Urban Climate Change Research Network
The Climate School | Columbia University

ARC 3.3
Climate Change and Cities

Third Assessment Report on Climate Change and Cities

Planning, Urban Design, and Architecture for Climate Action – Additional Resources

Evaluating Co-Benefits

Evaluating the co-benefits of competing climate strategies can help urban practitioners maximize beneficial outcomes for stakeholders within a given set of budget or spatial constraints. By way of example, building envelope thermal efficiency (i.e., providing adequate insulation and heat capacity, tailored to local climate and seasonal variations) and local renewable energy generation might have similar climate benefits and costs, but the former may also improve the health of residents by improving indoor environmental quality, require less maintenance by the community, and/or save space (whether on building rooftops or open areas) that can then be used for other needs.

C40, a global network of mayors working to confront the climate crisis in cities, has been at the forefront of developing such co-benefits analyses. The C40 Urban Climate Action Impacts Assessment provides a standard approach to linking a climate action, such as Green & Healthy Streets, to outputs and outcomes, such as increased walking and cycling facilities that lead to increased usage of these modal shares. The outcomes are then mapped to impacts, such as improved resident health and reduced noise. The C40 Opportunity 2030, Benefits of Climate Action in Cities report quantifies the impact of these co-benefits. Both reports include global case studies that can be used by urban practitioners to evaluate co-benefit opportunities in their local context. Once a co-benefit has been identified, tools dedicated to more specific analysis can be used, such as the Low Emissions Analysis Platform - Integrated Benefits Calculator (LEAP-IBC, Kuylenstierna et al., 2017) tool that focuses specifically on the impacts of reduced air pollution.

Research informing practice, practice informing research: Experience and experiment:

Further historical information related to the built environment in cities

The role of cities has diversified over millennia from the seat of religious and governmental authority to nodes of regional and international trade, headquarters for military power and industrial capacity, crucibles of learning, modern science and engineering, and sites of industrial and financial engines driving the global economy (Benevolo 1971). At every stage of development, advances in architectural and urban design, construction, and planning were informed by experience and experiment. The earliest texts devoted to architecture and planning provided guidance based on knowledge gained from experience in every aspect of buildings and cities including selecting favorable sites for human habitation, laying out road networks, securing reliable sources of water and constructing aqueducts, acquiring and utilizing appropriate materials in foundations and structures and more. The earliest architects and builders were keenly aware of the relation between the city, the local climate and the available and accessible natural resources: Socrates (in Senofonte, ἀπομνημονεύματα) emphasized the importance of building "the tallest buildings towards the south to take advantage of the sun during the winter and the lowest towards the north to keep out the cold winds", while Vitruvius (in De Architectura) highlighted that "if we want the design of our houses to be correct, we must begin to understand what the climate is like in the country in which they will be built. There are types of dwellings appropriate for Egypt, others for Spain, still others different for Rome and so for all the lands and countries with different characteristics."

Later, the emergence of the Industrial Revolution elevated experimentation primarily through the scientific method as the dominant source of new technical knowledge informing every aspect of human society, including the making of buildings and cities. In the past 300 years, an array of technological developments from experimentation have transformed buildings and cities. Since the 19th century, the increased availability of novel materials and technologies has contributed to accelerating urban population growth dramatically and disconnecting urban and building design from environmental and climate considerations.

For example, Joseph Aspdin's experiments led to the invention of modern portland cement in the early 19th century, 2000 years after ancient Roman cement was first used. Today, concrete is believed to be the second most consumed material after water, and accounts for 8 percent of CO_2 emissions (Olivier et al 2016). Since the 1950s and 1960s, major corporate labs in the US have invented thousands of synthetic polymers now used widely in buildings and cities (Bustillo Revuelta, 2021). Nowadays, plastics accumulation in the environment and landfills is recognized as a global pollution crisis (Nicholson et al., 2021). In 1933, Carrier Air Conditioning Company of America invented modern air conditioning, transforming the modern office building and, along with the elevator, transforming central business districts around the world. Today, the increased dependency from energy and fuels makes buildings accounting for 30% of global final energy consumption and 26% of global energy-related emissions (IEA, 2023). Climate sensitive urban design including building materials, waste management and the circular economy are all key considerations for climate change and cities.

Over time the activities of practice and research – experience and experiment – became more and more disengaged from one other in their methods of inquiry, dominant priorities, communities, and cultures. The mid-18th century saw the rise of schools of engineering and architecture, sometimes together with common faculty and sometimes separate. Since that time architecture and engineering education have become more distinct and separate, exacerbating and locking-in increasingly disconnected modes of inquiry with distinct sets of expertise, modes of communication and language, priorities and values, as well as measures of excellence. This is reflected today in the separate academic and professional societies serving architects, planners, engineers and scientists. It is also reflected in the separate accreditation boards for architects and engineers (e.g., in the U.S. the National Architectural Accrediting Board, NAAB and Accreditation Board for Engineering and Technology, ABET respectively).

Four mutually reinforcing and co-evolving areas of knowledge, action and self-reflection

Backcasting from co-created, long-term visions of sustainable futures creates 'transition pathways' from the present to the desired future. The vision informs projects in the present, which act as 'steps' along the transition pathway toward desired futures.

PRACTICES: • Foresighting • Critical/speculative design • Backcasting • The three horizons • Experiential futures • Future scenarios • Developing future narratives • Cosmopolitan localism • Everyday life and lifestyles • Domains of everyday life

New ways of designing will help realize the vision but will also change/evolve it. As the vision evolves, new ways of designing will continue to be developed.

Transition visions must be informed by new knowledge about natural, social, and built/designed systems. This new knowledge will, in turn, evolve the vision.

New ways of designing will arise out of compelling future visions, an understanding of systems dynamics and adopting new mind-sets and postures

PRACTICES • Design for 'initial conditions' • Placed-based, context-based design • Framing problems in spatio-temporal contexts • Network & alliance building • Transdisciplinary and co-design processes • Design that amplifies grassroots efforts • Beta, error-friendly approach to designing • Linking/amplifying projects • Mapping wicked problems

Theories from many varied fields and disciplines inform a deep understanding of the dynamics of change within the natural & social worlds.

PRACTICES: • Max-Neef's theory of needs • Sociotechnical regime theory • Living systems theory • Critiques of everyday life • Design for behavior change • Leverage points • Alternative economics • Social practice theory • Stakeholder conflict resolution • Social pyschology research • Ethnography research

Changes in mindset, posture and temperament will give rise to new ways of designing. As new design approaches evolve, designers' temperaments and postures will continue to evolve and change.

New theories of change will reshape designers' temperaments, mindsets and postures. And, these 'new ways of being' in the world will motivate the search for new, more relevant knowldege.

Living in & thru transitional times requires a mindset and posture of openess, mindfulness, self-reflection, a willingness to collaborate, and 'optimistic grumpiness'

PRACTICES • Shifting values: cooperation over competition, self-sufficiency, deep respect and advocacy for 'other' (cultures, species, etc.) • Indigenous, place-based knowledge • Understanding/embracing transdisciplinarity • Comfort with uncertainty, ambiguity, chaos and contradiction • Stakeholder conflict resolution • Radical collaboration • Understanding of worldviews

Figure 1 *New ways of design will be needed to serve a world in transition.*
(Source: Irwin et al., 2019)

Table 1. *Characteristics of adaptation and mitigation measurement* (elaborated from Christiansen et al., 2018).

Characteristic	Mitigation	Adaptation
Ultimate objective	Achieve carbon neutrality of urban systems, tackling both direct (scope 1) and indirect (scope 2 and 3) with a focus on critical sectors such as energy, transportation, construction materials, food, waste.	Achieving sustainable development goals while reducing impact of climate change on urban infrastructure and communities, considering both slow-onset changes (e.g. shift in seasonal temperature and precipitation averages) and extreme events (heat waves, floods, etc.)
Global target	Quantitative: keeping the global average temperature to well below 2 °C above pre-industrial levels (Paris Agreement)	Qualitative: 'enhancing adaptive capacity, strengthening resilience and reducing vulnerability' (Paris Agreement)
Subject of measurement	Mainly physical or chemical conditions: GHG emissions, CO_2 concentrations in the atmosphere by urban sector, urban climate parameters (with a focus on Urban Heat Island Effect and carbon storage capacity from green infrastructure)	Combinations of socio-economic and bio-physical conditions (e.g. health impacts of heat waves, economic impact of floods), by confronting changes in the built environment with current and future projected climate hazards
Type of measurement	Direct: emission reductions, anthropogenic GHG emissions expressed in CO_2 equivalents, essential climate variables including temperature (not limited to air temperature, but focusing on key parameters such as surface temperature of building envelopes and outdoor materials, Mean Radiant Temperature and Apparent Temperature).	Indirect, mostly depending on the availability of hazard-specific impact assessment models and simulation tools able to measure the effect of adaptation measures through scenario comparisons (e.g., current state/climate vs design scenario/future climate), including those related to both coping and adaptive capacity
Place dependence of definition of measurement unit?	No, there is universal applicability because the subject of measurement can be measured on objective scales like degrees Celsius, metric tons or parts per million.	Yes, vulnerability, risk and resilience are context-specific. Impact assessments should refer to Hazard, Exposure, and Vulnerability as determinants of risk (IPCC, 2022) to ensure comparability of measurements across contexts
Causality between intervention and outcome	Direct attribution of emissions reductions is possible for some interventions (e.g., installation of renewable energy), more difficult for higher-level policy interventions (e.g., incentives to public transportation and active mobility).	Attribution limited to assumptions within risk/impact assessments and affected by uncertainties due to climate change scenarios and other critical urban dynamics (e.g., demographics).
Additionality	Less conceptual, but practical challenges in demonstrating additional emissions reductions.	Conceptual and practical challenges in separating adaptation from development: different framings of adaptation are used.
Baseline	Absolute anthropogenic emissions in a particular year (e.g., 1990) or estimated future emissions (e.g., business as usual	No agreed baseline. Since climate impacts are increasing and fluctuate over time, reference events relevant in a city context should be determined based on

	scenarios); GHG concentration and composition in a particular year.	downscaled regional to local climate projections.

