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Urban Climate Integration Framework (UCIF): A Multi-Scale, Phased Model

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Abstract

Urban climate readiness requires multi-dimensional implementation strategies that operate effectively across both spatial scales and time horizons. This article introduces a multi-scale, phased model designed to support integrated climate action by distinguishing between metropolitan and building levels and addressing three core domains: physical resilience, decarbonization, and social/community engagement. The framework conceptualizes metropolitan and building scales as analytically distinct but operationally linked, allowing strategies to reflect the different systems, stakeholders, and capacities at each level. It also outlines a three-phase progression—Initial (assessment and goal setting), Readiness (planning and implementation), and Steady-State (monitoring and iterative adjustment)—to support staged, adaptive deployment. Each phase includes sample metrics and SMART goals that can be tailored to local context and tracked over time. By integrating theoretical insights with practical implementation tools, the framework offers a flexible yet rigorous approach for advancing urban sustainability. It emphasizes the importance of aligning technical interventions with institutional capacity and community participation to enhance effectiveness and equity. This model contributes to both planning theory and applied sustainability efforts by providing a structured pathway for cities to enhance climate readiness across systems and scales.

Keywords: urban sustainability; climate readiness; multi-scale planning; physical resilience; decarbonization; community engagement

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Academic Editors: Zhi Qiao, Chaobin Yang, Dongrui Han, Kun Jia and Lei Wang

Received: 30 July 2025
Revised: 23 September 2025
Accepted: 1 October 2025
Published: 3 October 2025

Citation: Robinson, S. Urban Climate Integration Framework (UCIF): A Multi-Scale, Phased Model. *Land* **2025**, *14*, 1990. https://doi.org/10.3390/land14101990

1. Introduction

With more than two-thirds of the global population expected to reside in cities by mid-century, ensuring urban climate readiness has become one of the defining challenges of sustainable development. Urban systems concentrate people, infrastructure, and economic activity, but they also concentrate vulnerabilities to climate hazards and emissions. These risks are increasingly conceptualized in terms of both physical risks from climate hazards and transition risks arising from decarbonization policies, technologies, and market shifts, as articulated by the Intergovernmental Panel on Climate Change (IPCC) and the Task Force on Climate-related Financial Disclosures (TCFD) [1,2] (now International Sustainability Standards Board (ISSB)). Scholarship has long recognized that cities are complex socio-ecological systems where resilience, mitigation, and equity must be pursued together [3,4].

Major strands of research that have advanced this agenda could be parsed into three areas, each offering important but partial contributions. One body of work has focused on sustainability indicators, providing benchmarks for progress at the city level. Reviews of indicator systems highlight the diversity and fragmentation of these measures, which enable comparison but often stop short of offering pathways toward implementation [3,5]. A second strand emphasizes systems-based planning, including frameworks such as ICARUS [6] and UPSUF [7], which strengthen ecological and design dimensions of climate action but less often address sequencing or nested scales of governance. A third strand centers on resilience and governance, underscoring adaptive capacity, participatory decision-making, and socio-ecological traits as critical for long-term sustainability [8–10]. These literatures have expanded the field but tend to treat resilience, decarbonization, and the attendant governance required for implementation as parallel rather than integrated domains.

The Urban Climate Integration Framework (UCIF) responds to these gaps by combining the dual structure of climate risk with the coordination demands highlighted in implementation research. It synthesizes physical resilience, decarbonization, and social and institutional engagement into a single model, while situating them across two scales of action: the metropolitan system, intended to encompass neighborhood or district structures where appropriate, and the individual building. In addition to its multi-scalar scope, UCIF advances a phased structure of assessment, readiness, and steady-state that links indicators, design strategies, and governance principles into an operational pathway. This structure moves beyond measurement alone to provide cities with a roadmap for sequencing interventions and adapting over time.

UCIF also bridges academic and practitioner perspectives. Practitioner frameworks such as the C40 Cities Climate Action Planning model provide global guidance but often leave open how strategic pillars translate into phased, multi-scale implementation. UCIF complements these models by embedding insights from academic research into a structured, testable design. Both emphasize mitigation, adaptation, and equity, yet UCIF extends this foundation through temporal sequencing, explicit multi-scalar application, and systems-based coordination. Appendix A Table A1 details complementarities and distinctions with C40, underscoring UCIF's role as a rigorous and adaptable framework for advancing climate readiness across diverse urban contexts.

Figure 1 shows the holistic view of the UCIF model. The following sections detail the model's theoretical foundations across scale, domain and phases. They present a structured implementation pathway supported by example metrics and real-world application scenarios.

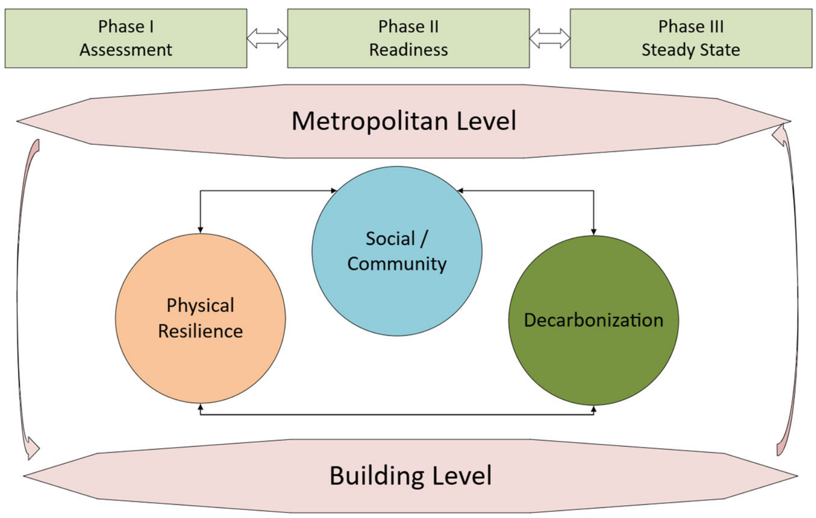

Figure 1. Urban Climate Integration Framework: A Multi-Scale, Phased Model.

UCIF framework showing three sequential phases (Assessment, Readiness, Steady-State) across domains (Physical Resilience, Decarbonization, Social/Community) and applied at both metropolitan and building scales.

2. Theoretical Framework and Model Core Components

This model conceptualizes urban climate-readiness as the alignment of three interdependent domains—physical resilience, decarbonization, and social/community engagement—across two spatial scales: metropolitan and building. These dimensions are conceptually distinct but interconnected, reflecting the multi-hazard nature of climate risk, the system-wide implications of energy transition, and the necessity of institutional and community engagement in long-term sustainability strategies [11].

