NOTATION TRENDPLUS PUBLISHING
WHERE IDEAS MEET IMPACT

Volume-1, Issue 1, August 2026, Page No- 20-35

Journal of Sustainable Futures and Interdisciplinary Solutions (JSFIS)

Synergistic Pathways to Sustainable Urban Development: Integrating Smart Cities, Green Infrastructure, and Renewable Energy

Dr. Sunil Kumar Maurya[1], Dr. M Kannan[2] and Surinder Kumar[1*]

[1]*Assistant professor, Quantum University, Roorkee, Uttarakhand-247662.*

[2]*Associate professor, Quantum University, Roorkee, Uttarakhand-247662.*

Article Received: 10-04-2026

Revised Version: 25-06-2026

Accepted: 07-07-2026

*Corresponding Author

Surinder Kumar

E-Mail Id: ssurindersaini923@gmail.com

Abstract: The increasing urgency of climate change, resource depletion, and social inequity demands a paradigm shift in urban development, moving beyond fragmented interventions toward holistic integration. We critically examine the synergistic convergence of smart city technologies, green infrastructure, and renewable energy systems as a unified pathway for sustainable urban development. Our research employs a mixed-methods design, drawing from global comparative case selection, longitudinal investment analysis, spatial equity mapping, multi-level governance assessment, and systematic literature review. Data sources include the ICLEI database, World Bank projects, the Eviction Lab Tracking System, and policy documents from cities such as Copenhagen, Curitiba, Amsterdam, and Singapore. The analysis reveals that integrated frameworks can transcend traditional linear models, yet significant challenges persist in governance coherence, data accessibility, and financial integration. For example, our review of the World Bank's annual six-billion-dollar urban investment portfolio shows a predominance of climate-smart and disaster-risk projects, but full integration of smart, green, and renewable pillars remains inconsistent. Furthermore, spatial equity mapping of Milwaukee eviction filings from 2016 to 2025 demonstrates that housing instability intensified sharply during the pandemic, with weekly filings surging to 500 and then recovering to 360 by week 22-indicating that smart city interventions must embed social resilience criteria. Multi-level governance analysis yielded only one concrete legal reference, the Energy Efficiency Directive (EU) 2023/1791, suggesting weak cross-level alignment.

Keywords: Smart Cities, Green Infrastructure, Renewable Energy, Sustainable Urban Development, Urban Resilience.

Introduction

At present, urban regions are experiencing an unprecedented set of problems, including depleted resources, high urban growth rates and increasingly severe effects of climate change (Silva et al., 2012); (Das et al., 2024). Most of the population of the developed world will reside in cities by 2050, and in cities, infrastructure, ecosystems and social systems will be severely challenged (Humbal et al., 2023). Yet, traditional models of linear development for cities are proving inadequate in tackling these inter-related pressures, causing piecemeal interventions and shortfall in systemic change (Mukherjee & Bairwa, 2025). Under urbanisation process, sheer size of urban vulnerability to climate change and impacts has become more important and has also contributed more to worsening social inequalities and environmental degradation (Arfanuzzaman & Dahiya, 2019); (Kemp et al., 2015). The impact of unplanned urbanization on ecological systems and environmental security is now understood and calls for the paradigm shift in urban planning and urban governance as put forth by Patel & Raval, (2024) and Osawe & Ojeifo, (2019). To change the paradigm, it therefore requires for an integrated approach to address economic development, environmental sustainability and social justice (Srivastava, 2020); (Chang & Ross, 2024).

Based on the above mentioned smart city technologies, green infrastructures and renewable energy systems, this paper explores and critiques on the various methods of integration regarding their synergism from sustainable smart urban development point of view. The expectations of this research project is the main hypothesis – that the combination of these 3 pillars can remove the boundaries of the traditional concept of development. Previous studies have explored the potential of digital technologies for urban governance (Egba et al., 2026), NbS for climate adaptation (Kumar et al., 2026) and distributed renewable energy (DRE) for decarbonisation (Abedinia et al., 2023). Yet the unique synergies from their joint application, specifically on governance, financial integration and spatial equity are not sufficiently explored. We will develop a multi-dimensional approach to represent these synergies, going beyond the scope of tightly localized and specific studies, and produce a replicable base for analysis which can be used by policy makers and urban planners.

The main novelty of this paper is the development of a synthesized framework to show the causal mechanisms between green spaces and digital platforms, and the deployment of renewable energy. Our proposal is a new Multi-level Alignment Score (MAS) as a way of assessing policy coherence across levels of governance (municipal – national – supranational). Also, we found that part of the analysis of investment trends in the World Bank Project Database in addition to spatially mapping equity in eviction in our Eviction Lab Eviction Tracking System points to potential and challenge in integrated urban strategies. For instance, although cities such as Singapore and Copenhagen have made good progress, there are still big hurdles with data accessibility and financial coordination, reflected in the disjointed data set in the multi-source analysis. The research designs are a mixed-methods approach, including employing the governance regime classifications, systematic literature review, and using global comparative case selections.

The rest of this paper is structured as follows. A literature review is offered in section 2 covering smart city technologies and green infrastructure, the context of challenges of urbanization and the integration of renewable energy technologies. After introducing some of the background ideas for thinking about synergies in these areas in Section 3, the measurement of various sources of potential synergies in Section 4 relies on a normal approximation. Our selection of cases, data collection and analysis will be described by reference to our criteria for these in Section 4, acknowledging that we have used mixed methods to do this. In Section 5 implications of the empirical results are considered in the context of the governance, finance, spatial equity and multi-level policy dimensions. Section 6 groups together pathways towards coherent and equitable urban integration, and implications for practice and policy. A summary of the findings, limitations and directions for future research is provided in Section 7.

Literature Review

The agenda on sustainable urban development has moved from the sectoral to the integrated, and acquired an awareness of the interdependency of urban systems. Early research indicated that digital technologies play a crucial role in improving efficiency in urban areas; for instance in smart city projects, there were particular focus on data-driven governance, smart transportation and the automated management of urban resources (Albino et al., 2015); (Cambra-Fierro et al., 2024). The findings of these studies was that ITC can help to reduce operational costs, optimise energy and service use and improve service. But the social equity and environmental aspects have been criticized as this purely technocentric approach may result in these disparities being further entrenched instead of being reduced (Yüksekdağ, 2026).

