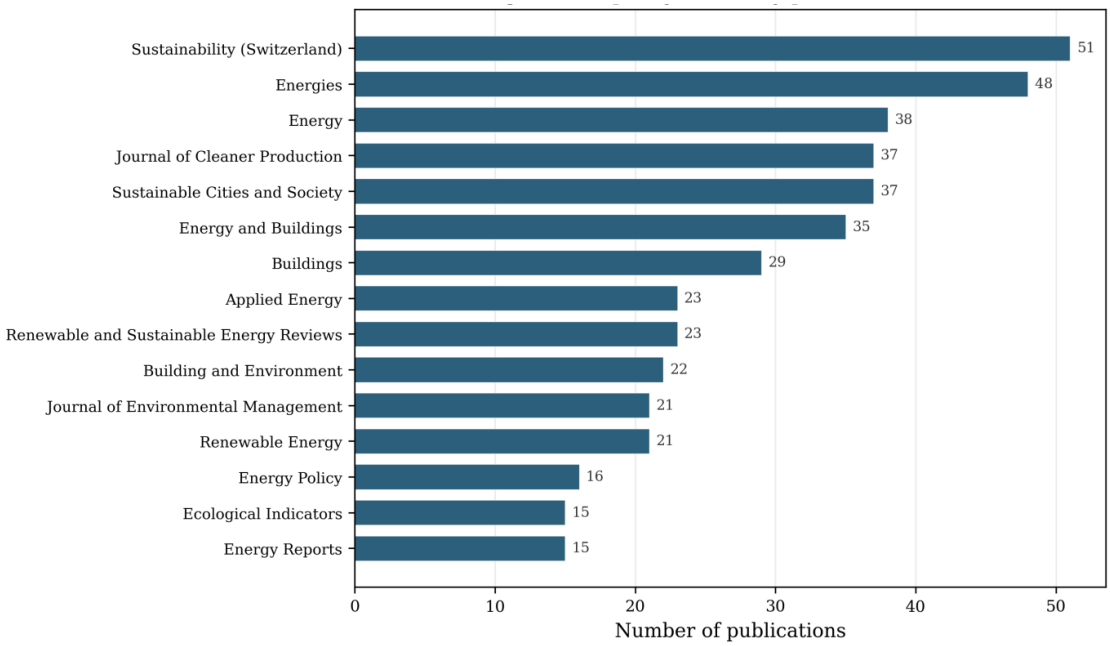

Figure 3: Top 15 journals by publication count.

3.2 Thematic Structure of NZCC Research

In Figure 4, the keyword co-occurrence network identified five thematic clusters. Cluster 0, anchored by "carbon emissions," "net-zero carbon," "life cycle assessment," and "built environment," represents the carbon accounting and assessment core of the field. Cluster 1, organised around "sustainability," "energy efficiency," "embodied carbon," and "circular economy," captures the materials and lifecycle perspective, linking building-scale interventions to broader sustainability objectives. Cluster 2, comprising "carbon neutrality," "climate change," "urban planning," and "carbon sequestration," addresses the policy and environmental framing of NZCC research and connects to the political and environmental drivers. Cluster 3, organised around "anaerobic digestion" and "waste activated sludge," represents a specialised waste-to-energy sub-literature; its weak connections to the four core clusters indicate that it constitutes a technically distinct and largely peripheral strand within the broader NZCC network. Cluster 4, centred on "renewable energy," "decarbonization," "district heating," and "hydrogen," covers energy infrastructure transformation and maps directly onto the technological drivers.

Two structural features of the network merit particular attention. First, "governance" appears as a peripheral node at the far edge of the network with minimal connections to any core cluster. This marginalisation is not merely a matter of low frequency; it indicates that governance is structurally disconnected from the field's intellectual core, treated as contextual background rather than as a mechanism interacting with technological and assessment themes. Second, the assessment cluster (Cluster 0) and the policy/environmental cluster (Cluster 2) show limited cross-linkage, with "life cycle assessment" and "urban planning" sharing no direct co-occurrence edge. This topological separation suggests that carbon quantification and governance analysis operate as parallel rather than integrated research programmes.