Each component is structured to allow analysis and action at both metropolitan and building scales [12]. Physical climate risk addresses acute and chronic hazards that vary spatially and require both large-scale infrastructure adaptation and site-specific interventions. Decarbonization encompasses energy systems, emissions reduction, and technological shifts that play out differently across power grids, industries, and building stock [13]. Social and community capacity includes public awareness, civic engagement, and the strength of local organizing structures that influence planning, coordination, and equitable implementation. Together, these pillars offer a comprehensive yet flexible foundation for operationalizing climate readiness across relevant urban contexts.

Together, these domains reflect insights from climate literature that emphasize interdependence across physical, technical, and institutional systems. Resilience scholarship highlights the ability of cities to withstand and adapt to hazards while retaining essential functions [1,14]. Decarbonization research underscores the urban concentration of emissions and the systemic need for energy transition across sectors [15,16]. Governance and community processes are consistently identified as determinants of adaptive implementation, with institutional coordination and public participation shaping outcomes under uncertainty [17,18]. UCIF unifies these strands by showing how physical resilience, decarbonization, and governance/community engagement interact as mutually reinforcing components, moving beyond parallel treatment to a framework designed for integrated climate readiness across scales.

Interaction among UCIF's three interdependent domains, with arrows representing feedbacks across resilience, decarbonization, and social/community engagement.

2.1. Physical Risk Readiness

Arguably, physical risk readiness represents the most imperative step for urban decision-makers because inaction poses a direct risk to the lives of urban residents. As the global population increasingly concentrates in cities, the vulnerability of urban infrastructure, economies, and communities to extreme weather events, sea-level rise, and other climate impacts intensifies [19]. Failing to adequately prepare for these risks can lead to significant economic losses, social disruption, and human suffering. Therefore, enhancing the capacity of urban areas to withstand and recover from climate-related hazards is not merely a matter of environmental stewardship, but a fundamental requirement for ensuring the long-term viability and prosperity of cities. The UCIF's emphasis on physical resilience calls for measures to ensure infrastructure robustness, such as flood barriers and green infrastructure at the metro scale, alongside adaptive building technologies.

Assessing physical risk readiness involves a multifaceted approach that considers various factors [20]. Assessing physical resilience allows cities to understand their current position, support decisions on strategies and measures to adopt, and add thoughtfulness to planning in the long, medium, and short terms while facilitating the assessment of progress [21]. The following demonstrates several key areas to consider.

- **Hazard Identification and Risk Assessment:** The specific climate-related hazards that pose a threat to the urban area should first be identified. This includes assessing the likelihood and potential intensity of events such as floods, hurricanes, heat waves, and wildfire. Risk assessment should also consider the vulnerability of different assets and populations to these hazards [19].

- **Infrastructure Resilience:** Evaluating the resilience of critical infrastructure systems, such as transportation networks, energy grids, and water systems, is essential. This involves assessing the ability of these systems to withstand extreme weather events and continue functioning during and after a disruption [20].
- **Building-Level Assessments:** Assessing the resilience of individual buildings, involves considering factors such as structural integrity, flood protection measures, and energy efficiency. Building codes and standards should be updated to incorporate climate-resilient design principles [21].
- **Community Preparedness and Governance/Institutional Capacity:** Identifying and strengthening the governance and institutional mechanisms necessary for effective climate risk management [17]. This involves establishing clear roles and responsibilities for different agencies and stakeholders, as well as developing policies and regulations that promote climate-resilient development [11].
- **Forward-Looking Analytics:** Using climate risk analytics to understand future risk is important and markets are already pricing this risk [22]. These analytics ideally could be from a variety of providers, use forward looking models and integrate data from multiple sources [23,24].

2.2. Decarbonization

Decarbonization represents a fundamental tenet of the UCIF, necessitating a transition away from carbon-intensive practices across all facets of urban operation. Cities are the largest energy consumers, accounting for 78% of energy consumption and generating 60% of GHG emissions [15]. Urban areas account for about two-thirds of the world's total primary energy consumption, of which the urban building sector constitutes a significant proportion approximately 40% [25]. Achieving deep decarbonization requires a multifaceted strategy that addresses energy production, transportation, building operations, and industrial processes [26]. The framework's emphasis on decarbonization calls for measures to promote renewable energy, energy efficiency, and sustainable transportation.

Decarbonizing urban environments presents both challenges and opportunities for the real estate market. Property developers could play a key role in driving a low-carbon housing industry [27]. To encourage low carbon solutions, one needs to consider the assumption of energy price escalation [28]. Real estate owners are being pressured to incorporate Environmental, Social, and Governance criteria, and CO_2e performance specifically, into investment strategies [29].

2.3. Considerations for Assessing Progress

Assessing decarbonization progress involves evaluating several key aspects of urban energy systems, a selection of which are discussed:

- **Energy Efficiency in Buildings:** Improving the energy efficiency of buildings is a critical component of urban [30]. This includes measures such as upgrading insulation, installing energy-efficient windows and lighting, and implementing smart building management systems. Building codes and standards could be updated to require higher levels of energy performance for new and existing buildings [16]. The real estate industry can further shift toward a decarbonized future by moving to all-electric buildings [31].
- **Renewable Energy Deployment:** Increasing the deployment of renewable energy sources, such as solar, wind, and geothermal, is essential for reducing reliance on fossil fuels. Cities can promote renewable energy by providing incentives for rooftop solar

installations, developing community solar projects, and procuring renewable energy for municipal operations [6].