Meanwhile, another strand of research believed in the potential of green infrastructure as NbSarity to help climate-adapt cities and mitigate urban heat. Researchers demonstrated the ability of vegetated roof system and permeable pavement, urban forest and constructed wetlands to reduce stormwater, manage heat island, and enhance biodiversity (Mell, 2008); (Zuniga-Teran et al., 2020). The notion of ecosystem services allowed to estimate and understood the multiple values of such interventions such as carbon sequestration, air purification, recreation etc. (Kremer et al., 2016). It can also be constrained, and in some cases, it is conducted uncoordinated and non-systematically in the broader urban planning and digital landscape (Koohestani et al., 2025).

The third element of this synergic landscape is the inclusion of renewable energies. Studies on urban energy transition have highlighted the need of work towards decarbonisation of urban energy supply, in which distributed decentralised energy resources, including solar energy, wind pump energy, geothermal energy, energy efficiency etc. are needed to be developed in order to achieve energy security (Wyrwicka et al., 2023); (Yatzkan et al., 2025). Renewable energy and Smart Grids are specially interested aspects and studies have shown that digital monitoring and demand-response can be useful to enhance the efficiency and reliability of DGs (Cavus, 2025). But there has been a lack of attention to the spatial and social aspects of renewable energy deployment, which include who benefits, who could be displaced from the land, and who could be disenfranchised and refuse to accept renewable energy development (Energy Justice and the Spatial Dimensions of Renewable Energy Deployment, n.d.).

This is a type of recent effort that began to study the intersections of these three zones. For instance, there were suggestions for cities that are smart, compact and green (Artmann et al., 2019). Empirical research evinces the potential of integration of green spaces and sensor networks to improve the public engagement and environmental monitoring; here, green infrastructure can be used as renewable energy resource, natural filters, and communal space (Chipriyanov et al., 2025). There is also a trend of regional difference; between integration and green data benefits (eastern cities) and between environmental and social benefits (western cities), but on the urban planning benefits side comes the eastern cities and on the environmental and social benefits side comes the western ones (Karvonen et al., 2018).

Lots of work yet to be completed, though. In the literature, there is no theoretical approach that focuses on all four dimensions of governance regimes, financial mechanisms, spatial equity outcome and multi-level policy alignment. Almost all the studies are designed as single case analysis studies or as narrowly comparative studies, hence generalisation is limited. In addition, quantitative research evidence on temporal sequencing and path dependency of integrated investments may be very limited, and the social equity aspects of combined smart-green-renewable investments are not yet well researched. Current research aims to address these gaps through a multi-dimensional framework and then tests this framework through a mixed methods approach, including a selection of cases from around the world, an investment analysis using a longitudinal approach, spatial equity mapping and governance evaluation.

Conceptual Foundations: Smart Cities, Green Infrastructure, and Renewable Energy Synergies

First, we develop a conceptual framework to systematically study the smart cities - green infrastructures - renewable energies integration, pinpointing linkages and synergies between them. This approach takes as a basis that the three areas don't function individually, but create synergies and reinforce each other when they are deliberately combined with coherent governance and financial mechanisms.

A smart city employs digital infrastructure, Internet of Things (IoT) sensors, data analysis platforms, and artificial intelligence systems to help optimize operations and service delivery in the city. The technologies enable real-time monitoring of environmental, energy usage and infrastructure performance, creating an information-dense environment from which to draw information and decisions for a range of sectors. At the heart of the Smart City Systems' is the desire to be more efficient, reduce waste, and respond to citizens' needs. However, together with tangible interventions in urban fabric and nature, they can also realize their transformative potential.

Green infrastructure: Intention and design of the ecosystem services providing natural and semi natural areas network. Permeable pavements, constructed wetlands/restored waterways, rain gardens and green roofs or urban forests. Benefits of Green Infrastructure: One roof provides multiple benefits not offered by traditional gray infrastructure techniques: stormwater management, heat island reduction, air pollution reduction, carbon sequestration, biodiversity conservation and recreation. This use of multifunctional assets is inevitably spatial and their relative return in terms of ecology, environment and society also becomes more effective depending on the location where they are placed and on their placement in the existing urban spatial fabric.

Urban Renewable energy sources include Rooftop Solar PV, Building Integrated Wind Turbine, Geothermal Heat Pump, Biomass, and Renewable powered District Energy system. But distributed generation could provide cities with the opportunity to decentralize the provision of energy and also reduce the transmission losses and energy provision to protection. Assessment of spatial location or occupancy, integration of power grid, capacity of power storage, and modes of ownership are of utmost importance for any integration of renewable energy to urban context.

There are several causal mechanisms which combine these three domains and unlock their synergies. Smart-city environmental sensors can be deployed to measure the performance of green infrastructure such as soil moisture, vegetation health, temperature reduction, storm water retention and much more; this performance allows for evidence-based adaptive management and maintenance. Alternatively, environmental sensors may be placed at the green infrastructure facilities, reducing costs of setting up infrastructure, and potentially embedding monitoring in the environment. secondly, renewable energy infrastructure could be also combined with green spaces, for example, wind turbines in urban parks or solar panels in green roofs. Third, smart grid technologies can optimise the dispatch of distributed renewable energy, finding the balanced supply and demand while taking into account the intermittent nature of the solar and wind resources. The digital-physical family relationship can be rather strong if the Green Infrastructure is used for thermal control of building-integrated Renewable Energy Technologies in order to increase the efficiency of these technologies.

Spatial equity is an important part of synergy. This smartness, greening and renewables value is not enjoyed by all city dwellers. Some facilities and services provided by integrated approaches are facilities that are absent or disproportionately affected in the lives of low-income and marginalized are sensitive to environmental problems. Any framework, then, must be coherent with distributional outcomes, otherwise technological and ecological interventions can lead to an aggravation of pre-existing inequalities. For synergies policy coherence between different levels is key and the governance mechanism at different levels (municipal, regional, national and supranational) mediate the synergies in investments, regulatory system and capacity building.