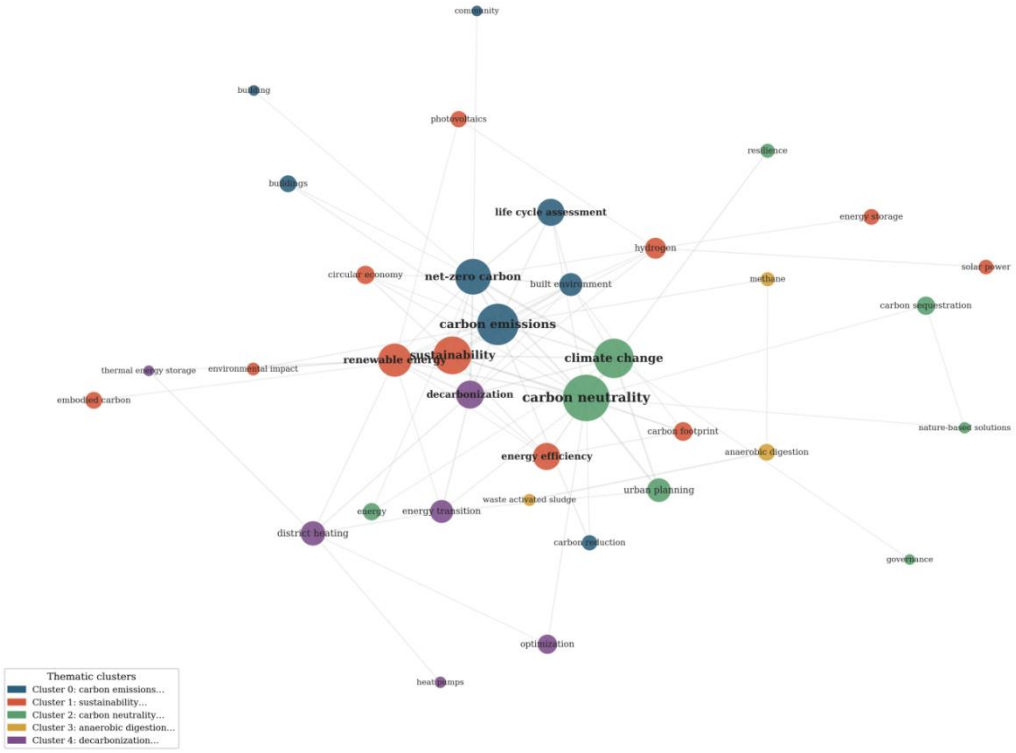

Figure 4: Keyword co-occurrence network.

3.3 Temporal Evolution of Research Frontiers

The burst detection analysis reveals a three-phase maturation trajectory (Figure 5). In the foundational phase (2007–2012), the earliest burst keywords were "climate change," "carbon sequestration," "solar power," "policy," and "resilience," reflecting a period in which the field was establishing its problem framing and foundational concepts. The implementation phase (2014–2019) saw the emergence of technology-specific keywords including "hydrogen," "heat pumps," "electric vehicles," "energy storage," "smart cities," and "energy policy," indicating a shift toward concrete technological deployment and system integration. The systemic phase (2020–present) is characterised by bursts in evaluative and integrative concepts: "decarbonization," "life cycle assessment," "climate change mitigation," "urban sustainability," "nature-based solutions," and "machine learning." This progression from problem framing through technology deployment to systemic evaluation follows a classic field maturation pattern.

Critically, no governance or institutional keyword appears as a burst term in any phase. While "policy" registered a brief burst in 2010–2011, this reflects general climate policy discourse rather than community-scale governance analysis. The absence of bursts for terms such as "governance," "institutional," "stakeholder engagement," or "participatory planning" confirms that the field's temporal evolution has been technology-led throughout, with no corresponding surge in governance or social science inquiry. This reinforces the structural observation from the keyword network and provides temporal depth to the governance deficit argument.