- **Sustainable Transportation:** Transforming urban transportation systems to prioritize walking, cycling, and public transit helps reduce greenhouse gas emissions. This includes investments in bicycle infrastructure, pedestrian-friendly streets, and high-quality public transportation networks [32]. Electrifying vehicle fleets and promoting the use of alternative fuels can also contribute to decarbonization [33]. Urban design can influence resident habits and preferences [34].
- **Waste and Materials Management:** Reducing waste generation and improving waste management practices are important for lowering emissions from landfills and waste incineration. This involves the establishment of sophisticated waste management systems. These systems should prioritize waste minimization through strategies focused on source reduction, enhancement of recycling infrastructure to optimize material recovery, and implementation of composting programs to divert organic waste from landfills. Furthermore, these systems should incorporate the deployment of technologies designed for the capture and utilization of methane emissions originating from landfills [35].
- **Industrial Decarbonization:** Although municipalities may have limited impact on regional industries, those within urban areas may adopt cleaner production processes and reduce their energy consumption. This can be achieved through measures such as energy audits, technology upgrades, and the use of renewable energy sources. Furthermore, the transition towards a circular economy can lead to a more sustainable and resource-efficient urban environment [36]. This circular economy would be characterized by the principles of reduce, reuse, and recycle, which can significantly diminish waste streams and associated emissions from industrial activities, fostering a more sustainable and resource-efficient urban environment [37].
- **Carbon Sequestration:** Exploring opportunities for carbon sequestration within urban areas, such as urban forestry and green infrastructure, can help to offset greenhouse gas emissions. Planting trees and creating green spaces can also provide other benefits, such as improved air quality and reduced urban heat island effect [6].
- **Policy and Governance:** Developing and implementing supportive policies and regulations is essential for driving urban decarbonization. This includes setting ambitious emissions reduction targets, establishing carbon pricing mechanisms, and providing incentives for clean energy investments [38].

2.4. Social and Community Engagement

Frameworks ideally consider the environmental, social, economic, and community aspects of urban development [39]. Communities should be explicitly recognized as potentially including both spatial and social constructs. Strong frameworks enable coordination among government agencies, community-based organizations, private sector actors, and residents, facilitating more inclusive and responsive planning [40]. Effective engagement requires collaboration across government agencies, residents, businesses, and community-based organizations enabling more effective response to emerging climate risks and long-term sustainability challenges [17].

Building resilience also depends on actively engaging diverse communities in the planning process [10]. Investments in infrastructure and local services not only strengthen urban systems but can also enhance quality of life and support economic development [41]. Effective partnerships are essential for advancing climate action, particularly when supported by mechanisms for participatory decision-making, cross-sector collaboration, and institutional capacity-building [8].

Considerations for Assessing Progress:

- **Community Participation:** Establishing mechanisms for meaningful community input in planning and development ensures that diverse voices are heard [42]. By actively involving residents in decision-making processes, urban planners can tap into local knowledge and insights, leading to more effective and sustainable solutions [43].
- **Stakeholder Collaboration:** Establishing platforms for collaboration and knowledge-sharing among diverse stakeholders can facilitate the development of innovative solutions to urban challenges [40]. These platforms integrate diverse perspectives and expertise, leading to more effective and sustainable urban development strategies. This may involve creating multi-stakeholder forums, partnerships, and networks to promote collective action [8,44,45].
- **Community Preparedness:** Evaluating the level of community awareness and preparedness for climate-related hazards can improve outcomes [46]. This includes assessing the availability of emergency shelters, evacuation plans, and communication systems, as well as the capacity of local organizations and volunteers to respond to disasters [47].
- **Transparent Decision-Making:** Ensuring transparency in decision-making processes is essential for building trust and accountability. When decision-making processes are transparent, stakeholders can understand the rationale behind decisions, participate more meaningfully in shaping policies, and hold decision-makers accountable for their actions [48]. This engagement fosters a sense of ownership and shared responsibility, aligning diverse interests towards common sustainability goals [49]. This includes making information about urban policies, projects, and budgets readily accessible to the public [50].
- **Equitable Access to Resources:** Promoting equitable access to resources and opportunities creates socially just and sustainable urban environments. This may involve addressing disparities in access to housing, transportation, education, and employment [10]. Inclusive processes that empower communities, promote transparency, and ensure accountability in decision-making supports equitable sustainability [51,52].
- **Policy and Governance:** Developing and implementing supportive policies and regulations is essential for driving urban sustainability. This includes integrating sustainability considerations into all aspects of urban governance, from land use planning to infrastructure development [53]. This could include setting ambitious emissions reduction targets, establishing carbon pricing mechanisms, and providing incentives for clean energy investments [54].
- **Governance and Institutional Capacity:** Identifying and strengthening the governance and institutional mechanisms are necessary for effective climate risk management [17]. This involves establishing clear roles and responsibilities for different agencies and stakeholders, as well as developing policies and regulations that promote climate-resilient development [11].

2.5. Multi-Scale Framework Design

Urban sustainability and climate-readiness challenges manifest differently at distinct spatial scales, necessitating differentiated but coordinated responses [55]. The metropolitan scale encompasses large-scale systems—such as transportation networks, energy grids, and stormwater infrastructure—that could serve as the backbone of citywide resilience and decarbonization efforts [56]. Further, the metropolitan scale could encompass local districts, neighborhood or planning commissions; the multi-scalar nature could easily be expanded to a third or fourth level where appropriate [12]. In contrast, the building scale represents the localized point of implementation and where behavioral, technological, and design choices at the individual level aggregate to influence broader sustainability outcomes. Structuring the model to accommodate both levels captures this nested interdependence while enabling the design of targeted strategies appropriate to the technical, institutional, and behavioral realities of each scale [57].

UCIF's dual scales of application, illustrating how metropolitan systems and building-level interventions interact through iterative feedback loops.

The UCIF treats these scales as analytically distinct yet operationally linked, acknowledging that such a separation may not be practical in every context. This structure enables the development of tailored strategies specific to the needs of each scale [58]. Urban resilience planning often falters when interventions at one scale neglect enabling or constraining factors at another. For example, building-level energy efficiency upgrades may be hampered by grid-level carbon intensity, while metro-level flood control investments may be undercut by unprotected critical buildings. The UCIF addresses this by designing separate logic paths for each scale, ensuring targeted actions and metrics while enabling synergy across physical and community systems [59].

The combined focus on buildings and metro-scale infrastructure supports adaptability and makes urban systems better prepared for climate impacts [60]. For instance, sustainable building standards at the individual building level can collectively reduce the demand for city-wide resources like water and energy, easing the strain on metropolitan infrastructure. Similarly, distributed renewable energy generation at the building level can contribute to the decarbonization of the city's energy grid [61].

Separating these levels also allows the UCIF to account for different actors, institutions, and implementation tools operating at each scale. Metro-scale strategies rely heavily on policy instruments, public investment, and interagency coordination, whereas building-level strategies are more reliant on private decision-making, tenant engagement, and site-specific retrofits. Treating these levels distinctly but within a unified model enables the framework to maintain analytical precision while encouraging integrative planning—an essential feature for adaptive urban sustainability approaches that must accommodate diverse geographies, capacities, and temporal horizons [62].