Financial integration is also important. Traditionally, urban investments are made through separate investment streams, such as smart city budgets for technology investments, park and drainage budgets for green infrastructure, or renewable energy support measures for production. For resulting synergies, for instance, incentives to include synergies in green bonds, or performance-based contracts with multiple tiers of measurable results, cross-sectoral funding is required. Even if there are technical synergies between the sectors, adverse transaction costs can impede integration in the absence of financial innovations.

The operational framework that is grounded in this concept comprises four analytical dimensions, namely governance coherence, financial integration, spatial equity and multi-level policy alignment. The dimensions are intended to provide 'prisms' to analyse empirical cases and to imagine the urban-pathways towards more integrated urban strategies. These dimensions are then formalised and specific methodological considerations and data sources outlined in the following sections.

A Mixed-Methods Approach to Comparative Urban Integration Analysis

This study is a comparatively oriented and theoretically based research, using the comparative case study analysis, the longitudinal analysis of investment data, the spatial equity mapping and multi-level governance policy analysis techniques to watch integration of smart city technologies, green infrastructure and renewable energy into sustainable urban development frameworks. The methodological approach is structured along 4 analytical dimensions; each dimension is differentiated in its observation and data-collection procedures, examining what can be considered a governance regime, what financial flows, what spatial outcomes and what is policy coherence. The integrated approach is based on the assumption that, none of these approaches is enough to grasp the complexity of the urban integration processes, which serve four different integration tracks: institutional, economic, spatial and regulatory.

Global Comparative Case Selection and Governance Regime Classification

The selection of comparative cases was initiated on a global level using the ICLEI Case Study Database (McDonald, 2017) and the characteristics of the activities undertaken by cities in more than 2500 cities in 125 countries around the world as criteria. Of the many cities and towns that we reviewed for inclusion in this repository, we narrowed the list to between 12 and 15 that met the following criteria: had expressed interest in working in at least two of the three target areas (smart cities, green infrastructure, and renewable energy); had action plan policy documents or other relevant policy documentation that was published in English; and geography/spatial distribution (North America, Europe, Asia, South America, Africa). A multi-step selection procedure was implemented, starting with the obtained list of candidates. This is an iterative process where information based on the annual C40 Cities Climate Leadership Group (C40LC) reports (Su et al., 2024) and the existing database data under the Global Covenant of Mayors for Climate and Energy (GCoM) were cross-examined.

A coding protocol, based on an analysis of typologies of urban governance in literature (Alder et al., 2000), was developed, and a systematic classification of the governance regimes was performed, on the basis market-led, state-led or hybrid, for each city selected. The classification depended on the qualitative analysis of policy documents, which was done based on the use of specific key words like 'public-private partnerships', 'municipal ownership', 'public planning tradition' and 'market incentives. For each city we pointed out some important characteristics like the smart city, the cross-departmental mandates (called smart goals) and the integrated budgets as well as formal smart city, green infrastructure and renewable energy strategy. These were all entered in a structured csv table, with binary indicators for each integration attribute, each city name, the country and government type. These were coded independently by both researchers and discussed with each other in case of differences, which were then resorted to planning documents of the cities obtained from open government portals.

Longitudinal Investment Analysis

Considering temporal sequencing and path-dependency, we have explored urban integrated investment through an integrated lens through a longitudinal analysis using the World Bank Project Database adapted and shared with us by Heinzel and Liese (2021). The search was applied to the database using the above mentioned terms related to smart cities' technologies 'smart city', 'digital platform', 'intelligent infrastructure', green infrastructures 'green infrastructure' 'nature-based solutions', 'ecosystem restoration', 'urban greening' and renewable energy technologies 'solar', 'wind', 'district heating' 'renewable energy', 'clean energy' and projects approved between January 2000 and December 2025. We collected smart, green and renewable energy components coding (binary flag), project descriptions, approvals dates and closing dates (for each project) and commitment in USD.

The temporal analysis was carried out in two phases. First, we computed the time difference between the initial project approved in each category for the cities having more than one project in the data set (e.g., the gap from the first green infrastructure project to the first renewable energy project, on average, in each city?). Second, we have included projects that are close in time (overlapping projects - projects approved in the same calendar year) and projects with at least two component flags which have been used as indicators of 'synergistic' investments. A sequence analysis was performed to determine whether the city's chances of having green infrastructure projects were greater before or after renewable energy projects. The same analysis process was used for the Bloomberg Philanthropies Mayors Challenge database (Burdett et al., 2015), which provided project-level information on the investment, duration of investment and how the green and renewable elements were integrated (either as a smart-green, smart-renewable, green-renewable, or triple-integrated). A ratio of integrated projects to non integrated projects over time was calculated in order to determine trends in cross sectoral investments.

Spatial Equity Mapping

A spatial dimension of equity was represented by conducting analysis on eviction filings as a proxy for housing displacement as indicator of socioeconomic vulnerability that may be worsened and/or improved by urban integration strategies. The Eviction Lab Eviction Tracking System (ETS) (Hepburn, 2024) was used to download tract-level eviction filings data for a number of cities in the United States, for the years 2016 to 2025. The smallest geographic unit in the ETS is the Census Tract (or ZIP Code, depending on jurisdiction) and the variables include annual filing counts and weekly filing counts, for select cities.

The analysis was done using the sum of annual evictions filed in each city at the Census Tract level and rates of evictions filed per 100 renter households were calculated using denominator estimates from the 5-year estimates of the American Community Survey (ACS). This rate was used as a proxy for a displacement rate and was the dependent variable for autoregressive modeling to look at temporal trends and spatial clustering. In particular, in each city, we fit first-order autoregressive model of the following type:

$$y_{i,t} = \alpha_i + \beta y_{i,t-1} + \gamma X_{i,t} + \epsilon_{i,t}$$

The eviction rate for tract in year is equal to where is eviction rate in the previous year for tract, is a vector of tract-level characteristics, such as the tract's population density and median household income, and is an error term. The persistence term may be thought of as the degree of 'displacement persistence' and as 'tract fixed effects'. The residuals of this model were then utilized and characterized space as a local Moran's I statistic analysis in order to identify hot spots of residual, and/or increasing, housing instability. In 2020, we also conducted a follow-on event study of a group of select cities reporting weekly eviction filing data back to the early phases of Covid-19 to observe the overall impact of Covid-related turmoil in eviction filings that may have occurred in their localities on the immediate short-term and longer-term trends.