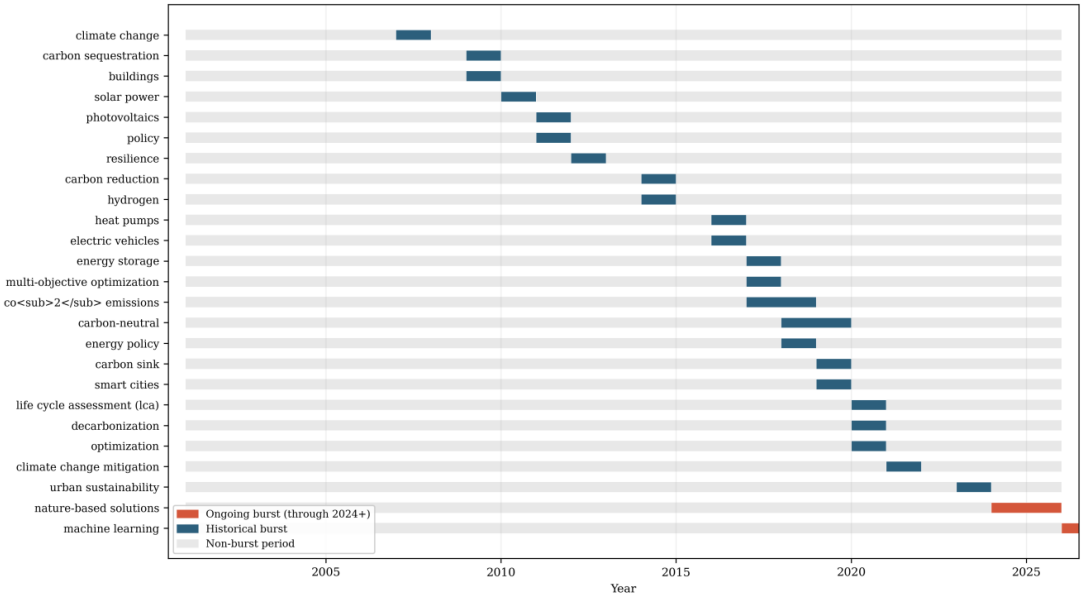

Figure 5: Top 25 keywords with the strongest citation bursts.

3.4 Driving Factors of NZCC Development

NZCC transitions are shaped by interacting drivers across technological, socioeconomic, political, and environmental domains. Identifying these drivers matters both for explaining divergent outcomes across communities and for informing replicable policy design.

3.4.1 Political and Regulatory Drivers

Governance frameworks and regulatory instruments establish the enabling conditions within which technological and socioeconomic drivers operate. Carbon pricing mechanisms, emissions regulations, renewable energy mandates, and net-zero building codes collectively define the institutional landscape that either accelerates or constrains community-scale transitions [21]. Urban planning policies and building standards shape the physical form of communities in ways that lock in or foreclose low-carbon trajectories over multi-decade timeframes [22]. Comparative evidence across cities demonstrates that policy design quality is a stronger predictor of transition outcomes than policy ambition alone [23].

3.4.2 Socioeconomic Drivers

Socioeconomic conditions operate as both enablers and constraints on NZCC transitions. Financial incentives, green infrastructure investment, and the declining cost-competitiveness of clean technologies have accelerated adoption in economies with mature capital markets, though financial barriers remain structurally significant in emerging markets where risk-adjusted returns on green investment are less predictable [24,25]. At the community level, behavioural change and social norm formation are increasingly recognised as co-determinants of transition outcomes alongside capital availability [26,27]. Stakeholder collaboration and public participation mechanisms shape the pace of low-carbon lifestyle adoption in ways that financial instruments alone cannot.

3.4.3 Technological Drivers

Technological advancement constitutes the most extensively studied driver of NZCC development. Clean energy transition, encompassing renewable energy deployment, electrification of consumption, and emerging hydrogen technologies, forms the foundational infrastructure layer of community-scale decarbonisation [28]. Energy efficiency improvements across residential, industrial, and transportation sectors further reduce the baseline demand that renewable systems must meet [29,30]. Digitalisation supports these efforts through artificial intelligence optimisation, life cycle assessment tools, City Information Modelling (CIM), and energy performance simulation platforms that support both design optimisation and operational management of net-zero systems [30,31]. The integration of smart microgrids with distributed renewable generation and community-level storage represents a particularly active research frontier, enabling demand-side flexibility and real-time load matching [32].