Defining Integration of Mitigation and Adaptation and Relationship to Climate Resilient Development

Climate change mitigation has an agreed-upon definition that involves reducing GHG emissions and enhancing processes that remove them from the atmosphere to prevent global warming (Walsh, 2011). Urban adaptation refers to the process of adapting cities and urban areas to climate change and is considered at parity with mitigation, where interactions are needed to efficiently maximize their potentials (Giordano et al., 2020; Sharifi, 2021). In this Element, urban resilience is defined as "the ability of an urban system — and all its constituent socio-ecological and socio-technical networks across temporal and spatial scales — to maintain or rapidly return to desired functions in the face of a disturbance, to adapt to change, and to quickly transform systems that limit current or future adaptive capacity" (Meerow and Newell, 2016).

Earlier research at the regional scale showed that urban sprawl with one central business district may lead to high GHGs by encouraging more long-distance automobile use (Zhang et al., 2017). Further, this work showed that a polycentric pattern could play a positive role on energy saving and thus GHG emission reduction by lessening traffic in the central district through shortening commuting distances and travel times. This earlier work concluded that new urban development and urban expansion are bound to produce more traffic-related GHG emissions in the suburbs and surrounding areas. However, more recent studies have shown that not all polycentric cities have more efficient energy consumption and GHG emission performance (Liu et al., 2020). Public transit that links mixed land-use areas may reduce the need to travel, especially by private vehicles with higher GHG emissions (Zamorano & Kulpa, 2014). These studies show that the impact of multi-center characteristics on GHG emissions should be verified using data from more urban areas (Liu et al., 2020).

Synergies, Conflicts and Trade-Offs

Adaptation and mitigation represent two approaches in response to climate change. They both seek to avoid the potential damages of global climate change and support the development of present and future generations in a sustainable manner (Dang et al., 2003). The Paris Agreement (2015), and the IPCC in its special report on the impacts of 1.5 °C global warming (IPCC, 2018) have declared that transformations towards sustainable development in a warmer world involve fundamental societal and systemic changes, and emphasize that synergies and trade-offs between and across adaptation and mitigation measures have to be carefully considered when planning climate sectorial actions.

Socio-economic factors such as investments in infrastructure and technical efficiency are factors that influence the capacity to adapt and make cities less vulnerable to climate change (Wiréhn et al., 2020). Both mitigation and adaptation are essential for climate change risk management at all scales, and synergies and trade-offs between mitigation and adaptation options can occur within the same sector or across several sectors (Shrestha and Dhakal, 2019). According to the IPCC (2007), synergy refers to the intersection of adaptation and mitigation so that their combined or "co-operative" effect is greater than the sum of effects if implemented separately (Corning, 1998). Trade-offs can be defined as the balancing of factors that cannot be attained at the same time or in combination, involving, for example, pathways to achieve various sustainable development goals (IPCC, 2014; Wiréhn et al., 2020).

There are a growing number of urban adaptation–mitigation interaction examples. Hamin and Gurran focus on interactions related to urban land use planning, noting key factors such as location of development, density, diversity of use, design elements, destination accessibility, and distance to transit (Hamin and Gurran, 2009). McEvoy et al. (2006) discuss the role of density and urban form, where more compact settlements may reduce energy demand and transport emissions but increase the urban heat island (UHI) effect and stormwater-related flooding at the local scale (McEvoy et al., 2006). This raises issues regarding competing demands for high density settlements related to climate change mitigation, e.g., for energy efficiency. In this sense, building vulnerability studies and comparative risk assessments of geophysical and climate-related hazards in multi-risk prone areas can lead to effective synergies for combined structural and energy retrofitting (Turchi et al., 2023). Demuzere et al. (2014) investigate the mitigation, adaptation, sustainability and health benefits of green infrastructure solutions, as well as potential trade-offs such as poorly planned vegetation inhibiting winter passive heating (Demuzere et al., 2014). The UCCRN's *Urban Planning and Urban Design* chapter in the *Second Assessment Report on Climate Change and Cities* (Rosenzweig et al., 2018), highlights urban design and planning strategies that prioritize investments in mitigation strategies that yield concurrent adaptive benefits over those that do not.

Investigations of adaptation-mitigation interactions at the building and infrastructure scales typically fall into three categories: operational energy use and GHG emissions, renewable energy production, and embodied GHG emissions. With respect to energy and GHG emissions, Ortiz et al. (2018) anticipate substantial end-of-century increases in peak cooling energy demand in New York City (Ortiz et al., 2018), while Davis and Gertler (2015) project a significant growth in Mexico's residential electricity consumption due to increased need for cooling by 2100 (Davis and Gertler, 2015). Bartos et al. (2016) model the impacts of rising temperatures on peak electricity demand and transmission capacity, noting that climate change may adversely affect electricity supply by reducing generation and transmission capacity while simultaneously increasing electricity demand (Bartos et al., 2016). Samuelson et al. (2020) demonstrate that many passive design strategies simultaneously reduce GHG emissions, lower heat emissions to the urban environment, and improve the adoption of passive solutions (e.g., shading, natural ventilation, evapotranspiration and evaporative cooling) to reduce heat wave impacts, though some strategies can result in trade-offs.

Several studies have investigated the relationship of renewable energy production and distribution to climate adaptation and resilience (Hussain et al., 2019; Mutani and Todeschi, 2018). Brown et al. (2018) assessed 24 studies proposing 100% renewable electricity systems and concluded that none provided convincing evidence that they met the feasibility criteria for reliability, including resilience to extreme climate events (Brown et al., 2018). Hills et al. (2018) studied off-grid solar electricity systems in two Fiji sites and determined some adaptation and resilience benefits, but noted higher than anticipated fossil fuel-based energy use from backup generators. However, they found that local renewables are inherently more adaptable and resilient as they do not rely on fuel deliveries or transmission grids, offer storage in local microgrids, and thus can better cope with power outages due to climate hazard events.

For adaptation-mitigation interactions associated with embodied carbon, Bocchini et al. (2014) use life cycle assessment (LCA) to compare total primary energy of materials and construction, global warming potential, lifecycle costs, and impact costs of two bridge design options with respect to an earthquake hazard. Plumblee and Klotz (2014) use a similar approach, coining the term "hazard life cycle assessment" (H-LCA), by translating the economic impacts of catastrophe modeling to environmental burdens. Matthews et al. (2016) also use integrated LCA to compare two design options for a house vulnerable to coastal flooding, incorporating the embodied carbon emissions associated with hazard-related repairs in addition to those from the initial construction stage.

Evaluation Criteria			Points
Distribute 200 points amongst the following criteria, allocating more points to criteria with higher priorities, 0 points if not applicable. A minimum 25 points each must be allocated to criteria A1 & M1.			
Climate Adaptation	A1.	Meeting/Leveraging climate adaptation goals	Min. 25
	A2.	Effectiveness to reduce hazard risk	
	A3.	Reliability to be able to function during hazard	
Climate Mitigation & Sustainability	M1.	Meeting/Leveraging climate mitigation and sustainability goals	Min. 25
	M2.	Effectiveness in reducing GHGs	
	M3.	Reliability/ Functionality in reducing emissions	
Technical Requirements	T1.	Simplicity of implementation	
	T2.	Simplicity of management/operations	
	T3.	Durability/ Longevity/ Duration of strategy	
	T4.	Independence from external systems/services	
Project Requirements	P1.	Alignment with other project goals/ requirements	
	P2.	Contributes to occupant health, comfort and well-being	
	P3.	Redresses current inequities or improves equity	
Direct Costs	C1.	Minimizes additional design costs	
	C2.	Minimizes additional construction costs	
	C3.	Minimizes total project costs	
	C4.	Minimizes operations & maintenance costs	
Indirect Costs & Benefits	I1.	Low opportunity costs	
	I2.	Avoids hazard-related costs (avoided costs or losses)	
	I3.	Low indirect costs (displacement, emergency management, health costs)	
	I4.	High resilience dividends & value-added	
Other	O1.	Other criteria (defined by team)	
	O2.	Other criteria (defined by team)	
	O3.	Other criteria (defined by team)	
		Total	200

Fig. 2. *Example of IBAMA evaluation criteria and example of diagram reflecting proposed building-scale strategies for compounding hazard of extreme heat and wildfire smoke event* (source: Judah, 2020).

Urban Climate Justice Dimensions

Worldwide urban settlements are attempting to face the climate crisis developing adaptation plans and climate-responsive urban policies that often tends to overlook structural patterns of inequitable development even if nurtured by justice objectives (Shokry et al., 2022; Amorim-Maia, 2022).