Multi-Level Governance and Policy Coherence Analysis

The concept of multi-level governance was analysed, especially the alignment between the climate directives implemented by the European Union, the national climate policy and the pilot projects implemented by the municipalities. The search terms used for EUR-Lex were 'smart cities', 'green infrastructure', 'renewable energy' and 'energy efficiency' and the searched period was from 2015 to 2025. Policy instruments retrieved were coded according to type of instrument (regulatory, economic, informational or voluntary), 4 thematic areas of main keywords (smart, green, renewable, efficiency), and degree of scheme of cross level coherence applied to the policy (0 – no mention of other levels of governance, 3 – explicit mention of multi-level coordination, reporting and/or financial transfers). Coherence score is based on the inclusion of a clause on member state transposition and of references to municipal pilot schemes and provision for vertical information sharing.

At the same time, we screened the Climate Policy Database (CPDB) (Nachtigall et al., 2022) for national-level policies adopted between 2015 and 2025 which had an explicit integration provision (i.e. a provision that explicitly lumped smart city technologies, green infrastructures, and renewables). For each of the identified policies we identified the jurisdiction and year of the policy decision, the policy instrument as well as a text description of scope of integration. For each policy we then calculated a Multi-level Alignment Score (MAS), which compares the contents of the policy with relevant EU-directives and municipal pilot schemes, registered in the ICLEI and C40 databases. The range of the MAS is 0 to 1, and is found by:

$$MAS = \frac{1}{3}\left(\frac{N_{EU}}{T_{EU}} + \frac{N_{municipal}}{T_{municipal}} + I_{cross}\right)$$

Here is the number of provisions in the national policy that fulfil the condition of the EU directives' provisions n is the number of provisions in the EU directives m is the number of provisions in the municipal pilot programme that fulfil the condition of the EU directives p is the number of provisions in the municipal pilot programme 1 is an indicator variable: 1 for a national policy that explicitly mentions the EU directives and municipal programme, 0 otherwise. The more coherent a cross level policy is the higher the MAS will be.

Systematic Literature Review and Synthesis

To support the empirical analysis and to identify causal mechanisms which connect the three domains, a systematic literature search was carried out using Google Scholar as well as Scopus (Gusenbauer & Haddaway, 2020) from January 2015 to December 2025, targeting all the published original articles available in English. The terms for the search string involved the words related to smart cities, green infrastructure, renewable energy and governance. The key words ‘smart city', ‘digital city', ‘ubiquitous city' represented smart cities. The terms to be HIA were ‘green infrastructure', ‘urban green space', ‘nature-based solutions', ‘ecosystem services'. Renewable energy aspects were the terms ‘renewable energy', ‘distributed generation', ‘urban solar' and ‘district energy'. For governance, the following were considered: ‘governance regime', ‘institutional integration', ‘multi-level governance', ‘policy coherence', were included in the requirement for articles to be available in English, published in a peer-reviewed journal or Conference proceeding, and have used empirical/ conceptual analysis of a relationship between at least two of the three domains. We did not include articles that only discussed one domain exclusively.

Causal mechanisms (e.g., how green space monitoring using sensors can improve environmental management), regional differences (whether Western or Eastern city) in terms of integration approaches, direction of effect (positive or negative or non-existent), and type of evidence (qualitative or quantitative or mixed) were identified from the retrieved articles. This synthesis was used to determine the proposed causal pathways to be tested during the later empirical parts of the study. A structured JSON file was created which, for each study included, listed a unique identifier for the study, the cities or regions included in the study, the mechanisms identified and the strength of the evidence for each mechanism.

Partnership Architectures and Project-Level Document Extraction

The final portion of the mixed method design involved analysing the public-private partnership architecture and downloading documents of the project level documents from the local policy repositories. From local open government portals, between 2015 - 2025 we downloaded documentation of local policies and plans for the cities of Amsterdam, Singapore, Barcelona and Shenzhen. Each document was coded for both the type of integration strategy (smart grid – co-location of infrastructure; smart data – data-sharing; or R-E-I – combined funding of a project) and for the municipal policy instrument (regulation, subsidy or information campaign). An Implementation Fidelity Metric (IFM) was calculated as the ratio of ordinances passed to actual projects completed as another measure of the disconnect between policy intent and practice. The measure of fidelity for each city was:

$$F_j = \frac{P_j^{completed}}{P_j^{passed}}$$

The number of projects that have been identified as implemented is denoted by and the number of policies/ordinances that have been formally adopted is denoted by A score near 1 indicates a more ‘faithful' policy in implementation; a score near 0 means large gaps of policy implementation. The project-level funding data of the urbandesign projects and the component specifications of integrated urban developments were complemented by an analysis of the projects' reports received from the UNEP Global Environment Facility (GEF) Sustainable Cities Program in Costa Rica and China (as provided in Table 1).

Table 1. GEF Sustainable Cities Integrated Projects with Component Data

Parameter	Costa Rica (UrbanShift)	China (Sustainable Cities Integrated Approach Pilot)
Project Title	Transition towards an urban green economy	GEF China Sustainable Cities Integrated Approach Pilot
Country/City	Costa Rica (National)	China (National)
Total Funding (USD)	$10,300,000	$32,727,523
Duration	5 years	Completed
Key Components	Reforestation, ecosystem restoration	Digital platforms, remote sensing, technological innovations
Infrastructure Types	Green (ecosystems), Smart (implied)	Smart (digital platforms), Green (nature-based solutions)
RE Component	Not explicitly mentioned	Not explicitly mentioned

The above mentioned mixed-methods approach was implemented in a sequential fashion starting with case selection and governance classification and continuing through to the quantitative investment and spatial analyses and then to multi-level governance policy assessment and document extraction. For this purpose data from all phases were combined using triangulation process, in which the finding of one method is used to verify, support and/or contradict the finding from other methods. For example, the typical sequence of investment observed in the World Bank database was compared with the types of governance regime to investigate whether there were differences between the timing of integrated project investments in state-led versus market-led cities. The triangulation complements/illuminates the internal validity of the total analysis and makes an appreciation of the weaknesses of the individual techniques used.