3.4.4 Environmental Drivers

Environmental pressures function as both motivational and material drivers. Intensified flooding, drought cycles, and extreme weather events act as urgency multipliers, strengthening the case for net-zero-oriented urban systems [33]. Availability of renewables, such as adequate solar or geothermal, remains a foundational material driver, enabling communities to decouple energy consumption from fossil fuels [34]. Urban greening and ecologically informed design complement energy transitions by enhancing carbon sequestration and thermal resilience [35], though large-scale renewable deployment can conflict with other sustainability objectives [36].

3.5 Monitoring and Evaluation Frameworks

Carbon emission monitoring at the community scale employs a multi-layered methodological ecosystem. Neighbourhood Sustainability Assessment tools such as Leadership in Energy and Environmental Design for Neighbourhood Development (LEED-ND) provide structured evaluation frameworks [8], enhanced when integrated with standardised protocols such as the Global Protocol for Community-Scale Greenhouse Gas Emission Inventories: An Accounting and Reporting Standard for Cities. Carbon footprint analysis remains the most widely applied quantification approach, with emissions typically structured through Scope 1 (direct), Scope 2 (indirect energy), and Scope 3 (supply chain) [37]. Vargas-Salgado et al. [21] demonstrated that Scope 3 emissions alone can constitute up to 77% of total neighbourhood emissions, highlighting the inadequacy of boundary-limited inventories. Calculation methods include the emission factor method [14], Life Cycle Assesment (LCA), input-output analysis [38], and consumer lifestyle approaches [39], each offering different analytical depth and data requirements.

Spatially, Geographic Information Systems (GIS) based modelling platforms integrate land use, population density, and building typology data to produce visualised emission distributions [22,40]. Bottom-up monitoring complements spatial models through granular field data on energy consumption [37], mobility [26], and waste flows [27]. Emerging methodologies include satellite-based atmospheric monitoring [41], and Artificial Intelligence (AI) driven sensor networks for real-time carbon tracking [42] which is advancing neighbourhood-level Measurement, Reporting and Verification (MRV) capability [14,42].

3.6 Geographic and Spatial Landscape

The geographic distribution of research confirms a pronounced concentration in developed economies (Figure 6). China leads with 264 papers, followed by the United Kingdom (123), the United States (94), and France (90). Among developing economies, only India (30) and the UAE (9) appear in the top 20. No African, Latin American, or Southeast Asian country reaches the threshold. The spatial scale analysis shows that community/neighbourhood- scale research dominates (974 papers), with city-scale (592), building-scale (431), and national/regional (365) also heavily represented, confirming that papers frequently address multiple scales (Figure 7). Despite the high community-scale count, cross-tabulation reveals that only 5.4% of community-scale papers engage governance substantively, confirming that the majority are technically rather than institutionally

focused.