Justice in climate action is understood as constituted by three folded dimensions: procedural, distributive, and recognitional justices (Foster et al., 2019; IPCC, 2022). Recently, restorative justice as a fourth dimension has been introduced as complementary to these three dimensions (Juhola et al., 2022). An emerging body of literature is focusing on how these four dimensions are understood and embedded in climate resilient planning (Mohat et al., 2022; Anguelovski et al., 2020; Hughes and Hoffman, 2020). Planning and design are called to tackle these dimensions by developing multi-scale and multi-stakeholder processes highlighting the justice outcomes of proposed spatial transformations.

Despite there being no evidence on methods and tools for clearly achieving this objective on the ground, some considerations can be built up from literature about how spatial disciplines can encompass more equitable and just results (Hughes and Hoffman 2020; Klinsky and Mavrogianni, 2020), outlined in Table 3 of the Element.

Participatory processes have been widely promoted within urban climate resilience planning for their capacity to enhance bi-directional communication, tackle systemic societal inequalities, build individual and societal capital, reduce unintended consequences, and build community trust and community capacity through engagement (Nost, 2019; Satorras et al., 2020). However, literature has identified a gap between theory and practice and the need to reframe climate governance mechanisms towards more inclusiveness and co-production (Satorras et al., 2020; Williams and Jacob, 2021).

Table 2. *The role of culture in developing urban strategies for climate adaptation*

The role of culture in identifying urban strategies for climate adaptation

As urban solutions are being shared and mainstreamed worldwide, the ability to successfully adapt planning and design examples to different contexts has become crucial. This is essential not only to ensure the successful implementation of climate action in urban settings but also to account for the diverse communities that exist in local contexts. Culture relates to climate and environmental justice because “all understandings of the environment are politicized and are framed by broader power relations and political-economic structures and processes” (Leck, 2017, p298). In this sense, cultural knowledge that comes from historically oppressed groups or individuals can be systematically ignored in adaptation and mitigation strategies. It also points out that groups in power positions need to actively include culture in the climate change narrative, as it becomes a valuable tool for promoting climate and environmental justice.

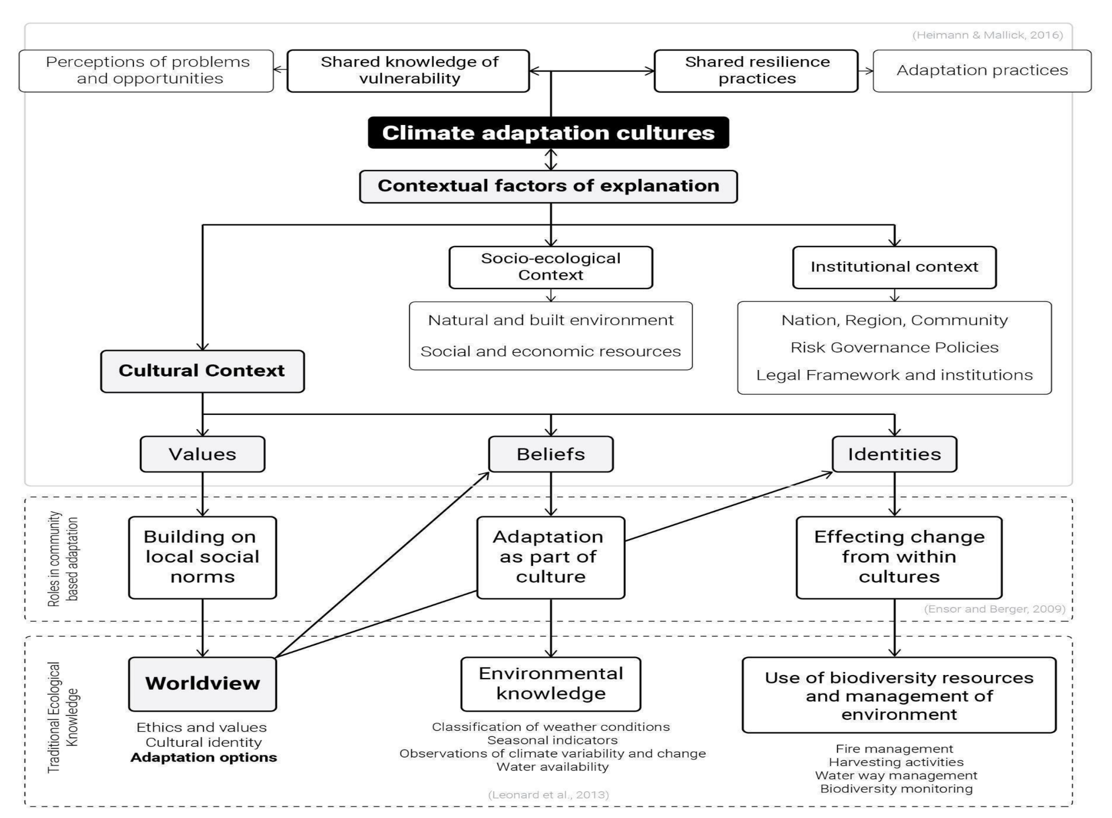
In terms of urban planning and design, culture is specifically important because spatial places are relevant in the way in which groups and individuals self-identify (Heimann & Mallick, 2016). Moreover, the identity of social groups can be related to spatial elements from their surroundings like water sources, landscape elements, or native ecosystems. As climate adaptation is related to relocating communities or changing conditions concerning land or water sources, culture can inform why certain groups may prefer different adaptation strategies (Heimann & Mallick, 2016). Since culture can also exist and change at different scales (Leck, 2017), it is important to consider it in the different scales of urban planning in climate adaptation strategies.

When considering the specific approach to culture as a “shared knowledge” of climate change, there are two different sub-forms of knowledge, shared knowledge of vulnerability and shared knowledge of resilience (Heimann & Mallick, 2016). The first one relates to how communities perceive the opportunities and problems that are related to climate change (Heimann & Mallick, 2016). The second relates to practices that communities may have in place that are associated with resilience strategies (Heimann & Mallick, 2016). Both types of knowledge can act as lenses that frame and inform how communities act and adapt to climate change, which in turn are connected with their livelihoods and traditions (Leck, 2017). Being aware of both is imperative to propose adequate urban planning considerations to different communities and contexts.

Implementation of adaptation strategies within different cultures

Establishing “best-practices” for adaptation doesn’t usually account for cultural differences, which explains why strategies from the Global North can meet restrictions and challenges when implemented in the Global South, and all the way around (Heimann & Mallick, 2016). To think of adaptation measures in a global setting, that can be easily transferable and shared worldwide, it is necessary to consider cultural, ecological, and institutional contexts (Heimann & Mallick, 2016; Ensor and Berger, 2009). To this point, adaptation strategies shouldn't be imposed from the outside, or different contexts, but rather have the complete engagement of communities to drive adaptation action from within culture, rather than from without it (Ensor and Berger, 2009). From a planning and design perspective, this entails adapting best practices from cities with diverse cultural contexts to local solutions. This involves considering stakeholder and community engagement processes through a cultural lens when adapting these solutions.

This approach promotes a productive role of culture (Ensor and Berger, 2009), where shared knowledge from communities and groups defines the opportunities for adaptation, predicts best practices and success stories, and builds resilience from local cultures (Ensor and Berger, 2009). Consequently, culture can provide a series of habits, skills, and styles (Leck, 2017), that can create an “adaptation driven by culture” toolkit. Opposed to this is the fact that considering adaptation strategies without addressing socio-cultural beliefs can lead to ineffective and resisted policies, and maladaptation (Leck, 2017).



Traditional Ecological Knowledge in Urban Planning and Design (TEK)

Traditional ecological knowledge is understood as the “knowledge of the environment that is derived from experience and traditions particular to a specific group of people” (Leonard et al., 2013, p.2). Although TEK is usually associated with ancestral communities, it can be attributed to groups and communities that have historical continuity in a particular environment, with particular resource use (Leonard et al., 2013). In the context of TEK, people’s resilience is permeated by local social networks or traditional community structures that constitute the “social capital” for adaptation (Heimann & Mallick, 2016).

To understand how TEK can inform climate change and adaptations strategies, it can be divided into three categories (Leonard et al., 2013): Environmental knowledge, the use of biodiversity resources and environmental management, and knowledge associated with worldviews (Leonard et al., 2013). Each TEK category informs different processes associated with climate change planning and adaptation.

When including TEK (Traditional Ecological Knowledge) in urban planning and design, especially in a climate resilient perspective, it is possible to gather specific information for implementation associated with the traditions of the communities that will be affected by the various proposed interventions. In this regard, it is feasible to design community engagement based on the different categories of TEK. For diagnostic and planning purposes, efforts can be focused on environmental knowledge, which relates to seasonal indicators, water availability, and, in general, various observations of climate variability and change (Leonard et al., 2013). For Monitoring, Evaluation, and Learning (MEL), it is important to consider the use of biodiversity resources and environmental management to ensure the long-term sustainability of the interventions. Finally, the worldview should serve as the framework in which we test adaptation solutions for different communities, understanding how their cultural identity interacts with their ethics and values concerning urban climate action (Leonard et al., 2013).