3. Phased Implementation/Application of Model

The preceding sections have introduced a conceptual framework for climate-readiness rooted in three interdependent vectors: physical resilience, decarbonization, and social/community engagement. These domains are examined across two spatial scales—metropolitan and building.

To put this model into practice, a phased implementation structure translates its principles into actionable steps. This approach provides a clear sequence for progressing from preliminary assessments to the institutionalization of climate-readiness practices. Each phase builds upon the insights and capacities developed in the previous stage, allowing for structured transitions and reducing the risk of reactive or fragmented efforts [63].

While the framework outlines *what* constitutes climate-readiness conceptually, the phased model provides guidance on *how* these elements may be introduced, sequenced, and evaluated over time. The intent is to support implementation that is both dynamic and responsive to local context, while preserving consistency across metrics and interventions at different scales.

The three-phase architecture aligns closely with adaptive planning principles, in which systems move through iterative cycles of assessment, intervention, and reevaluation. Phase I emphasizes empirical diagnostics and goal-setting; Phase II advances project formulation and early implementation; and Phase III focuses on the monitoring, refinement, and institutional embedding of climate resilience strategies [64]. Testable metrics and SMART goals across all phases enhance transparency, accountability, and comparability [10].

While the framework is structured in three phases, it is not intended to imply a rigid or linear process. In practice, urban adaptation often combines assessments, pilot projects, and revisions simultaneously. For example, a city may pilot building-level floodproofing measures while also installing temporary flood barriers along a vulnerable waterfront, monitoring their effectiveness during seasonal storms. Lessons from both scales could then inform revisions to metropolitan resilience plans before scaling up further interventions. Similarly, a city may begin piloting energy-efficiency retrofits in municipal buildings while also testing a district-scale renewable energy system, with performance data from the building interventions and grid integration lessons from the district system combined to revise metropolitan decarbonization strategies before wider deployment. UCIF accommodates this reality by framing phases as overlapping cycles rather than fixed steps.

Each phase includes a representative discussion of building- and metro-level considerations across the three core domains, followed by sample testable criteria. This structure is intended to serve as a flexible guide for cities to adapt to local priorities, constraints, and institutional capacity. Figure 2 visualizes the phased implementation approach, highlighting the progression from diagnostic assessments to long-term institutionalization of climate-readiness practices.

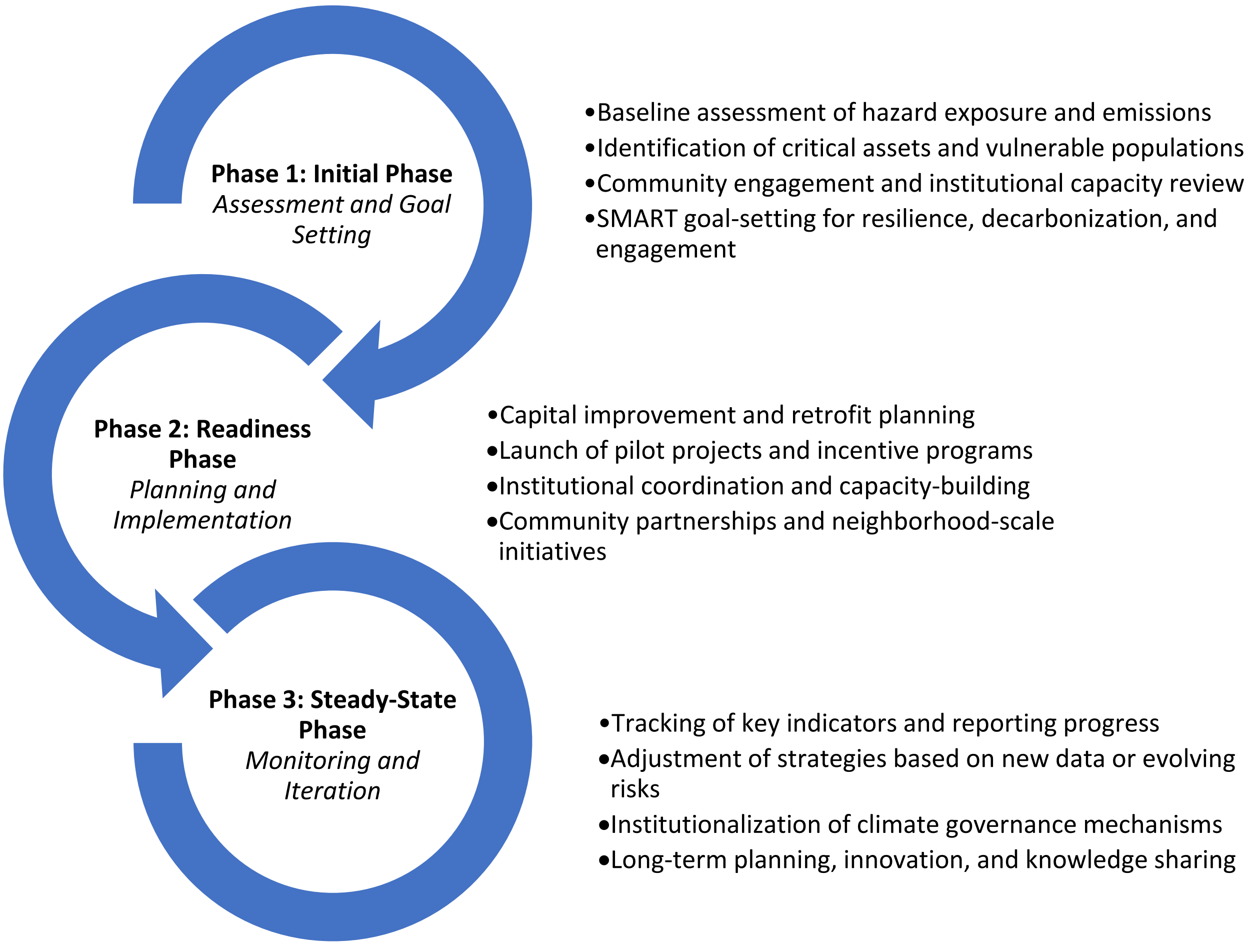

Figure 2. Urban Sustainability Phases.

3.1. Phase 1: Initial Phase (Assessment and Goal Setting)

The initial phase establishes the foundational knowledge base and strategic direction necessary for effective climate-readiness plans. This phase emphasizes diagnosis—focused on evaluating current conditions, identifying vulnerabilities, and setting clear, measurable goals for both resilience and decarbonization across metropolitan and building scales. While certain forward thinking cities are well into or advanced beyond Phase I, the vast majority of urban areas would benefit from structured investigation of key risks.