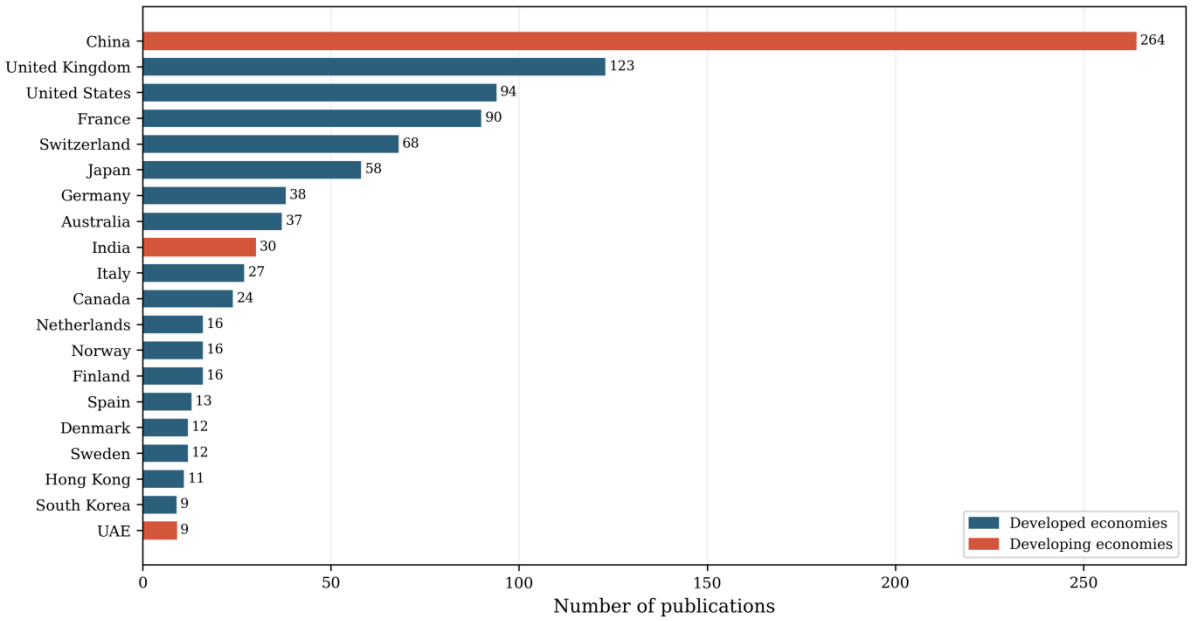

Figure 6: Geographic distribution of NZCC research (top 20 countries).

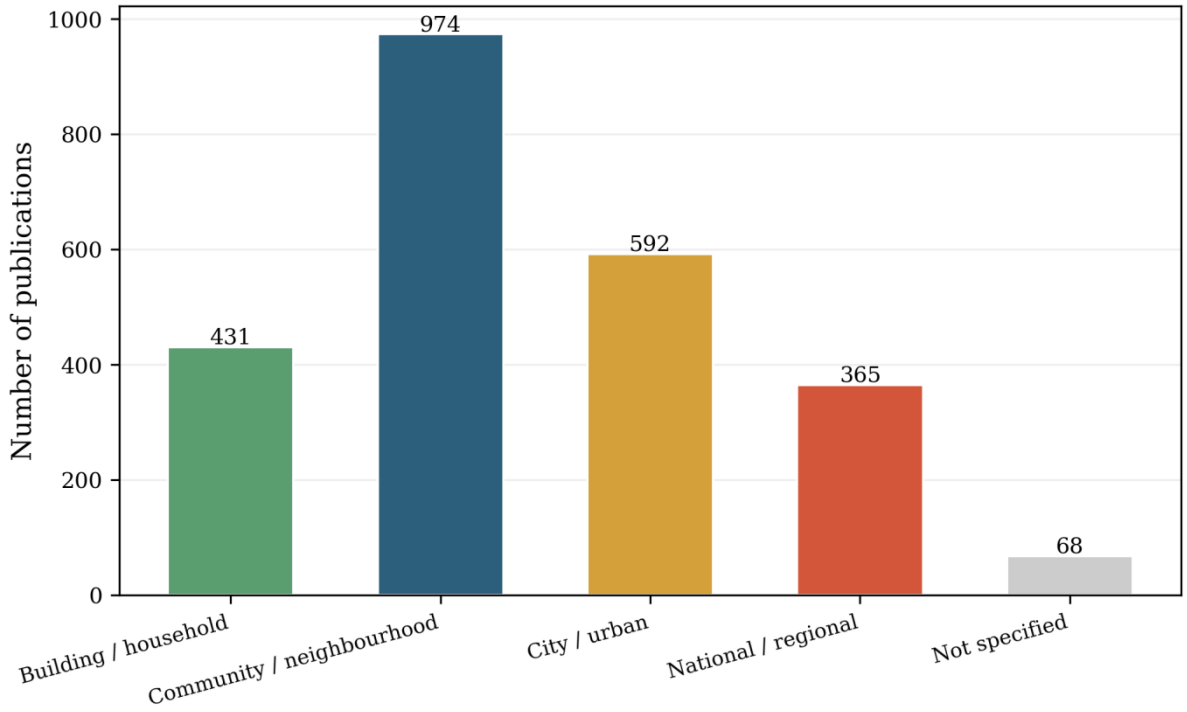

Figure 7: Spatial scale of analysis in NZCC literature

4. Discussion

4.1 The Governance Deficit in NZCC Research

The bibliometric evidence confirms that governance is structurally marginal in NZCC research. In the keyword co-occurrence network, "governance" occupies a peripheral position with minimal connections to any core thematic cluster, indicating that governance is not merely understudied but structurally disconnected from the field's intellectual core. In the journal distribution, no governance, urban planning, or social science journal appears among the top 15 publication venues; journals such as Environmental Policy and Governance, Urban Studies, and Research Policy are absent from the dataset entirely. The burst analysis shows no governance or institutional keyword registers as a burst term in any period from 2001 to 2026, confirming that the field's temporal evolution has been technology-led throughout, with no corresponding surge in governance or institutional inquiry. Not to forget that only 5.4% of community-scale papers engage governance substantively. Collectively, these patterns suggest that governance is treated as a contextual background rather than as a causal mechanism in NZCC research.