It is necessary to improve the knowledge base for climate change adaptation projects, incorporating traditional and ancestral knowledge of local communities on the functioning of ecosystems and nature-society interaction. This will help ensure that knowledge holders participate in assessments, decision making, implementation, and management.

Social Technology: solution based on empowering and emancipatory processes of vulnerable communities

A reference of participatory process and recognitional equity based on popular practices and knowledge that has been applied to reduce socio-climatic vulnerabilities, especially in Latin America, is the social technology. Defined as re-applicable products, techniques or methodologies, developed in interaction with the community and appropriated by it, which represent effective solutions for social transformation to improve living conditions and social inclusion (ITS, 2004; Dagnino, 2011; Pozzebon, 2015; FBB, 2021). The social technology movement gains strength at the beginning of the 21st century in Brazil, as a sociotechnical reconfiguration movement that redesigns scientific and technological knowledge according to the interests of the social groups involved and that defends that social transformation is only effective with the action and the real appropriation of technology by individuals and communities directly affected by the problem, prioritizing the process and not the product (ITS, 2004; Dagnino, 2014; Pozzebon, 2015).

Technology can be classified as social when it proposes to act on a social problem and its values are informed by the development of society not the market, when it is developed based on the needs and interests of local communities, lived and identified by them, considers the knowledge of the actors directly affected by the problem and when it includes emancipatory and self-management processes and promotes appropriation, engagement, empowerment and autonomy of individuals and communities (Neder, 2011; Dagnino, 2014; Pozzebon, 2015; Addor, 2021). They are alternative technologies to conventional technology, sustainable and low-cost, appropriate to the principles of solidarity economy and social justice (Dagnino, 2014). It can be considered as a social-individual-that-adapts, based on popular know-how (Neder, 2011) and on the ecology of knowledge (Santos, 2007), whose proposal is to break with the hierarchy of knowledge, based on the dialogue between scientific, technical, popular, local and ancestral knowledge (ITS, 2004).

In social technology, technology is inseparable from the culture of the social individual that gives rise to it (Neder, 2011; Pozzebon, 2015). The incorporation of individual and community knowledge and their interaction with the technicians and researchers involved is decisive for social practice. Within this interaction there are three inseparable principles: the formative experience – formation through the day-to-day experience of social individuals as learning and training; technological culture – treated as a process of socio-technical adequacy; and the self-organization of social individuals – understood as a space for the construction of appropriate methods of self-management by the social groups involved (Neder, 2011).

The development of urban climate change adaptation and mitigation solutions based at the field of social technology are able to contribute to greater resilience of urban marginalized communities to respond to crisis contexts (Figueiredo and Perkins, 2013; Ventura et al. 2013; Addor, 2021), as well as promoting justice for those most vulnerable to its impact .Social technology can be identified in solutions for urban climate change adaptation, as well as being included in urban planning and design actions, such as: in the development of popular plan of urbanization and land regularization for informal settlements (Figueiredo et al. 2019); in urban co-design such as those developed in Brazilian favelas to qualify open spaces (Montuori et al., 2017); the self-management in social housing, highlighting experiences of social production of housing by urban social movements in Brazil led by the National Movement for the Fight for Housing, present in 17 states across the country (Ferreira and Pereira, 2008); for food security, such as popular urban agroecological practices, as in the cases developed in urban peripheries and slums in São Paulo and Rio de Janeiro, Brazil (Levidow et al. 2021) for water security and access to water, as in the application of cistern systems in the Brazilian Semiarid region (Ventura et al. 2013); or for disaster risk reduction (DRR), such as community-based early warning systems (EWS), as in the cases for floods and landslides in São Paulo, Brazil (Marchezini et al,. 2017).

Other terms also dispute the epistemological field of social transformation through the appropriation of technology and social inclusion, such as social innovation and grassroots innovation, , which in general mean a network of activists and organizations that generate new bottom-up solutions for sustainable development and sustainable consumption that respond to the local situation and the interests and values of the communities involved (Smith & Seyfang, 2013; Hossain, 2016). But they differ from social technology mainly due to the absence of the counter-hegemonic political-social character present at the origin of the post-colonial Latin American social technology movement and the efficiency paradigm related to innovation associated with market logic. Pozzebon (2015) defends the use of the term *tecnologia social* in its native language (portuguese) to reinforce its status as a concept developed by South American researchers and professionals that deserves to be better known in the North Global.

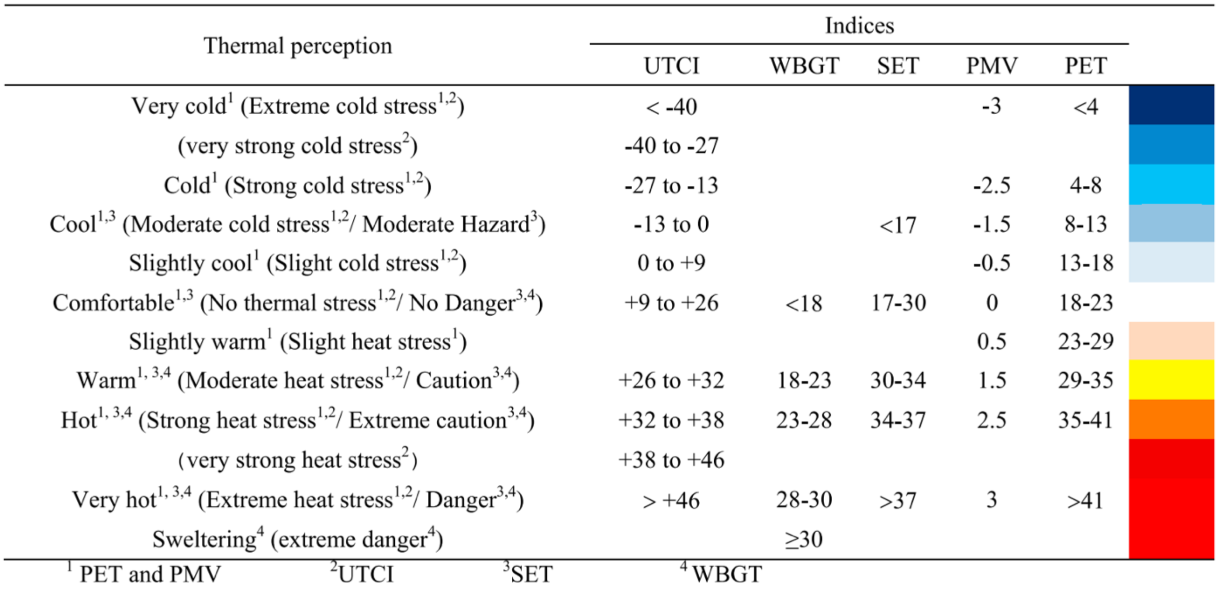
The development of urban climate change adaptation and mitigation solutions that are structured on the methodological bases proposed by the field of social technology are able to contribute to greater resilience of urban marginalized communities to respond to crisis contexts (Figueiredo and Perkins, 2013; Ventura et al., 2013; Addor, 2021), as well as promoting justice for those most vulnerable to its impact, by placing people at the center of solutions and incorporating inclusive, emancipatory and empowerment processes, capable of strengthening minority bases and reformulating relationships of power (Heimann and Mallick, 2016; Robinson, 2018).

Table 6 City Climate Plans with Participatory Processes for Urban Climate Planning

City Climate Plan	Participatory Process Implemented

New York's participatory budgeting process (myPB) (USA)	Facilitation process for investment of more than $200 million in 700 community-designed projects (C40 Cities, 2019)
Minnesota Climate Action Plan (USA)	Environmental justice groups in Minneapolis organized for nine months from 2011-2012 to ensure equity and inclusion in the plan (Gonzalez et al., 2017)
CityAdapt Project, San Salvador, El Salvador, and Xalapa (MEXICO)	Project funded by GEF and implemented by the United Nations, which developed climate adaptation plans for San Salvador, El Salvador, and Xalapa, Mexico. The project involved: working hand-in-hand with communities to identify vulnerability hot spots; conducting participatory workshops to identify possible and necessary actions; conducting workshops to validate the portfolio of actions; presenting results to the different decision-makers to ensure support and; creating a monitoring and evaluation system in collaboration with the communities (PNUMA, 2021).
Barcelona Climate Plan (SPAIN)	Plan elaborated through a process referred to as "co-production" with citizens, which consisted of three phases (Satorras, et al., 2020). 1) Collecting proposals from citizens through face-to-face workshops, self-organized sessions, and the digital platform Decidim. 2) Validation and prioritization of the proposals. The municipality organized face-to-face workshops where the proposals were presented. 3) Evaluation and acceptance or rejection of the proposals. The reasons for the decision were posted on the Decidim platform.
Sustainable Sydney 2030 Strategy (AUSTRALIA)	Plan developed and tested through a citizen's panel of 30 representative community members (C40 Cities, 2019).
Greenpoint and Williamsburg neighborhoods in Brooklyn, New York (USA)	Residents partnered with the U.S. EPA to develop strategies for understanding their exposure to multiple pollutants and ways to address their risks (Urban Sustainability Directors Network, 2017).
Sustainable Food Production for a resilient Rosario (ARGENTINA)	The program repurposed under-utilized land for urban and peri-urban agriculture to improve food security, provide nutrition to low-income residents, and strengthen resilience to flood and extreme heat (Amorim-Maia et al., 2022).
Manhattan Climate Action Plan."- WE ACT, New York (USA)	The plan results from six months of planning in community forums throughout the borough. It promotes environmental policies and justice through four pillars: energy democracy, emergency preparedness, social hubs, and participatory governance (Gonzalez et al., 2017)
Detroit Climate Action Collaborative (DCAC) (USA)	The action prioritized community involvement as a key aspect of the plan's formulation, incorporating local insights and increasing climate change awareness in Detroit. To achieve this, a range of activities were organized such as focus sessions involving various stakeholders, a local climate conference, targeted consultations with commercial and religious groups, an open feedback mechanism concerning the CAP, a community questionnaire, and documentary films. The process led to the creation of the Detroit Climate Ambassadors program, a resident-led effort to educate, prepare, and tackle climate change in neighborhoods (Hughes, 2020).
Cleveland Climate Action Plan (USA)	Cleveland undertook a year-long community engagement process for developing its 2018 CAP Update. 300 residents participated in 12 neighborhood workshops, and the city received more than 200 comments during the public comment period. A Climate Action Advisory Committee was created with more than 90 members that include representatives from business, churches, academia, NGOs, the city, the county, community organizations, foundations, and Ohio Sea Grant (Hughes, 2020).