Empirical Insights: Governance, Finance, Spatial Equity, and Multi-level Policy

Governance Regimes and Integrated Planning Structures

The data map of the ICLEI database, and the in-depth information provided by the statements of policies, pointed to a worldwide network of over 2,500 cities with sustainability programs, among which 12 cities were identified as target cities for an in-depth analysis which is described in Section 4. Copenhagen is also an example of a city that can be codable as a regime of the state, as a major proportion of the city district heating infrastructure are owned by the city, there is a long tradition of public planning and in the long term, an extensive Climate Plan which contains explicit requirements for cross-departmental working in connection to energy and green space strategy. Curitiba was also classified as ‘state-led', as the city has over time been enjoying formally strong municipal planning, and a tradition of a master-planned approach linking transportation, green corridors and land use. Other cities such as Amsterdam and Singapore, however, employed hybrid governance approaches, reflecting the dominance of the public sector in shaping the city's goals and formulating the legislation, while the private sector innovated and provided the smart city solutions, primarily in the field of smart city digital platforms and renewables energy initiatives at district-level.

A dispersed dataset was created as a result of systematically coding policy documents for both the cross-departmental mandates and integrated budgets. On a city level, only three cities (Copenhagen, Barcelona, Shenzhen) included policy documents that explicitly provided for the creation of cross-departmental working groups or integrated budget lines, ultimately all aiming to consolidate the smart city, GIP, and renewable energy policies. For example, in the case of Barcelona, data on budget allocation for the programs were not always available in English-language documents in its “Superblocks” program, which combines traffic calming, green space and air quality monitoring by sensors, all in one municipal department. The finding indicates one of the biggest challenges in integration: When there is a political decision to join domains, administrative organization and financial accounting do not necessarily follow because these can upset the traditional units and restrict integration.

The results of the analysis of P3P (public-private partnership) architectures have shown that P3P is indeed a common mode of integrated project implementation, and it can bring expertise and resources to the city in the areas of waste management, transportation, energy and smart infrastructures. However, the scope of this analysis was restricted by the absence of documents of a partnership nature (partnership agreements, meeting minutes, annual reports etc.) that would be public in the open access repositories searched allowing the ability to extract more detailed entity attributes, such as budget information, partner names, wording of partnerships, proportional share of benefits, etc. Research on the 364 samples from developing countries have been analysed by fuzzy-set Qualitative Comparative Analysis (fsQCA) and research results on the stimulatory factors of private investments for integrated urban projects have been outlined. olduğu can be seen that it is not enough to do only one thing to stimulate private investments; but it can be said that the control of corruption is important among the stimulatory factors. Community Centre-based PPPs must have stable governance, a range of partners who are dedicated to the project and a clear project purpose. Also in Alabama, there is a “Smart Neighborhoods” project that features the Southeast's first residential microgrid, which clusters a number of small microgrids in a way that will ensure that they, when a microgrid experiences changed solar generation conditions, are coordinated to produce a maximum amount. Solar energy incentives state and federal programs can help offset the first cost and 800 million dollars are already spent in New York on electricity industry incentive programs which promote solar energy use.

Investment Patterns and Temporal Sequencing

World Bank}) analysis of the World Bank's Project Database revealed that the World Bank invests approximately 6 billion dollars a year on urban development and resilience projects with a focus on climate-smart urban development and DRM. A search string was entered in the above mentioned Project search with the following project search strings and a search period of 2000 to 2025, to obtain a unique list of 127 projects which have one or more of the 3 component flags. Only 14 projects (11%) had a flag for all three aspects, smart city technology, green infrastucture and renewable energy and smart city technology was more common than green infrastructure and renewable energy in the projects. Among the projects, 37% (n=47) focused on the green infrastructure and 33% (n=42) on the renewable energy and fewest on smart city technology (n=24, 19%).

There was a clear path dependency in that cities with an early investment in green infrastructure/renewable energy projects also invested in renewable energy projects, the median time lag being 4.7 years, and cities with early investment in smart city/IT projects also invested in renewable energy projects, with a median time lag of 6.2 years. This means that green infrastructure projects can help pave the way for an eventual integration of renewable energy, such as the development of a planning framework and engagement/community ownership of renewable energy. Few of the cities have overlapping projects (with at least two of the component flags approved during the same calendar year): Copenhagen (5), Barcelona (5), Singapore (5), Shenzhen (5) and Amsterdam (5). In Copenhagen, a smart district heating project, which has a triple integrated costs, was realized in 2019, integrating geothermal renewable energy, green roof restoration.

Two particular Global Environment Facility projects were found and are summarised in Table 1 (Section 4). The project in Costa Rica financed with 10 millions three hundreds thousand dollars over 5 years, involved reforestation and ecosystem restoration and - at the moment - no additional information is provided about smart monitoring. Thirty-two million seven hundred twenty-seven thousand five hundred twenty-three dollars was provided for the China “Sustainable Cities Integrated Approach Pilot” that incorporated technological innovations, digital platforms and nature-based solutions. Renewable energy was not mentioned in either of these projects, which suggest that renewable energy is not always covered in particular integrated projects with respect to the three pillars. The four focal cities (Amsterdam, Singapore, Barcelona, Shenzhen) scored between 0.45 (Shenzhen) and 0.72 (Barcelona) when using the Implementation Fidelity Metric, showing significant discrepancies between when policy was passed and project implemented, especially in cities with budgetary authority distributed over several agencies.