This marginalisation is a multi-factor problem rather than a simple oversight. Firstly, the field's disciplinary origin in building energy science and engineering has channelled subsequent research toward quantifiable, modellable problems such as energy balance optimisation, renewable integration, and lifecycle carbon accounting [43,44]. Governance, by contrast, is harder to operationalise, harder to

measure, and harder to publish in energy-oriented journals. The journal distribution confirms that the top venues reward technical contributions, creating a publication incentive structure that systematically marginalises institutional analysis. Secondly, the dominant research funding structures in this field have prioritised technological demonstration over governance evaluation [45]. Ntafalias et al. [46] report that 80% of PED case studies are funded through research grants rather than commercial deployment, indicating that the research agenda is shaped by funding priorities that favour engineering solutions. Thirdly, governance research at the community scale requires demanding methodological approaches, including longitudinal case studies, stakeholder interviews, and institutional analysis, that are time-intensive and do not align well with the three-to-five-year project cycles typical of energy research funding [6].

The consequences of this deficit for both knowledge production and practice are substantial. Evidence suggests governance arrangements determine transition outcomes more strongly than technology availability alone. Gohari et al. [17] demonstrate through cross-city comparison that governance structures, stakeholder networks, and implementation phasing are the primary differentiators between PED projects that progress and those that stall. Uspenskaia et al. [47], drawing on the SPARCS smart city project, identify regulatory gaps and cross-departmental coordination failures as the most persistent barriers to net-zero district implementation, outweighing technical obstacles. The resistance to zero-emission neighbourhood infrastructure stems not from technological inadequacy but from professional tensions between building and energy disciplines, shifting political priorities, and local social norms that technology-focused interventions cannot address [6]. Despite these findings, the broader field has not followed up systematically, resulting in a literature that has skewed towards technological solutions but cannot explain why some communities achieve durable decarbonisation while others, with equivalent technological endowments, do not.

Communities designing NZCC programmes currently lack an evidence base for choosing between binding versus voluntary governance frameworks, mandated versus incentive-based compliance mechanisms, or top-down technocratic versus participatory planning processes. Li et al. [48], reporting on Japanese zero-carbon community demonstration projects, find that resident participation and multi-level governance coordination were decisive for project success, yet these governance variables are rarely incorporated into the assessment frameworks that dominate the field. Salvia et al. [49] identify governance, alongside technical, social, economic, and spatial dimensions, as a critical determinant of cities' capacity to engage in climate neutrality transitions, yet the bibliometric evidence shows that the NZCC literature has not operationalised this insight at the community scale. Thus, the governance deficit reflects a disconnect between the capacity to quantify carbon outcomes and the capacity to analyse the institutional arrangements.

4.2 The Disconnect Between Assessment Frameworks and Transition Analysis

The keyword co-occurrence network reveals that the assessment cluster (carbon emissions, LCA, built environment) and the policy/environmental cluster (carbon neutrality, climate change, urban planning) operate with minimal cross-linkage. "Life cycle assessment" and "urban planning" share no direct co-occurrence edge. In a well-integrated field, one would expect keywords such as "governance effectiveness," "policy evaluation," or "institutional performance" to co-occur with "LCA" and "carbon accounting." Their absence indicates that researchers quantifying carbon are not posing governance questions, and researchers analysing governance are not producing carbon evidence. The burst analysis reinforces this observation temporally: evaluative keywords such as "LCA" and "decarbonization" surged in 2020–2021, while governance-related keywords did not burst in any period, confirming that the two streams have expanded in parallel rather than in coordination.