Climate Resilient Cities in Latin America Initiative, Dosquebradas, (Colombia); Santa Ana, (El Salvador); and Santo Tomé (Argentina)	This project sought to develop a practical way to integrate stakeholders into the decision-making process using specific tools. These tools were the QUICKScan methodology and decision-support toolbox developed by Wageningen Environmental Research (WEnR/Alterra) and the European Environmental Agency (EEA). The QUICKScan methodology has been implemented to integrate different data, knowledge bases and perspectives, and needs of stakeholders. The stakeholder engagement was carried on creating a Climate Resilient Cities Initiative platform and workshops with stakeholder mapping, interviews, policy recommendations, and capacity development (Hardoy et al., 2019)
City-Wide Disaster Preparedness and Community Resiliency Plan, City of Cambridge Alewife (USA)	A Participatory Action Research model was used to gather local knowledge from Alewife's low-income families and service providers on the city's disaster preparedness and resilience programs. Through focus groups and interviews, a Local Perceptions Report was created to inform development of the City-Wide Disaster Preparedness and Community Resiliency Plan (Douglas et al., 2018).
Paris “Oasis Schools” and Barcelona “Escuelas refugios climaticos”	Community-based projects to retrofit schools as climate shelters. Schools as a neighborhood scale infrastructure are considered a hotspot for climate adaptation becoming a community hub. From pilot projects, these initiatives turned in urban policies based on collaborative design processes with the local community.



Thermal perception	UTCI	WBGT	SET	PMV	PET
Very cold[1] (Extreme cold stress[1,2])	< -40			-3	<4
(very strong cold stress[2])	-40 to -27				
Cold[1] (Strong cold stress[1,2])	-27 to -13			-2.5	4-8
Cool[1,3] (Moderate cold stress[1,2]/ Moderate Hazard[3])	-13 to 0		<17	-1.5	8-13
Slightly cool[1] (Slight cold stress[1,2])	0 to +9			-0.5	13-18
Comfortable[1,3] (No thermal stress[1,2]/ No Danger[3,4])	+9 to +26	<18	17-30	0	18-23
Slightly warm[1] (Slight heat stress[1])				0.5	23-29
Warm[1, 3,4] (Moderate heat stress[1,2]/ Caution[3,4])	+26 to +32	18-23	30-34	1.5	29-35
Hot[1, 3,4] (Strong heat stress[1,2]/ Extreme caution[3,4])	+32 to +38	23-28	34-37	2.5	35-41
(very strong heat stress[2])	+38 to +46				
Very hot[1, 3,4] (Extreme heat stress[1,2]/ Danger[3,4])	> +46	28-30	>37	3	>41
Sweltering[4] (extreme danger[4])		≥30			

[1] PET and PMV [2]UTCI [3]SET [4]WBGT

Figure 3. *Comparing thermal perceptions in various bioclimatic indices*
(source: Zare et al., 2018).

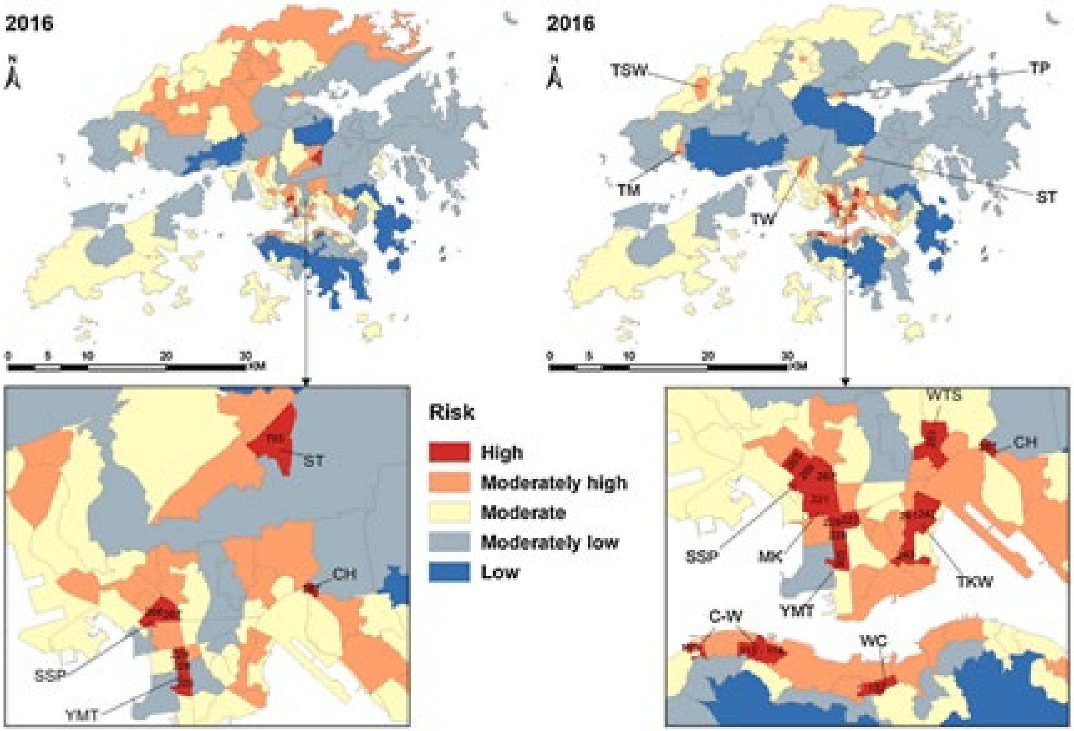


Figure 4. *Spatial distribution of heat vulnerability levels in Hong Kong, 2016*
(source: Hua et al., 2021).

List of representative guidelines published in recent years:

- The "Climate Change Policy Guide" issued by APA (American Planning Association) emphasizes planners' roles and responsibilities in framing climate change policies in comprehensive plans, climate action plans, and other long-range planning documents. General policy areas correspond to the six principles (Livable Built Environment, Harmony with Nature, Resilient Economy, Interwoven Equity, Healthy Communities and Responsible Regionalism) established by APA's Comprehensive Plan Standards for Sustaining Places, which organize the range of topics and issues planners address in their work into an integrated framework.

- Practical guideline of Climate protection in spatial plans-design possibilities of regional plans and urban plans (Klimaschutz in der räumlichen Planung-Gestaltungsmöglichkeiten der Raumordnung und Bauleitplanung) were issued by Federal Environment Agency of Germany. This report introduces regulatory requirements of German climate protection policy on space planning and explores strategic focus of climate protection policy in the four spatial planning dimensions of land use, energy, transportation and architecture from the federal, state, regional and local levels (Ahlehelm et al., 2013).

- The Low Carbon City Development Program (LCCDP) guidebook published by the World Bank in 2014 aims to help city and urban practitioners in designing and implementing a Low Carbon City Development Program and to plan, implement, monitor and account for low carbon investments and climate change mitigation actions across all sectors over time (Barrios et al., 2014).

- The "Climate Resiliency Design Guidelines" were developed by the New York Mayor's Office of Resiliency, in collaboration with city agencies to regulate design codes and standards to respond to challenges from climate change, including the risk of heat waves, increasing precipitation, and sea level rise (NYC Mayor's Office of Recovery & Resiliency, 2018). The updated version was published in September 2020. Apart from recommendations for efficient, resilience design, a series of toolkits about exposure screening, risk assessment, and benefit-cost analysis are introduced to provide detailed instruction on how to supplement historic climate data with specific, regional, forward-looking climate change projections for incorporation into the design of City facilities (Figure 16).

- In the subtropical city of Hong Kong, the main challenge addressed by local researchers and administrators is the extreme heat events and thermal discomfort during the hot humid and long-term summer season (Environment Bureau Hong Kong, 2017). Meanwhile, the living environment is further deteriorated by its high-density morphology. Based on the scientific understanding that thermal comfort can be achieved by enhancing natural ventilation (Ng and Cheng, 2012), an Air Ventilation Assessment (AVA) System was introduced in 2006 for a better urban living (Ng, 2009). Recently, a design guidebook on urban microclimate design was published in 2017 by Hong Kong Green Building Council (HKGBC, 2017) providing a summary of feasible approaches to improve the city's environment through urban and building design.