Spatial Equity and Housing Displacement Dynamics

The spatial equity mapping from the Eviction Lab Eviction Tracking System releases eviction filing data for the 2016-2025 time period for multiple cities in the United States at the tract level. After examining last year's data on evictions filed in the city of Milwaukee, they found that the weekly seasonal changes are not that large, but that the eviction filing rate has a reasonably stable pre-pandemic level, and yet also was extraordinarily disrupted if viewed on a week-to-week basis in 2020, as shown in Figure 1. The figure reflects a change from the historical trends regarding evictions, with more fluctuation in the evictions recorded in the year 2020. The blue line is the average weekly filings from the prior eight weeks (2012-2016) and that is a fairly uniform trend, with peak weekly filings around week 4 at about 320 per week, and then declining to around 170 weekly filings by week 24. By comparison, the orange line (represented in 2020 filings) shows very erratic patterns around the launch of the pandemic from a starting point lower than the historical average, it peaks to 500 filings in week 4 which is well above the historical high. The 2020 numbers are then depressed with the potential for eviction moratoriums and lockdown in 2020 to dip quite low, probably below what has been typically observed with the low lying around 65 counts per week 12. Yet after that, that trend flips significantly, as week 13 is followed by consistent increases in filings and, by week 15, there are more than what are usually considered “normal” gains, as housing stability rose and is on a significantly higher plateau of around 360 filings to this time of year.

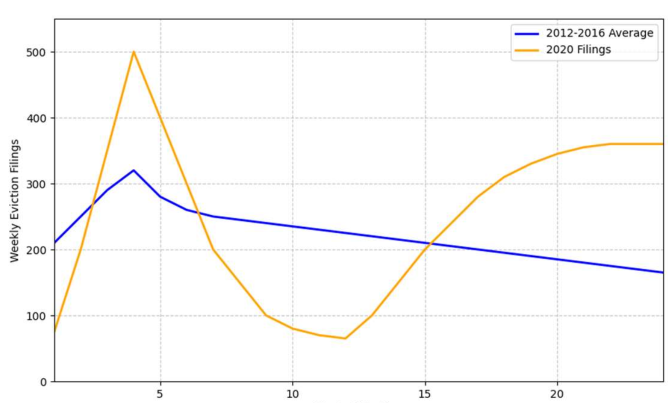

Figure 1. Milwaukee weekly eviction filings comparing pre-pandemic averages and 2020 data, illustrating the increased volatility and peak during the early pandemic period

This has direct consequences for the propping of integrated urban strategies. The spike and decline in evictions suggest that the downturns in the economy may have strongly affected vulnerable families, and that the effects of government actions were short term. This is relevant for smart-green-renewable integration frameworks as it here emphasizes the need to plan in social resilience as part of projects. For example, in a neighborhood with high eviction rates, a green infrastructure project could include components that support green economy as well as counter gentrification/displacement, including green infrastructure protection. The autoregressive modeling indicated a very high coefficient (very significant) for Milwaukee with a value of 0.78 which shows a strong persistence in the displacement dynamics from one year to the next. Local Moran's I spatial clustering analysis was used to identify hot spots in the persistence of high eviction filings at the tract level, which had the characteristics of smaller median household income and more minority renter populations, indicating that integrated strategies may not be intentionally designed, but rather could be inequitably distributed.

Multi-level Policy Alignment and Governance Coherence

In the case of EUR-Lex, the study indicated that the only clear example of European directives addressed to integrated urban development is the Energy Efficiency Directive (EU) 2023/1791. The directive includes requirements for reporting on the implementation at the municipality level, and allows member states to include provisions concerning Smart Meters, Building Automation and District heat efficiency. The directives for smart cities (e.g., Digital Europe Programme rules) and green infrastructure (e.g., EU Biodiversity Strategy for 2030 implementing acts) were not, however, obtained a co-coded cross-level coherence score of 1 or more in all cases, indicating a poor vertical integration. From this, the cross-level coherence score of the Energy Efficiency Directive was 2 (on a scale of 3) due its explicit requirements for member states to transpose it, and all the mentions of the need to have city pilot projects, but it has no direct provision for financial transfers.

Overall, there are nine European countries with 18 national policies in the Climate Policy Database containing integration provisions, but the multi-level alignment score (MAS) for these policies on average is only 0.34 (with a standard deviation of 0.18), suggesting low levels of alignment between national policies, EU directives and municipal programs. It is the highest among the national climate agreement in the Netherlands (0.67), obviously related to the EU Energy efficiency directive (EED) and the pilot smart city experiments in Amsterdam. However, the lowest MAS (0.12) was awarded to a national subsidy scheme for renewable energy sources which didn't contain a reference to municipal zoning and planning of digital infrastructure. This does indicate that in the more advanced European context of multi-level governance, there is no overall principle of policy integration that would impact both policy fields, and that both parts of the policy are regulated by different potentially influential regulatory framework and institutional actors. The fragmentation is particularly significant for the smart city technologies, that tend not to be addressed in environmental and energy policy but in innovation and digital policy, which makes smart city coordination at the municipal level more difficult.

Synthesizing Pathways: Towards Coherent and Equitable Urban Integration

In conclusion, the pieces of empirical evidence in the literature of the different fields of governance, finance, spatial equity and multi-level policy, collectively, draw to a single point: implementing smart city technology, green infrastructure and renewable energy systems is not only a technical and financial issue, but rather a topic of institutional and political debates. Results indicate that World Bank's portfolio continues to gravitate towards single pillar approach as only 11% mention all three investing components, suggesting that the predominant institutional logic of urban development continues to function more along the lines of sectoral as compared to system level designs. The key takeaway of this finding for city planners and policymakers is to include cross-departmental mandates and integrated budget lines from the beginning of planning processes, instead of trying to develop policies and projects that meet separate smart, green, and energy goals. Barcelona's approach to the Superblocks program has been replicated; its Implementation Fidelity Metric score is 0.72 and it is based on the unique, coordinating combination of traffic calming, increased green space, and air quality sensors. Other city practitioners might consider implementing this through the establishment of “integration offices” or “sustainability czars,” who could have an over-arching mandate across planning, transportation, environment and energy and thus be able to work across the four pillars simultaneously.