The bifurcation becomes more evident when considering the distinct epistemic foundations of each research stream. The assessment and monitoring literature is characterised by methodological pluralism ranging from emission factor approaches and lifecycle assessment to GIS-based modelling, sensor networks, and satellite-derived observations, all of which converge on the production of quantified carbon outcomes [50,51]. These approaches are data-intensive but mainly rely on energy use, activity data, and emission factors, yet remain largely detached from the governance conditions under which those emissions are produced. As a result, they provide robust estimates of carbon magnitude without offering explanatory insight into its underlying drivers. By contrast, the governance and transition literature is oriented toward institutional diagnosis. Drawing on case studies, stakeholder interviews, and policy analysis, this body of work interrogates regulatory design, coordination failures, and socio-political constraints shaping community-level transitions [17,52]. However, its explanatory categories are rarely tested against independently verifiable emission outcomes. The absence of quantified carbon metrics limits its capacity to assess whether identified governance configurations translate into materially different decarbonisation trajectories.

This division reflects not merely a difference in methods, but a deeper separation between measurement and explanation within the field. The lack of integration between these streams limits the field's capacity to establish causal relationships between governance design and measurable decarbonisation outcomes. It is not yet possible to determine whether communities with binding governance frameworks achieve measurably lower emissions than those with voluntary frameworks, whether participatory planning produces different carbon trajectories from technocratic planning, or whether specific standards configurations, such as GPC-compliant inventories or ISO-certified accounting, correlate with actual emission reductions rather than merely with reporting compliance. The existing literature demonstrates that carbon reporting outcomes are highly sensitive to methodological choices, particularly boundary definitions, yet these choices are implicitly shaped, enabled, or constrained by governance and financing arrangements that remain largely unexamined [44,53]. As a result, current assessment frameworks risk producing formally "accurate"

but institutionally detached representations of climate performance, limiting their validity as indicators of real-world decarbonisation outcomes.

However, recent advances in satellite-based atmospheric monitoring are producing spatially resolved carbon data that is independent of institutional self-reporting and could, in principle, serve as an objective verification layer linking governance interventions to observed emission changes [41,42]. Data-driven monitoring frameworks integrating GIS, building information modelling, remote sensing, and machine learning are similarly positioned to bridge quantitative assessment with institutional evaluation [54]. However, whether these tools will be deployed to meaningfully integrate governance and assessment, or instead reinforce a technologically sophisticated but institutionally detached evidence base, remains uncertain. Furthermore, the assessment-governance disconnect has a geographic dimension that compounds its analytical consequences. Technical assessment tools like carbon inventories, Life cycle Assessment (LCA) and satellite-derived MRV presuppose data infrastructure, institutional capacity, and standardised reporting systems that exist primarily in developed-country contexts. This means the disconnect is not only intellectual but also spatial. Developing countries where integrated assessment-governance research is most urgently needed are precisely those where the preconditions for current assessment tools are weakest.

4.3 The Developing Country Deficit

NZCC research is concentrated on developed economies. China leads the dataset with 264 papers, followed by the United Kingdom (123), the United States (94), and France (90). Among developing economies, only India (30) and the UAE (9) appear in the top 20 research contexts. No African, Latin American, or Southeast Asian country reaches the threshold. The combined developing-country share stands at approximately 25% of the literature, and community-scale governance research in these contexts represents only 13.4% of the dataset. Yet the scale of this mismatch is striking when set against projected urbanisation trajectories. According to the World Urbanization Prospects 2025, the global city population is projected to grow by 986 million between 2025 and 2050, with over half of that growth concentrated in just seven countries: India, Nigeria, Pakistan, the Democratic Republic of the Congo, Egypt, Bangladesh, and Ethiopia [1]. The same report shows that of the roughly 400 cities that grew faster than 4 per cent per year between 2015 and 2025, one third were in sub-Saharan Africa and a further quarter in Central and Southern Asia. The NZCC research landscape is therefore producing knowledge for contexts that are already relatively well-served while neglecting those where community-scale decarbonisation frameworks will be most urgently needed.