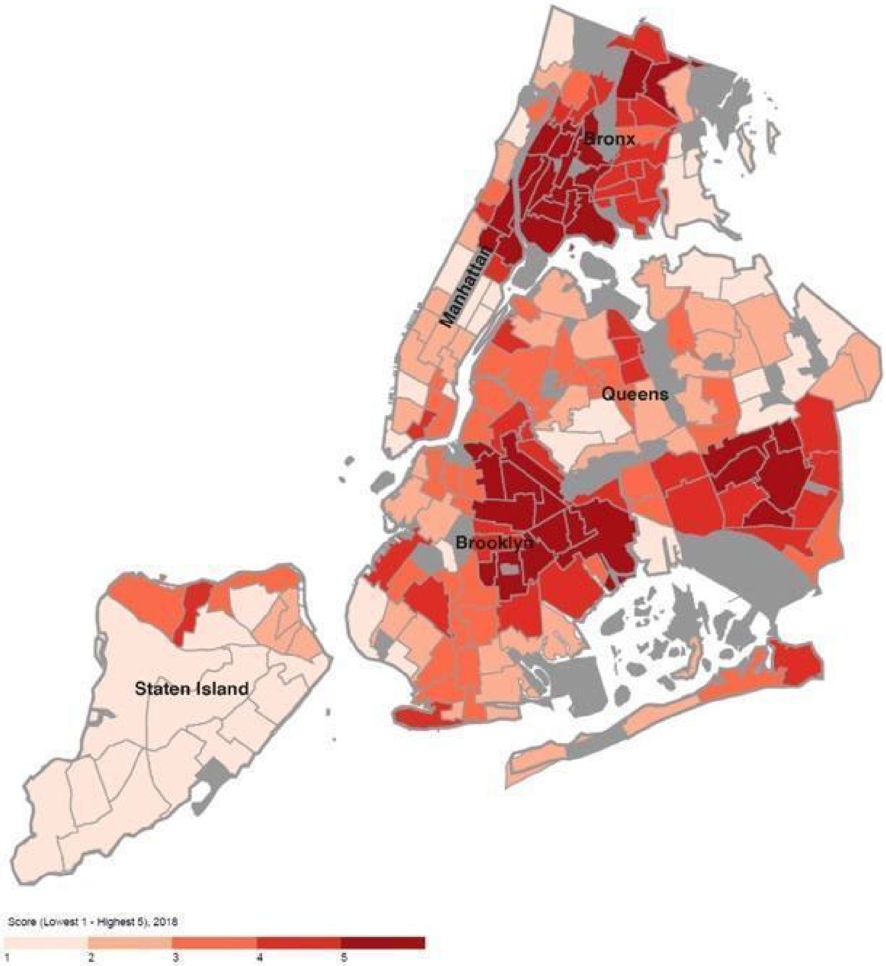


Figure 5. *Heat Vulnerability Index (HVI) for New York City Neighborhood Tabulation Areas (NTA). This analysis identifies physical, social, and economic factors associated with increased*

risk of heat-related morbidity and mortality (source: NYC Mayor's Office of Recovery & Resiliency, 2018), data available at https://data.cityofnewyork.us.

Many mega cities in mainland China are facing severe air pollution issues, as measured by PM2.5 (i.e. fine particles less than 2.5 micrometers in diameter, posing the greatest risk to health among air pollutants for their ability to penetrate lung alveoli and blood system), especially in winter. Wind channels and ventilation corridors at city and district scales can have a significant effect on ameliorating the impact of PM2.5. In recent years, a series of planning actions and standards were published by national and local governments to regulate urban development and design practices (Ren et al., 2018).

Table 3. *Climate change capacity-building resources for built environment professionals.*

Sector	Author	Tool type	Title	Description (level of application*)
Built environment	Cross Industry Action Group (CIAG)	Curriculum and continuing professional development resource	*Climate Framework* (CIAG 2021)	As described by CIAG (2023a) this is a curriculum framework for actors across the built environment to facilitate the development of climate change knowledge and skills. For built environment professionals across a range of current knowledge and skill levels. (Individual)
	Construction Industry Council (CIC)	Climate Change Action Plan	*Carbon Zero: the professional institutions' climate action plan* (CIC, 2021)	A plan to address the climate change and biodiversity emergencies and deliver on net zero across professional institutions and organizations in the UK property and construction industries. Follows their 2020 declaration of a climate change and biodiversity emergency and 2019 commitment to respond to the UK 2050 net zero carbon emissions target. Identified 10 actions ranging from education and qualifications to standards and regulations, to application, ethics and advocacy.
	CIAG – with links to various actors	Repository	*Cliamte Framework Library* (CIAG, 2023b)	Repository of resources to facilitate climate change action and capacity building for built environment professionals. (Individual)
	Royal	Practice	*RIBA Climate*	Provides built environment professionals, with key

	Institute of British Architects (RIBA)	Guide	*Guide* (Hasman, 2023)	information on how to stop climate change and adapt to its impacts in their day-to-day work. (Institutional)
Urban Planning	United Nations Human Settlement Program (UN-HABITAT)	Practice Guide	*Planning for Climate Change* (UN-HABITAT, 2014)	Was developed as a guide for urban planners and other urban professionals (particularly in low and middle-income countries) to understand, assess and take action on climate change – at the local level. (Individual; Institutional)
	Planners for Climate Action (P4CA)	Repository	*Climate Action Resources* (P4CA, 2023a)	Information and publications related to climate action in cities, and involving urban planning. (Individual; Institutional)
	P4CA	Curriculum	*P4CA and Uni Course Manual Repository* (P4CA, 2023b)	A repository of climate change related urban planning university course manuals. (Individual)
	American Planning Association (APA)	Practice Guide	*Climate Change Policy Guide* (Angus et al., 2020)	A policy guide identifying solutions to climate change for local, state and federal urban planning policy makers. Also intended to assist in formulating position statements, legislative recommendations and program funding. (Systemic)
	RTPI & TCPA (UK)	Practice Guide	*The Climate Crisis A Guide for Local Authorities on Planning for Climate Change 2021 (4th Ed, 2023)*	This guide is intended as an introduction to some of the key issues. It is a starting point on the vital journey to put in place practical solutions to counter outcomes of climate change having severe impacts on the most vulnerable. The 4th edition includes technical updates to reflect the latest evidence and practice, as well as revised national policy and guidance.
	Designing Buildings	Repository	Designing Buildings Wiki	The repository gives free access to 14,500 articles about planning, design, construction and operation of built assets. It is curated, structured and linked together to create a single, growing, evolving resource. 26,000 construction terms and industry acronyms are defined, internal links help get to the knowledge as quickly as possible.
	APA	Practice Guide	*Planning for climate mitigation and adaptation* (Bucchin and Tuley, 2022)	Provides information and tools for urban planners to lead community responses to climate change. Provides guidance on climate change adaptation and mitigation for planners. (Individual; Institutional)
Landscape Architecture	International Federation of Landscape Architects (IFLA)	Principles to guide practice	*IFLA Global Accord – adaptation for a changing world* (IFLA, 2017)	In recognition of the challenge of climate change, the accord establishes three guiding principles to assist decision making in practice, particularly with consideration of future generations: resilient, transformative, sustainable. (Institutional)
	IFLA	Position statement and call for action	*IFLA Climate ACTION! 2019-2021*	Articulates a plan for engagement with members, partners and colleagues in allied built environment professionals to facilitate action on climate change. (Institutional;

			(IFLA, 2019)	Systematic)
Architecture	Royal Danish Academy – Architecture Design Conservation and the International Union of Architects (UIA)	Practice guide	*An Architecture Guide to the UN 17 Sustainable Development Goals Volume 2,* (2020).	A guide to the UN SDGs for architects and other built environment professionals, and to showcase examples of implemented projects - with goal 13 addressing climate change explicitly. (Institutional)
	RIBA	Voluntary performance targets	*RIBA 2030 Climate Challenge.* First published in 2019, updated in 2021 (RIBA, 2021a)	Articulates voluntary performance targets (operational energy and water use, and embodied carbon), for RIBA Chartered Practices to aim towards. Were developed in consultation with other built environment professional associations. Additional resources to support implementation are provided: https://www.architecture.com/about/policy/climate-action/2030-climate-challenge/resources (Institutional; Systematic)
	RIBA	Professional competency	*Climate Literacy Mandatory Competency* (RIBA 2021b)	Articulates a mandatory competency for architects to be competent to practice. Is part of a wider set of Mandatory competencies under *Way Ahead: The RIBA Education and Professional Development Framework* (RIBA 2021c). Current and future members will need to undertake and pass the assessment as part of their membership renewal. (Individual)

How/Modalities

Capacity Building tools are crucial in climate change policies/actions, but ineffective if not correctly integrated in the planning and design process. Capacity building tools may be clustered into two main categories: tools for awareness and knowledge improvement for the diffusion of urban climate change in large social-cultural landscapes, and tools for capacity enhancement to enable and improve the implementation, realisation, stabilisation of urban climate change polices, actions, and initiatives. The following subsections introduce the core concepts at the base of such tools.