This phase is grounded in empirical assessment and participatory planning. Integrating data analysis with community input helps reflect local needs and align with broader sustainability objectives [6,8,65].

3.1.1. Building Level

Physical Resilience

At the building scale, the first priority is evaluating exposure to climate-related hazards such as flooding, heatwaves, and wind events. Structural vulnerability audits could assess building envelope integrity, roof type, drainage capacity, and the ability of structures to provide passive survivability (e.g., thermal safety during grid outages). Priority might be given to buildings that serve essential functions such as healthcare facilities, schools, and emergency shelters [21,66].

Decarbonization

Decarbonization readiness at the building level begins with baseline energy audits that identify current consumption patterns, fuel sources, and system inefficiencies. Electrification status, HVAC system type, and the presence (or absence) of renewable energy systems should be documented. Opportunities for near-term energy efficiency upgrades or solar integration may be noted for prioritization in subsequent phases [67].

Social/Community Engagement

Resident engagement capacity can be assessed through surveys and community feedback mechanisms that gauge climate awareness, perceived barriers to participation, and historical involvement in sustainability-related initiatives. Additionally, buildings may also be evaluated for the presence of organizing structures (e.g., homeowners' associations, tenant unions, green teams) that could facilitate resident mobilization during implementation [68,69].

3.1.2. Metro Level

Physical Resilience

Cities should undertake a thorough evaluation of hazard exposure and infrastructure vulnerability. This includes geospatial mapping of flood zones, heat islands, and areas with poor drainage or fire risk. Infrastructure categories—transportation, utilities, stormwater systems—should be evaluated for their ability to withstand and recover from projected climate stressors using both historical data and forward-looking climate models [70,71]. Long-term risks, such as rising sea levels and increasing temperatures, require analysis to fully understand their future consequences.

Decarbonization

Municipalities should compile a detailed emissions inventory segmented by major contributing sectors (buildings, transportation, industrial). Grid mix analysis is essential to understand the carbon intensity of electricity supply, and the baseline penetration of low-carbon technologies (e.g., district heating, transit electrification) should be mapped. This step could also include identification of high-emitting districts or neighborhoods for targeted improvement [72].

Social/Community Engagement

Local organizations and community groups can also be mapped to identify opportunities for collaboration and ensure inclusion of frontline voices. Key considerations are whether climate plans are comprehensive, how well agencies coordinate, and what mechanisms exist for public input. Equity considerations may be integrated early by identifying historically underserved or climate-vulnerable communities and the organizations that represent them [73].

3.1.3. Testable Criteria

A number of different measures could be established to establish baselines and evaluate progress in the initial phase. Precise and quantifiable metrics aligned with the overarching objectives of climate readiness would be optimal. Table 1 represents a sample set of potential criteria but is not an exhaustive list.

Table 1. Phase I Testable Sample Testable Criteria and SMART Goals.

Topic	Measure Description	Example Metrics	Example Smart Goal
Physical Resilience	Percentage of hazard resilient critical buildings/hazard resilient overall buildings	% with Raised mechanical/electrical equipment, impact-resistant windows, flood gates, elevated backup generator, dual water supply, etc.	Increase the percentage of resilient critical buildings by 25% within 5 years in flood-prone districts.
	Infrastructure stability and resilience	Number of water overflows, power outages, transportation delays, etc. Fragility index, e.g.,	Reduce infrastructure-related disruptions by 25% within 5 years based on annual fragility index scores.
	Composite hazard exposure maps with building and infrastructure overlays	Hazard-adjusted density of high-risk parcels per km^2. Density of parcels with inadequate drainage, wildfire exposure density, etc.	Reduce the density of high-risk parcels by 10% per kmÂ^2 in hazard-prone zones within 4 years.
Decarbonization	Average building energy use intensity (EUI) by use type	EUI for commercial/residential/industrial sectors, segregated by use. Tons of CO_2e emitted by built environment	Decrease average EUI by 20% in commercial buildings within 5 years through targeted retrofits.
	Grid carbon intensity	Annual average emissions per kWh for localized grid, % renewable energy, assessment of future needs	Achieve a 50% renewable energy mix in the local grid and reduce carbon intensity by 30% within 5 years.
	Total annual greenhouse gas emissions from manufacturing/industrial/infrastructure activities	Total tons of CO_2e emitted by industry, infrastructure (e.g., waste management) CO_2e	Lower industrial sector GHG emissions by 15% within 3 years through cleaner production incentives.

Table 1. *Cont.*

Topic	Measure Description	Example Metrics	Example Smart Goal
Social/Community Engagement	Proportion of residents aware of local climate risks	% of survey respondents identifying top local climate hazards, % agreeing on need for additional resilience	Raise awareness of local climate risks to 75% of residents via campaigns within 2 years.
	Number and activity level of neighborhood sustainability groups	Count of active groups per 10,000 residents; frequency of events per year	Increase active neighborhood sustainability groups by 30% in all districts within 3 years.
	Existence and strength of public-facing climate planning platforms	Presence of interactive dashboard; update frequency; public usage statistics	Launch and maintain a climate dashboard with monthly updates and 2000 monthly users within 2 years.
	Number of community-led climate resilience projects initiated	Number of projects funded or supported by the city that are initiated and led by community organizations	Fund at least 10 new community-led resilience projects annually over the next 3 years.

To aid in accountability and progress tracking, optimal goal setting should generally include SMART goals (specific, measurable, achievable, relevant, time-bound) goals tied to resilience enhancements, emissions reductions, and social engagement benchmarks. For instance, to evaluate baseline emissions, cities could create a thorough inventory of emissions across essential sectors.

3.2. Phase 2: Readiness Phase (Planning and Implementation)

The readiness phase translates diagnostic insights from Phase 1 into actionable strategies, programs, and infrastructure investments. During this stage, cities and building actors shift from assessment to active implementation by crafting and executing detailed climate adaptation and mitigation plans. Successful implementation of this phase depends on aligning technical upgrades with institutional capacity and sustained community engagement across metropolitan and building scales. This phase incorporates both short-term pilot projects and medium-term infrastructure or policy deployments, designing efforts that are feasible, grounded in empirical baselines, and ideally equitable. SMART goals offer strong tracking of execution during this phase.