This geographic imbalance is caused by research funding, data availability, and developmental stages. Developed countries including the EU Horizon programmes and OECD-country research councils funded the overwhelming majority of NZCC research, creating a geographic bias toward European and North American case studies. Ntafalias et al. [46] report that 80% of PED case studies originate from publicly funded research projects, meaning the research agenda reflects funder priorities concentrated in developed economies. Next, the assessment tools dominant in the field require baseline data quality that is frequently unavailable in Global South cities, effectively excluding them as research sites. Fundamentally, communities in many developing countries have lower per-capita carbon emissions precisely because of lower welfare and consumption levels. The developmental priorities of these communities, aligned with (Sustainable Development Goals) SDG 8 on decent work and economic growth, centre on improving living standards, expanding infrastructure, and increasing access to energy services [55]. Framing these communities through a net-zero carbon lens without acknowledging their developmental needs risks imposing emission reduction obligations on populations whose consumption levels are already far below those of the developed-country communities that dominate the NZCC literature. Climate mitigation at the community scale cannot be pursued in isolation from these developmental realities [2,49].

China's quantitative dominance within the developing-country category warrants disaggregation. Chinese NZCC research is driven by national policy mandates, and is concentrated in economically advanced eastern coastal cities [13,54,56]. This creates a literature that reflects political priorities and fiscal capacity rather than the diversity of governance conditions, climatic zones, and economic structures that exist within China. The experience of a well-capitalised and developed city like Shenzhen or Shanghai offers limited transferability to a central or western Chinese city with constrained fiscal capacity and a coal-dependent energy grid. The fastest-growing urban settlements globally are predominantly small and medium-sized cities below 250,000 inhabitants which planning capacity and resources are weakest, and for which NZCC frameworks offer the least guidance [1]. This dynamic, widely documented in developed-country contexts as green gentrification, is likely to be intensified in developing-country settings where income inequality is greater and social safety nets are weaker. Communities that cannot yet meet basic developmental needs should not be expected to finance advanced low-carbon infrastructure designed for affluent contexts [45,57].

Current NZCC frameworks are implicitly calibrated to developed-country assumptions where mature governance institutions, available investment capital, established data infrastructure, and a building stock dominated by completed construction requiring retrofit [58]. Developing countries face a fundamentally different structural condition. Rapid urbanisation means that new construction and retrofit of existing communities must proceed simultaneously, yet this dual challenge is sharpest in the small and medium-sized urban centres of sub-Saharan Africa and Central and Southern Asia, where 74 per cent of cities have higher population densities today than in 2000, often reflecting inadequate infrastructure rather than planned compactness [59,60]. The standards architecture analysed in this review requires baseline data quality and institutional reporting capacity that excludes cities in the Global South that are unable to produce compliant inventories. This exclusion inadvertently reproduces the geographic inequality it claims to address.

Addressing the developing-country deficit, therefore, requires not the replication of existing frameworks in new geographies but fundamental adaptation, including modified boundary definitions that accommodate informal governance structures, alternative data proxies for data-scarce environments, phased approaches that align emission reduction with economic development, and explicit mechanisms to prevent the displacement of low-income residents through green gentrification.

5. Conclusions and Future Research Directions

Several limitations should be acknowledged. The analysis draws exclusively on the Scopus database, potentially missing relevant literature indexed only in Web of Science, CNKI, or regional databases. The English-language restriction excludes non-English scholarship, particularly from China, Japan, and continental Europe. Geographic tagging was based on keyword and abstract mentions rather than author affiliations, capturing research context rather than research origin. The automated keyword normalisation and cleaning procedures, while systematic, may introduce residual noise or false exclusions. Despite these limitations, the converging evidence across four independent bibliometric methods provides a robust foundation for the gaps and research agenda identified.

This review identifies three persistent gaps, each substantiated by converging quantitative evidence: the peripheral status of governance, the minimal linkage between carbon accounting and governance structures, and the structural marginalisation of developing countries. Governance and its weak linkage with carbon accounting and measurement are aligned with the current situation, where widely recognised and unified standards are missing. Furthermore, with developing-country contexts accounting for approximately 25% of the literature, community-scale governance research in these settings represents only 13.4% of the dataset, and no African, Latin American, or Southeast Asian country appears among the top 20 research contexts.

Future research should focus on integrating institutional analysis with community-scale carbon assessment to establish empirical links between governance configurations and measurable emission outcomes. Thus, building feedback loops between assessment outputs and governance inputs is required so that monitoring evidence can inform and calibrate institutional interventions. Moreover, developing countries need context-sensitive NZCC frameworks that account for informal governance, constrained capital, and data scarcity.

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