Tools for awareness and knowledge improvement

Tools for improving awareness aim to increase cultural understanding of climate change challenges, reach a wide range of diverse groups, and ultimately encourage transformational behavior of citizens and local communities (Colucci, 2018). Tools for improving knowledge are mostly connected to the dissemination of climate change information (e.g., on its causes, impacts, and solutions, see section 10), including the mapping of expected impacts at regional/city level of extreme events and slow-onset variations, embedded in maps and visuals highlighting the effects current/future climate and possible (re)development strategies (e.g. through scenario modelling exercises, see section 10). This involves scientific knowledge transfer and dissemination, including knowledge related to cultural and political spheres. Tools for awareness and knowledge improvement aim to transition socio-cultural modes to more sustainable ones, thus integrating climate change into citizen behavior and political decision-making. For example, a capacity-building tool can improve citizen awareness of the need to adopt more sustainable behavior and provide practical suggestions for reducing the impact of everyday actions (e.g., embracing the transition to slower mobility, renewable energy, water conservation, and sustainable food consumption). Awareness and knowledge tools could be targeted to citizens, community groups, practitioners, and decision-makers.

Tools for enhancement of capacities to enable implementation

Another domain of capacity building is to enable the implementation of climate change policies, strategies, and actions. Here the task is to improve the capacity of cities to manage the implementation of climate change interventions. The target groups are civil society organizations, practitioners, and the technical staff of public and private bodies. These kinds of capacity-building tools provide the skills needed to ensure that climate change policy implementation is a long-term success, coherently integrated in the urban design process from a cross-sectoral perspective (see section 10).

For instance, the Italian Resilience Practices Observatory has documented that the adoption process often activates both capacity-building tool domains. In the first phases of the process, the resilience interventions utilize capacity-building tools to improve the abilities of practitioners to manage the implementation process (e.g., organizational software and other information technologies). Several cities in Italy (see Osservatorio Resilenza) have launched specific initiatives of capacity building aimed at enhancing the skills of targeted stakeholders engaged in the project implementation and goals achievement. Another example of urban resilience practices is in Milan, which launched a project focusing on local sustainable food system improvement. In the project’s first phase, the Practices launched "internal" capacity building activities (NGO members, engaged actors of the partnerships) mainly oriented to improve organizational, ICT or other "missing" capacities in management processes. In the subsequent phases, the Practices activated both capacity building tools to improve the citizen's awareness towards more sustainable food behavior (e.g., orienting the individual purchase towards local sustainable food markets, sustainable diets, etc.) and tools to improve the capacities of local farmers (private actors) in re-organizing the production models, such as local (private/public) markets to sell local products.

Urban Transformation Through an Expanded Climate and Innovation Agenda

Critical barriers to adaptation include limited resources, lack of private sector and citizen engagement, insufficient mobilization of finance, low climate literacy, lack of political commitment, limited research and slow uptake of science, and a low sense of urgency. UNEP (2022) states that estimated adaptation costs in developing countries are five to ten times greater than current public adaptation finance flows. Suppose approaches to addressing the climate emergency remain static and focused only on reducing GHG emissions and optimizing existing systems. In that case, the gap will widen, and inequalities will be worsened.

For example, instead of viewing mobility as simply traveling from one place to another, see it as providing access. When viewed this way, opportunities for urban innovation are opened, such as providing online services and changing approaches to urban design, introducing key concepts like “Mobility as a Service” (MaaS), which provides users access to multiple modes of transportation through one combined platform, and Transit Oriented Development (TOD), a planning approach that mixes land use around transit hubs, as critical components. IPCC AR6 made important contributions to incorporate a view of human flourishing and well-being in climate mitigation by providing services that are low in energy, material or land but high in providing the underpinnings for well-being (Creutzig et al., 2022).

Scaling Sustainable Innovative Solutions Toward Transformative System Change

Despite the climate emergency being a complex and dynamic challenge, most approaches to addressing it are from a static or conservative perspective (Borie et al., 2019). Static approaches aim to optimize and maintain the stability of an existing system by building upon previous iterations through gradual improvements. Static approaches are, therefore, most fitting for conservation efforts and short-term strategies. They are less complex and require less time to develop. However, they do not have the same potential for long-term transformative change or an inbuilt flexibility to adapt to changing conditions indicated via feedback loops. Transformative change challenges the established governance processes and planning mechanisms rather than merely protecting them. Climate change is situated within a complex, heterogeneous, dynamic, and uncertain system in which different components are interconnected and influence each other through human-induced and natural stimuli. In complex systems such as this, static methods are insufficient. They may even lead to maladaptive consequences such as increasing disparities in the ability of people to live flourishing lives and have their needs met.

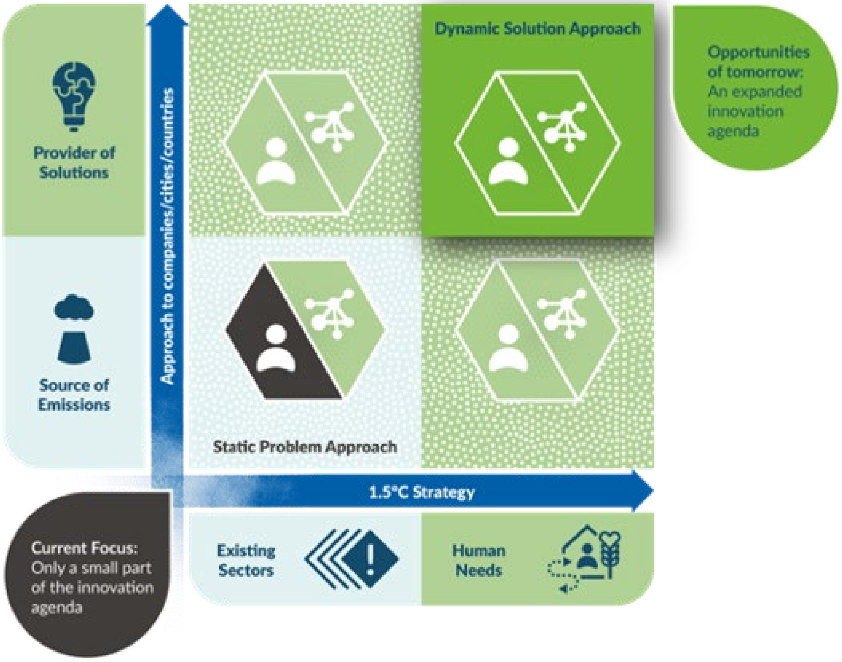


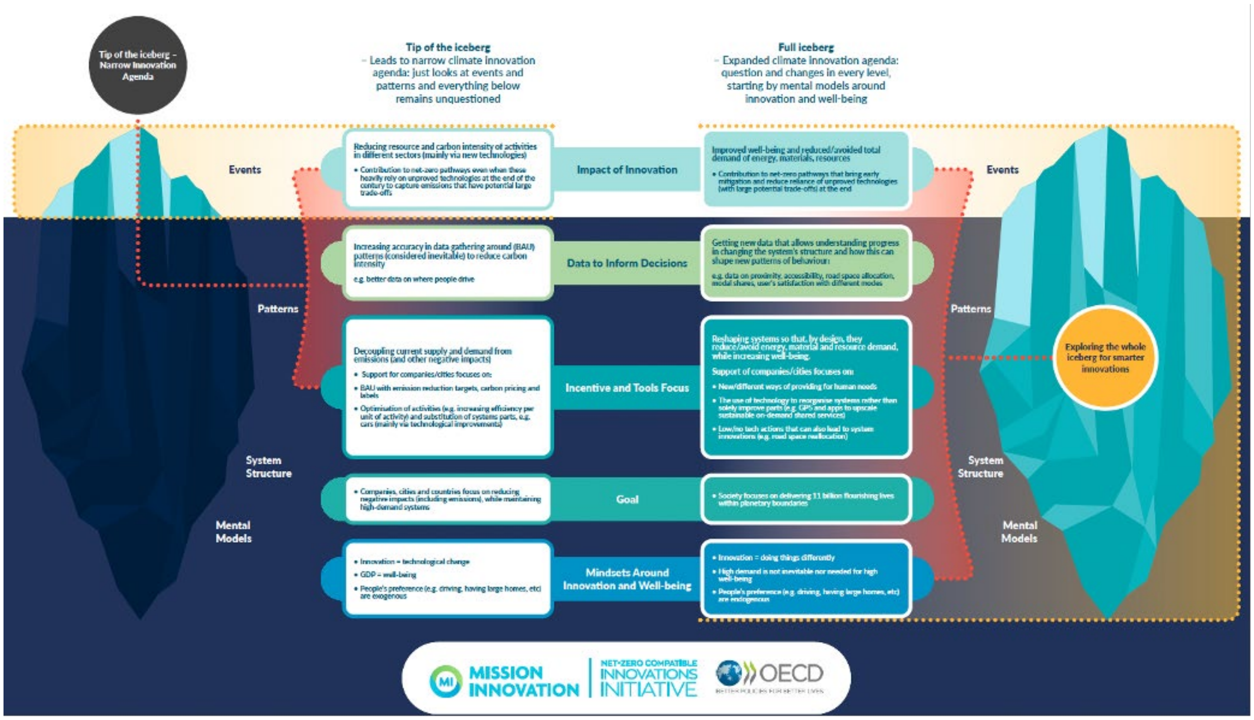
Figure 6. *Static versus dynamic approaches* (source: Mission Innovation, 2023).