3.2.1. Building Level

Physical Resilience

At the building level, readiness planning begins with site-specific adaptation policies. For buildings in flood-prone areas, this includes the installation of flood barriers, sump pumps, and backup power generation systems. Mechanical and Equipment could be raised to a roof or meaningfully above statistical tail flood levels. Heat-vulnerable properties may prioritize shading devices, heat-reflective materials, and passive cooling strategies. Owners of critical structures—such as hospitals and emergency shelters—should finalize building-specific continuity and emergency response plans. Compliance with updated resilient building codes could be verified or pursued through retrofitting plans [74].

Decarbonization

Building operators and owners should develop tailored decarbonization roadmaps, with an initial priority on retrofitting for energy efficiency and electrification. This includes upgrading HVAC systems to electric heat pumps, replacing gas appliances, and improving insulation and fenestration. Where feasible, rooftop solar or battery storage installations could be implemented. Cities can support adoption through financial incentives and technical guidance for owners and tenants [29].

Social/Community Engagement

Operationalizing engagement strategies involves activating internal sustainability teams, green committees, or building councils to coordinate climate actions. Buildings could host workshops or distribute informational materials to build capacity and increase tenant participation [75]. Buildings may also connect with citywide resilience efforts through coordinated neighborhood forums or digital engagement platforms, such as feedback dashboards [76].

3.2.2. Metro Level

Physical Resilience

Cities should finalize and begin executing capital investment plans to strengthen physical resilience. Examples include bioswales, cool roofs, and upgrades to critical infrastructure like stormwater systems and substations, heat mitigation strategies (urban forestry, cool roofs), and critical infrastructure upgrades (elevated substations, expanded stormwater networks). Emergency response systems should be stress-tested, and hazard communication tools, such as warning systems, deployed or upgraded. Institutional actors ideally coordinate across transportation, utilities, and emergency management departments to ensure municipal resilience [77].

Decarbonization

At the metro level, planning efforts should culminate in the launch of comprehensive climate action plans with detailed decarbonization pathways. Priority actions may include incentives for zero-emissions building construction, municipal fleet electrification, and transit-oriented development zoning. Grid resilience and decarbonization should be addressed in partnership with utilities, through both infrastructure upgrades and policy incentives that accelerate the renewable transition [78].

Social/Community Engagement

Governments should launch or expand participatory governance structures for climate planning. This could include establishing standing climate resilience advisory boards, institutionalizing regular town hall meetings, and supporting neighborhood-led initiatives with funding and technical assistance. Specific tools such as open-data climate dashboards and participatory budgeting mechanisms could be rolled out to build transparency and encourage co-production of solutions. Capacity-building programs could help engage and empower frontline organizations and underserved communities, building their adaptive capacity and voice in decision-making [79].

3.2.3. Testable Criteria

The readiness phase transitions from diagnostics to action. At this stage, urban stakeholders develop and initiate the interventions identified during Phase 1, deploying resources toward prioritized risks and opportunities. The aim is to operationalize resilience and decarbonization goals through concrete planning, investment, and institutional alignment. This phase places a strong emphasis on feasibility and stakeholder inclusion, encouraging strategies are technically sound, socially supported and financially viable. Planning should remain adaptive to evolving climate projections and informed by ongoing engagement with residents, businesses, and other stakeholders.

At the building level, implementation focuses on tangible upgrades—e.g., energy retrofits, resilient design modifications, or electrification—targeting the vulnerabilities identified in Phase I. At the metro scale, cities move toward integrated capital planning, zoning reform, and infrastructure modernization to mitigate physical risks and reduce emissions. Parallel efforts in governance include formalizing community engagement mechanisms, building institutional capacity, and embedding equity throughout the climate response. Each component is tied to a set of measurable indicators and SMART goals to monitor deployment progress and improve accountability. Table 2 shows sample measures, as before, this list is demonstrative and not exhaustive.

Table 2. Phase II Testable Sample Testable Criteria and SMART Goals.

Topic	Measure Description	Example Metrics	Example Smart Goal
Physical Resilience	Number of implemented building-level resilience upgrades in critical facilities	Number of floodproofed schools, hospitals, emergency shelters	Implement at least 50 resilience upgrades in critical buildings by 2027
	Infrastructure adaptation projects completed in high-risk zones	Linear feet of stormwater upgrades, green infrastructure installations	Complete 10 infrastructure adaptation projects in flood-prone areas by 2026
	Integration of hazard overlays in zoning and permitting decisions	Number of zoning decisions that integrate composite risk data	Integrate hazard overlays into 100% of zoning applications by 2025
Decarbonization	Retrofit projects initiated for energy efficiency improvements	Sq. ft. of buildings retrofitted; Number of HVAC electrifications	Retrofit 1 million sq. ft. of commercial space for energy efficiency by 2028
	Expansion of renewable energy procurement or on-site generation	MW of solar capacity added; Number of government buildings with renewables	Achieve 30% renewable energy in municipal operations by 2027
	Implementation of clean industrial production protocols or systems	Number of low-carbon pilot projects or factories transitioned	Launch 5 clean production pilots across industrial zones by 2026
Social/Community Engagement	Community climate adaptation training or workshop participation	Number of workshop attendees; % coverage of priority populations	Train 10,000 residents from vulnerable communities in adaptation skills by 2027
	New local climate task forces or governance structures initiated	Number of task forces by district; Number with decision-making authority	Establish active climate task forces in 100% of city districts by 2026
	Breadth and diversity of public consultations in climate planning	Count of meetings with >3 demographic groups represented	Conduct quarterly consultations with at least 4 stakeholder sectors by 2025
	Co-created plans with community groups adopted into formal strategy	Number of adopted plans co-written by community orgs	Adopt 5 community co-developed plans into official strategy by 2027

3.3. Phase 3: Steady-State Phase (Monitoring and Evaluation)

The steady-state phase represents the institutionalization of climate resilience and decarbonization practices as routine elements of urban governance and building operations. It emphasizes long-term monitoring, iterative evaluation, and the formal embedding of adaptive capacity into policy frameworks, building systems, and civic engagement routines [17]. This phase ensures that initial and readiness-phase achievements are sustained, scaled, and responsive to emerging conditions, including shifts in climate risk profiles, technology, policy, and community needs. Ideally, cities and buildings reach this phase with systems in place for ongoing assessment, funding continuity, and regulatory coordination that no longer rely solely on project-based systems but are instead embedded into standard operating procedures.

At both the metro and building level, Phase 3 activities include formalizing data collection systems, maintaining or upgrading policies based on performance evaluations, and institutionalizing feedback loops for stakeholder engagement. Governance bodies refine regulations based on observed outcomes and expand successful pilots into citywide or portfolio-wide standards. Additionally, this phase provides a platform for long-term equity monitoring, ensuring that vulnerable populations continue to benefit from, and shape, climate action [80]. Scenario testing, climate foresight exercises, and integration into long-range capital planning and budget processes are hallmarks of a mature, steady-state system.