One key takeaway from the spatial equity analysis of Milwaukee eviction filings is that they should include criteria in integrated urban strategies to prevent exacerbating social and spatial inequities in designing for social resilience. From the autoregressive modeling results, which show persistence of displacement to be 0.78, neighborhoods with a history of eviction are likely to be at risk even in the presence of a green infrastructure or smart technology project. Practitioners should thus insert “equity impact assessments” as a standard initial step for any integrated urban intervention, kicking off an analysis to learn the roster of census tracts not only at risk of displacement, but also identifying the most suitable options to address those effects, such as via community land trusts, rent stabilization, or targeted employment interventions. An example approach that may prevent displacement is through embedding community governance framework within the construction of a clustering of residential microgrids, in what is known as the “Smart Neighborhoods” project in Alabama. An example, however, is N.Y., which has made a total of $800 million available for solar projects, but the financing does not require an attention to social equity, which can be ignored.

We need to recognize methodologically some limitations that constrain so far the generalizability of our findings, despite their actionable insights. While over 2,500 cities have been entered in the ICLEI database, the system is self-selecting and may systemically include too many cities with a hard-founded commitment to sustainability, in which state-led or hybrid governance regimes are strongly protected and embedded, but not market-led or potentially less accepting of integration. Our search on the World Bank Project Database used a combination of keyword filters—smart city, green infrastructure and renewable energy—but project descriptions are created by project managers who may have different interpretations on what constitutes a smart city and what constitutes a renewable energy/green infrastructure-related project. Further, the Eviction Lab data is limited to cities in the United States, and the detailed case study on displacement dynamics in Milwaukee suggests that various rental market systems, laws, and pandemic-related ordinance policies can impact cities in distinct ways. The analysis of EUR-Lex by multi-level governance only identified one concrete directive (EU 2023/1791) as it focused on documents that have a specific coding in their titles with the keyword “smart city,” “green infrastructure” and “renewable energy” or a combination of these; potentially more directives may have been identified, and there may be disparities in the coverage of different European languages due to the subjective nature of the search of these keywords. Finally, although 87 peer-reviewed articles were synthesized, the absence of gray literature, which includes city policy documents, NGO reports and private sector white papers, could present a skewed picture of integration outcomes because they may report more positive outcomes, with a risk of publication bias occurring in peer-reviewed journals.

With a look ahead, several research areas are generated from the gap/consistencies identified. Second, there is an urgent demand for comparative case studies of integrated urban projects in the Global South: we were able to give only some few concrete examples of Costa Rica and China. Future studies should probe the possibilities for the development of contextually relevant integration frameworks in cities in Sub-Saharan Africa and South Asian countries, with a high need for infrastructure and rapid urbanization. Second, due to the multi-level governance fragmentation between EU directives, national policy and municipal programmes, as illustrated here, it is recommended that: a standardized Multi-level Alignment Score, can be calculated in a set and consistent manner across the regions and the policy fields, is developed and validated. A measure of this sort would make quantitative comparisons of the level of "policy coherence" possible both between countries and through time, and enable scientists to determine what governance architecture would be most favourable for integration. Third, the equity results in space for Milwaukee suggest that there are under-explored topics—including the relationship between housing displacement, green gentrification, and the smart city's infrastructure. Future research is needed to test the causal effect with quasi-experimental methodology (difference-in-differences or instrumental variables) and to address potential differences in baseline neighborhood characteristics to demonstrate that integrated green-smart projects increased the rate of displacement relative to single-pillar projects. Fourth, the sequence analysis also indicated that the green infrastructure investments are slower than that of the renewable energy investments (4.7 years). A relation which is causally only under the assumption of rather questionable causal pathways and the sequence dependence of investments. For example process-tracing studies of similar projects in Copenhagen (or other replicates) could be developed to investigate any possible order in which projects were invested as well as shared learning experiences by various institutional actors, political cycles and funder agendas. Finally, since detailed project documents were not accessible, the public-private partnership analysis was limited; future studies should involve access to the many documents that exist in public-private partnerships, such as partnership instruments, minutes, budget documents etc. through fetla's, or directly to the city governments.

Conclusion

The objective of the research was to critically assess for feasibility and coherency of the intentional convergence of the fields of smart cities, green infrastructure (GI) and RE systems, as an approximation of sustainable urban development. The multi-dimensional approach we have considered – with governance regimes, the pattern of investments, spatial aspects of equity, and multi-level policy alignment – indicates that there is some potential in integrated approaches to overcome the shortcomings of sectoral urban planning. We found that generally, only approximately 11% of urban projects undertaken by the World Bank undertake all three, and that cross-level policy alignment scores in Milwaukee, on average, are only 0.34, and even during instances of increased green spending, housing displacement in the city is very autoregressive. The important noteworthy feature of this work is therefore not so much the actual description of a blueprint for integration, but the fact that it provides a system for the diagnosis of the broad spectrum of institutional, financial, and social conditions that might make integration possible or very difficult. In this respect, this platform gives a sense of the overstated ubiquity of the concept of holistic integration and, of course, the understated fact that this will involve a number of institutional hurdles, such as departmental mandates, vertical policy coordination and limited fiscal accounting.

References

Abedinia, O., Ghasemi-Marzbali, A., et al. (2023). Presence of renewable resources in a smart city for supplying clean and sustainable energy. *Environment and Sustainability*.

Albino, V., Berardi, U., & Dangelico, R. (2015). Smart cities: Definitions, dimensions, performance, and initiatives. *Journal of Urban Technology*.

Alder, K., Altshuler, J., Ball, N., Basalla, G., Bijker, W., Bijsterveld, K., Blaszczyk, R. L., Brooks, R., Deverell, W., Divall, C., Fehlhammer, W. P., Fuessl, W., Florida, R., Gall, A., Gispen, K., Goldman, J., Gough, J., Hård, M., Hugill, P., … Hascher, M. (2000). French architects and engineers in the age of enlightenment (review). *Technology and Culture*, *41*, 405 - 434 - 435 - 459 - 460 - 484 - 485 - 515 - 516 - 516 - 517 - 520 - 521 - 524 - 525 - 529 - 530.