Ultimately, the steady-state phase is about creating self-sustaining urban systems—both physical and social—that remain adaptive and responsive in the face of a changing climate. A pivotal aspect of this transition involves integrating climate risk considerations into standardized industry practices, such as incorporating climate projections into building codes, infrastructure design protocols, and financial risk assessments [80,81].

3.3.1. Building Level

Physical Resilience

In the steady-state phase, building-level resilience measures are no longer experimental or one-time investments but are incorporated into maintenance schedules, building management plans, and retrofitting cycles. Asset managers and owners monitor key indicators such as drainage system performance, envelope durability, and emergency system reliability using sensor-based technologies or inspection logs. Passive survivability features—such as thermal autonomy or off-grid backup systems—should ideally be evaluated annually and upgraded as standards evolve. Where appropriate, these measures are codified into building operations manuals or required by insurance or municipal regulation [21].

Decarbonization

Decarbonization efforts at this stage are embedded into lifecycle operations and financial planning. Energy monitoring systems should continuously track building performance, flagging underperformance relative to benchmarks (e.g., ENERGY STAR scores or EUI targets). Asset owners should formalize carbon accounting protocols and pursue third-party validation or disclosure frameworks (e.g., International Organization for Standards, CDP). Strategic upgrades—such as electrification or renewable integration—transition from grant- or pilot-driven initiatives to standard practice across portfolios. Ongoing staff training ensures operational teams remain aligned with decarbonization goals and technological advancements [82].

Social/Community Engagement

Resident engagement becomes an institutionalized function, integrated into building operations and governance structures. Tenant associations or sustainability committees might hold regular forums for input and disseminate progress updates via dashboards or newsletters. Data on participation, satisfaction, and equity outcomes could be gathered and analyzed to ensure continued inclusivity. These plans may be embedded into lease agreements, management contracts, or ESG reporting, formalizing accountability for ongoing community engagement and regulatory compliance. Where appropriate, building owners may partner with community-based organizations to maintain outreach momentum and adapt programming to demographic or policy shifts [83].

3.3.2. Metro Level

Physical Resilience

At the metropolitan level, steady-state resilience includes robust, centralized systems for infrastructure monitoring, emergency response coordination, and proactive maintenance. Cities should implement climate-informed asset management plans with performance indicators tied to risk thresholds. Infrastructure failures (e.g., flood pump breakdowns, grid overloads) are logged, analyzed, and used to inform future investments. Planning departments institutionalize hazard overlays into zoning codes, building permits, and capital improvement plans, ensuring that physical risk is accounted for in all major development or redevelopment processes [84].

Decarbonization

Municipalities shift from programmatic to structural decarbonization by aligning planning, budgeting, and procurement with climate goals. Emissions inventories are updated regularly using real-time data feeds or utility partnerships. Carbon budgeting systems may be implemented, setting annual or sector-specific caps. City-owned fleets and facilities operate under emissions-reduction KPIs, while permitting and tax policy are used to promote private-sector decarbonization. Integrated resource planning across sectors (e.g., energy, water, waste) helps pursue emissions reductions holistically and equitably [85].

Social/Community Engagement

Climate governance becomes routine through permanent structures such as resilience offices, standing climate commissions, and embedded climate staff in key departments. These entities track performance on engagement and equity goals using public dashboards, annual climate reports, and feedback mechanisms. Participatory processes such as climate budgeting, foresight workshops, and citizen panels are formalized, enabling long-term civic influence. Municipal support for grassroots organizations continues through operating grants, technical training, and access to decision-making processes, reinforcing the adaptive and inclusive ethos central to long-term climate resilience [86–88].

3.3.3. Testable Criteria

In the steady-state phase, testable criteria shift from tracking the deployment of interventions to evaluating their durability, effectiveness, and equity over time. Metrics in this phase are designed to assess not only continued performance but also the institutionalization of adaptive practices. Unlike earlier phases that emphasize foundational assessment or implementation rollouts, the steady-state phase focuses on sustaining progress through routine monitoring, iterative improvement, and transparent governance.

Key indicators include performance benchmarks for resilient infrastructure and buildings, operational emissions reductions, and the consistency of stakeholder engagement. Additionally, this phase introduces criteria to evaluate system-wide learning mechanisms, equity audits, and public transparency platforms. These metrics are particularly important for institutionalizing climate governance, as they reinforce feedback loops between observed outcomes and future planning decisions. As with earlier phases, SMART goals (specific, measurable, achievable, relevant, and time-bound) remain a central tool for performance accountability and ongoing policy refinement. Table 3 offers a representative list of potential measures.

Table 3. Phase III Testable Sample Testable Criteria and SMART Goals.

Topic	Measure Description	Example Metrics	Example Smart Goal
Physical Resilience	Maintenance adherence for resilient building features	% of critical buildings inspected and maintained per year	Ensure 100% of flood-resilient buildings undergo annual inspection and maintenance starting by 2026
	Performance of critical infrastructure during hazard events	% uptime of utilities during climate events; response times	Maintain 98% service uptime across water and energy systems during severe events by 2028
	Annual review of climate-adjusted zoning and building codes	Number of revisions based on updated hazard projections	Review and update zoning/building codes annually using latest climate data beginning in 2026
Decarbonization	Annual reduction in operational building emissions	Tons CO_2e/year avoided through operations	Reduce operational building emissions by 5% annually for all municipal properties between 2026–2030
	Renewable energy share in municipal and public sector portfolios	% of total electricity demand met with renewables	Maintain 75% renewable energy share in city operations each year from 2027 onward
	Industrial sector carbon intensity tracking	CO_2e/unit of output for industrial sectors	Achieve 10% reduction in industrial carbon intensity every three years through 2035
Social/Community	Public engagement with climate dashboards or planning platforms	Monthly users; feedback forms submitted	Sustain 2500 monthly users on the public climate portal with 200+ feedback inputs/year by 2027
	Equity audit of city resilience/decarbonization investments	% of funds directed to vulnerable districts; Gini index of investment distribution	Conduct and publish annual equity audit; increase low-income neighborhood share by 15% over 5 years
	Implementation of institutional learning and feedback loops	Number of plan updates tied to monitoring; formal feedback channels	Update the urban climate plan every 2 years based on stakeholder feedback and monitoring by 2028
	Retention and evolution of multi-stakeholder governance structures	% of advisory groups active after 3 years; meeting frequency	Maintain at least 90% active participation in local climate governance groups through 2030

4. Challenges and Barriers to Implementation

Implementation of the UCIF may encounter significant challenges that reflect the complexity of coordinating climate action in urban contexts. Financial constraints are among the most prominent. At the metropolitan scale, municipal governments may face limited fiscal capacity to finance resilience projects, while competing priorities in housing, transport, and social services reduce available resources. At the building scale, high upfront costs for retrofits and renewable technologies can deter investment, particularly where landlords and tenants face split incentives. Within UCIF, these barriers map most directly onto the decarbonization domain and are likely to emerge during the readiness phase, where financing mechanisms and equitable cost-sharing are critical for advancing from planning to implementation.

Institutional and political barriers also present significant risks to effective adoption of UCIF. Fragmented governance structures may limit coordination across jurisdictions, while administrative capacity can be constrained by staffing limitations and competing mandates. Political resistance and shifting priorities following electoral cycles may undermine momentum, while land use and ownership conflicts may slow down adaptation strategies that require collective action or reallocation of land. These barriers intersect strongly with UCIF's governance and engagement domain, highlighting the importance of stakeholder coordination and participatory processes across both metropolitan and building scales.

Finally, barriers may arise unevenly across UCIF's phased structure. As noted earlier, the phased structure is intended as an organizing device rather than a strictly linear sequence. In practice, cities may combine assessments, pilot projects, and revisions simultaneously, and UCIF is designed to accommodate this reality through its phased but flexible structure. In the assessment phase, limited data and monitoring capacity may constrain baseline evaluation of climate risks. During readiness, mobilizing finance, building political coalitions, and aligning technical expertise are central challenges. In the steady-state phase, sustaining long-term commitment, institutionalizing accountability, and embedding adaptive learning mechanisms may prove difficult in the face of fiscal and political pressures. By situating these barriers within UCIF's phases, domains, and scales, the framework not only acknowledges the obstacles cities may face but also provides a structure for anticipating when and where they are most likely to emerge.

5. Conclusions

This paper introduced the Urban Climate Integration Framework (UCIF) as a novel model that integrates insights from sustainability indicators, systems-based planning, and governance and resilience scholarship. Unlike prior approaches that treat these strands in parallel, UCIF synthesizes them into a phased and multi-scalar design. Its innovations lie in temporal sequencing, explicit attention to both metropolitan and building scales, and the embedding of systems coordination as a central object of analysis.

UCIF is intended as both rigorous and adaptable, capable of guiding urban climate action in ways that align academic theory with practitioner needs. While practitioner frameworks such as the C40 Climate Action Planning model provide valuable global roadmaps, UCIF complements them by offering a testable structure that clarifies sequencing, cross-scale linkages, and operational guidance. This combination underscores UCIF's potential to bridge scholarship and practice.

Importantly, the framework is not a rigid or linear template. Cities may combine assessments, pilot projects, and revisions simultaneously, and UCIF accommodates this reality by framing phases as overlapping cycles. By situating likely barriers—financial, political, institutional, and technical—within its phased structure, UCIF provides not only a guide to action but also a tool for anticipating implementation challenges. Future research and applied work can test, adapt, and refine the framework across diverse urban contexts, further strengthening its capacity to inform climate readiness strategies.

Future research could also explore empirical validation of the proposed indicators. While the UCIF suggests a series of metrics for tracking progress, some of these have yet been operationalized across multiple urban contexts. Comparative case studies across cities differing in geography, governance structure, and climate exposure would help test the generalizability and utility of the model. Additionally, future work might extend the model to incorporate fiscal readiness and economic resilience more explicitly, particularly as cities begin to confront climate-related impacts on credit ratings, insurance markets, and long-term investment flows. Lastly, the role of digital technologies—including open data platforms, predictive analytics, and citizen science—merits deeper integration as both a capacity-building tool and a domain of climate-readiness.

Funding: This research received no external funding.

Data Availability Statement: Data is contained within the article.

Acknowledgments: The author thanks Matt Liesch, Howard Haines, anonymous reviewers and the special issue Editors for valuable feedback.

Conflicts of Interest: The author declares no conflict of interest.

Appendix A

The UCIF is primarily positioned as an academic framework, but it also aligns with applied practitioner models. To illustrate complementarities without shifting the paper's focus, Appendix A Table A1 compares UCIF with the widely used C40 Cities Climate Action Planning (CAP) framework. This comparison highlights how UCIF extends applied approaches through temporal sequencing, explicit multi-scalar design, and integration of systems theory.

Table A1. UCIF and C40 Comparison.

Dimension	UCIF	C40 CAP Framework	Similarities	Differences
Conceptual foundation	Academic synthesis of indicator systems, socio-ecological resilience, and governance research	Practitioner framework aligning city action with the Paris Agreement	Both treat mitigation, adaptation, and equity as central	UCIF is a research-based, testable model designed to extend theory; C40 is a practice-based roadmap built to support municipal compliance and reporting
Structure	Three sequential phases: Assessment → Readiness → Steady-State	Three thematic pillars: Commitment/Collaboration → Challenges/Opportunities → Acceleration/Implementation	Both organize climate action into structured elements	UCIF emphasizes temporal progression across phases; C40 emphasizes thematic categories without explicit time sequencing
Domains of action	Physical resilience, decarbonization, and social/community engagement	Mitigation, adaptation, equity, governance	Both highlight integrated domains of climate action	UCIF links domains directly to IPCC/TCFD climate risk categories (physical and transition); C40 frames domains as policy goals for cities
Scale	Explicit dual scale: metropolitan systems and individual buildings	Primarily citywide planning and governance	Both focus on city-level climate action	UCIF operationalizes interventions across multiple scales, bridging infrastructure and asset-level decisions; C40 centerd on municipal scale

Table A1. *Cont.*

Dimension	UCIF	C40 CAP Framework	Similarities	Differences
Implementation and Practitioner Interface	Frames coordination as a systems requirement across phases; designed as an adaptable academic model transferable across contexts	Provides practical guidance, technical assistance, and roadmaps tailored to municipal governments	Both emphasize governance, engagement, and support for city action	UCIF treats coordination as an analytical focus grounded in systems implementation theory and offers conceptual generalizability across cases; C40 emphasizes pragmatic delivery through local powers, resources, and partners, providing context-specific guidance for municipal climate planning

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