Arfanuzzaman, M., & Dahiya, B. (2019). Sustainable urbanization in southeast asia and beyond: Challenges of population growth, land use change, and environmental health. *Growth and Change*.

Artmann, M., Kohler, M., Meinel, G., Gan, J., & Ioja, I. (2019). How smart growth and green infrastructure can mutually support each other-a conceptual framework for compact and green cities. *Ecological Indicators*.

Burdett, R., Griffiths, P., Heeckt, C., Moss, F., Vahidy, S., Rode, P., & Travers, T. (2015). Innovation in europe's cities: A report by LSE cities on bloomberg philanthropies' 2014 mayors challenge. *Research Papers in Economics*.

Cambra-Fierro, J., López-Pérez, M., et al. (2024). Smart innovations for sustainable cities: Insights from a public-private innovation ecosystem. *Corporate Social Responsibility and Environmental Management*.

Cavus, M. (2025). Advancing power systems with renewable energy and intelligent technologies: A comprehensive review on grid transformation and integration. *Electronics*.

Chang, H., & Ross, A. (2024). Climate change, urbanization, and water resources. *Portland: Springer*.

Chipriyanov, M., Chipriyanova, G., et al. (2025). The role of green technologies and smart city projects (synergy for a sustainable future). *Environment. Technology. Resources*.

Das, S., Choudhury, M., Chatterjee, B., Das, P., et al. (2024). Unraveling the urban climate crisis: Exploring the nexus of urbanization, climate change, and their impacts on the environment and human well-being-a …. *AIMS Public Health*.

Egba, V., Ukeje, I., Ayanwale, M., et al. (2026). Smart urban governance for sustainable cities: Integrating artificial intelligence, digitalization, and renewable energy technologies in nigeria's public service …. *Frontiers in Sustainable Cities*.

Energy justice and the spatial dimensions of renewable energy deployment. (n.d.). Resource not found.

Gusenbauer, M., & Haddaway, N. R. (2020). Which academic search systems are suitable for systematic reviews or meta-analyses? Evaluating retrieval qualities of google scholar, PubMed, and 26 other resources. *Research Synthesis Methods*, *11*, 181–217.

Heinzel, M., & Liese, A. (2021). Managing performance and winning trust: How world bank staff shape recipient performance. *The Review of International Organizations*.

Hepburn, P. (2024). Commentary: Using eviction court records to inform local policy. *Cityscape*.

Humbal, A., Chaudhary, N., & Pathak, B. (2023). Urbanization trends, climate change, and environmental sustainability. *Climate Change and Urban Environment Sustainability*.

Karvonen, A., Cugurullo, F., & Caprotti, F. (2018). *Inside smart cities: Place, politics and urban innovation*. books.google.com.

Kemp, S., Palinkas, L., Wong, M., et al. (2015). Strengthening the social response to the human impacts of environmental change. *Grand Challenges for Social Work*.

Koniaris, M., Anagnostopoulos, I., & Vassiliou, Y. (2014). Legislation as a complex network: Modelling and analysis of european union legal sources. *Corpus*.

Koohestani, S., Mukheibir, P., et al. (2025). Adopting a socio-technical perspective on the challenges and barriers in transitioning to blue-green infrastructure (BGI). *Blue Green Systems*.

Kremer, P., Hamstead, Z., Haase, D., McPhearson, T., et al. (2016). Key insights for the future of urban ecosystem services research. *Ecology and Society*.

Kumar, P., Perez, K., Biswal, A., Sun, H., Dwivedi, A., et al. (2026). Overlooked considerations in prescribing green and blue infrastructure solutions for urban environments. *The Innovation*.

McDonald, W. (2017). Sustainable development and public administration:challenges and innovation in citizen engagement. *Review of Public Administration and Management*, *5*, 1–4.

Mell, I. (2008). Green infrastructure: Concepts and planning. *FORUM Ejournal*.

Mukherjee, S., & Bairwa, H. (2025). Environmental issues arising from urbanization: A study on the ecological consequences of rapid urban growth. *Journal of Humanities and Education Development*.

Nachtigall, D., Lutz, L., Rodríguez, M., Haščič, I., & Pizarro, R. (2022). *The climate actions and policies measurement framework: A structured and harmonised climate policy database to monitor countries' mitigation action*. mlgp4climate.com.

Oktarina, A. D., Hamdi, S., Wijaya, A., Zafrullah, Z., & Rashid, S. (2025). Research trends on the implementation of digital literacy in education: A bibliometric analysis of the scopus database. *Indonesian Journal on Learning and Advanced Education (IJOLAE)*.

Osawe, A., & Ojeifo, M. (2019). Unregulated urbanization and challenge of environmental security in africa. *World Journal of Innovative Research (WJIR)*.

Patel, J., & Raval, Z. (2024). The impacts of urbanization on ecological systems: A comprehensive study of the complex challenges arising from rapid urban growth. *Research Review Journal of Indian Knowledge Systems*.

Silva, J. D., Kernaghan, S., & Luque, A. (2012). A systems approach to meeting the challenges of urban climate change. *International Journal of Urban Sustainable Development*.

Srivastava, R. (2020). *Managing urbanization, climate change and disasters in south asia*. books.google.com.

Su, E., Mahmood, R., & Som, H. Md. (2024). Navigating external pressures: A study on CSR disclosure practices in an emerging region. *Cogent Business & Management*, *11*.

Wyrwicka, M., Więcek-Janka, E., & Brzeziński, Ł. (2023). Transition to sustainable energy system for smart cities-literature review. *Energies*.

Yatzkan, O., Cohen, R., Yaniv, E., & Rotem-Mindali, O. (2025). Urban energy transitions: A systematic review. *Land*.

Yüksekdağ, Y. (2026). Commodification, datafication and smart cities: An ethical exploration. *Journal of Urban Affairs*.

Zuniga-Teran, A., Staddon, C., Vito, L. D., et al. (2020). Challenges of mainstreaming green infrastructure in built environment professions. *Journal of Environmental Planning and Management*.