Dynamic solutions and innovations are needed to enable non-linear responses that allow for continuous and rapid change and long-term viability (Greiff et al., 2012). Within the context of the ECIA, dynamic solutions refer to solutions that:

1. Address human needs;
2. Leverage technologies of the fourth industrial revolution (e.g., AI and Machine Learning, IoT, Augmented and Virtual Reality, and Big Data);
3. Involve all stakeholders in an innovation ecosystem (e.g., nature-based solutions);
4. Are affordable and inclusive in their implementation;
5. Facilitate solution export and scaling (e.g., experimentation, clustering, and embeddedness).

Current governance and planning capacities are overwhelmed by contemporary challenges' complexity and dynamic nature. Moving from reactive to anticipatory innovation to eventually agenda-setting innovation requires a "full iceberg approach" under which local institutions build the capacity to engage with complexity and identify and address the root causes of issues.

Sustainable solutions leverage systems thinking by using human needs as the guiding principle to achieve climate action and innovation. This is well-illustrated by the iceberg model of systems thinking (Figure 23). Events could be a once-off phenomenon. Patterns and trends determine whether events have repeated and, if so, how and, on the surface, why. Structures and systems look deeper at identifying the factors, processes, and behaviors contributing to the event. At the deepest level are the mental models constituted by beliefs and assumptions that create the environment in which the problem was caused. Within this level are the root causes of the events.



Tip of the iceberg – Leads to narrow climate innovation agenda: just looks at events and patterns and everything below remains unquestioned		**Full iceberg** – Expanded climate innovation agenda: question and changes in every level, starting by mental models around innovation and well-being
Reducing resource and carbon intensity of activities in different sectors (mainly via new technologies) • Contribution to net-zero pathways even when these heavily rely on unproved technologies at the end of the century to capture emissions that have potential large trade-offs	Impact of Innovation	Improved well-being and reduced/avoided total demand of energy, materials, resources • Contribution to net-zero pathways that bring early mitigation and reduce reliance of unproved technologies (with large potential trade-offs) at the end
Increasing accuracy in data gathering around (BAU) patterns (considered inevitable) to reduce carbon intensity e.g. better data on where people drive	Data to Inform Decisions	Getting new data that allows understanding progress in changing the system's structure and how this can shape new patterns of behaviour: e.g. data on proximity, accessibility, road space allocation, modal shares, user's satisfaction with different modes
Decoupling current supply and demand from emissions (and other negative impacts) • Support for companies/cities focuses on: • BAU with emission reduction targets, carbon pricing and labels • Optimisation of activities (e.g. increasing efficiency per unit of activity) and substitution of systems parts, e.g. cars (mainly via technological improvements)	Incentive and Tools Focus	Reshaping systems so that, by design, they reduce/avoid energy, material and resource demand, while increasing well-being. Support of companies/cities focuses on: • New/different ways of providing for human needs • The use of technology to reorganise systems rather than solely improve parts (e.g. GPS and apps to upscale sustainable on-demand shared services) • Low/no tech actions that can also lead to system innovations (e.g. road space reallocation)
• Companies, cities and countries focus on reducing negative impacts (including emissions), while maintaining high-demand systems	Goal	• Society focuses on delivering 11 billion flourishing lives within planetary boundaries
• Innovation = technological change • GDP = well-being • People's preference (e.g. driving, having large homes, etc) are exogenous	Mindsets Around Innovation and Well-being	• Innovation = doing things differently • High demand is not inevitable nor needed for high well-being • People's preference (e.g. driving, having large homes, etc) are endogenous

Figure 7. *The Full Iceberg Model* (source: Mission Innovation).

Currently, the dominant approaches to addressing the problems that we face globally do not engage adequately with systemic complexities. Current approaches are reactive and consider events, patterns, and trends at the surface but do not engage with the complexities of the structural and systemic levels. As a result, many solutions and innovations arising from these approaches address symptoms rather than causes and neglect or exacerbate human needs. The negative effects of these approaches are that they often take a short-term perspective and fail to consider the inter-relationships between different systemic elements, which can lead to maladaptation.

Human needs can be used to guide a systemic approach to understanding issues. Through this process, innovations and solutions can achieve transformative change.Technology is required to move towards transformative change, as well as the expertise to identify the needs of cities and combine the technology with agency, policy, and business models towards a cohesive process of transformative change.

As an example, in the context of urban mobility, a narrow perspective focusing solely on transportation or moving from point A to B would suggest solutions like increasing the use of electric cars and establishing charging infrastructure. This approach is reflected in urban typologies built around dominant transport modes, such as fragmented and sprawling development resulting from unbalanced investment promoting private instead of public transport infrastructure. This approach overlooks the fundamental question: why do people require cars, and what are their actual transportation needs? Moreover, while commendable, the transition to electric vehicles does not address the underlying issue of inefficient infrastructure and utility systems that persist from the era of internal combustion engine vehicles.

A more comprehensive viewpoint involves delving into the human needs that vehicles serve, such as access to nutrition through food availability, access to education, access to healthcare services, or the ability to engage in outdoor activities. Historically, urban planning has often revolved around transport infrastructure, particularly in top-down master planning. This has led to unintended consequences, including the rise of private vehicle usage and urban disinvestment in public transport infrastructure in cities like Cape Town, South Africa (Mitchell, 2014). Such planning has also contributed to fragmented, sprawling development that hinders access to essential public amenities.

A new direction involves utilizing innovative big data and machine learning technologies supporting geographically differentiated and spatially contextualized measures for climate-resilient cities to direct urban planning and design to human flourishing and well-being for all, by upscaling geographically differentiated solutions in urban areas and providing tailored solutions for decarbonizing cities worldwide (Milojevic-Dupont and Creutzig, 2021).

Many innovative possibilities emerge when we reframe critical urban systems such as energy and transportation in terms of its fundamental purpose, i.e., facilitating 'access' to human needs. By considering urban subsystems as a means to fulfill various human needs, we can envision a more holistic and efficient urban future.

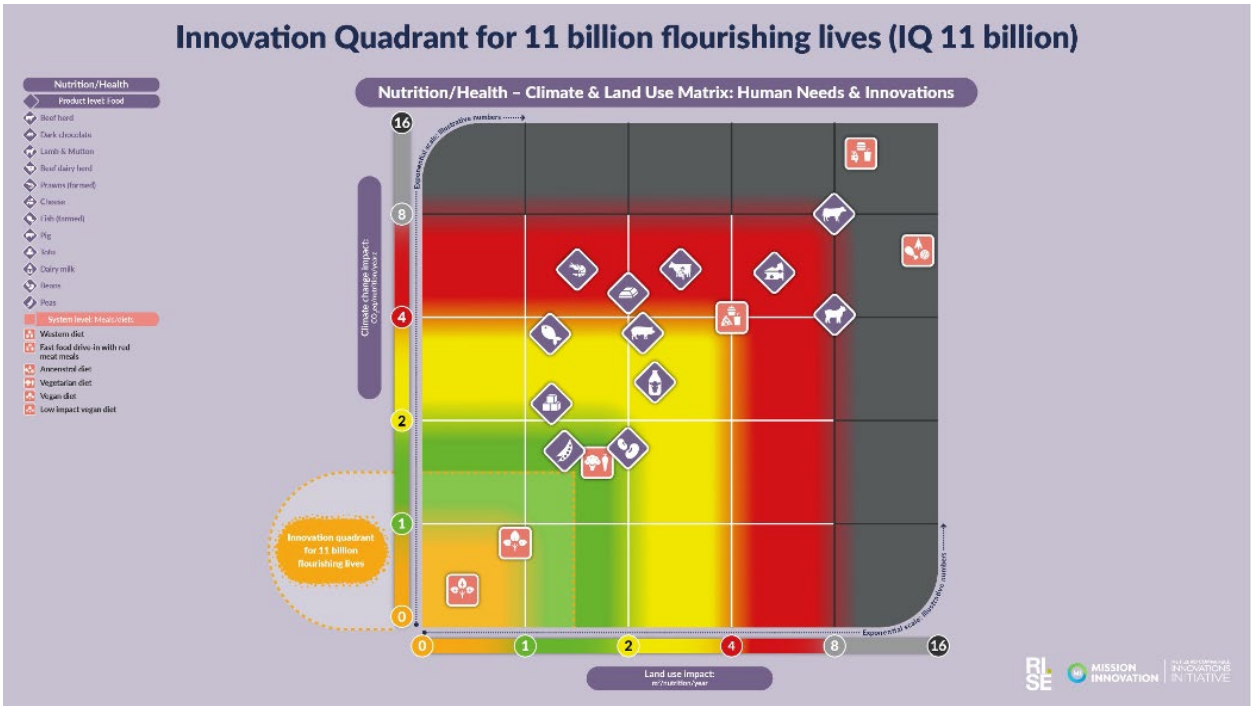


Figure 8. *Innovation quadrant for 11 billion flourishing lives: moving from improving products to delivering new system solutions* (source: Mission Innovation NCI).

Table 4. Steps, methods and activities of the UDCW's phase "Stakeholder Priorities".

Step	**Methods/Activities**
Workshop Preparation and Introductory Session	Regionally to locally downscaled climate change scenarios (including both seasonal variations of temperature/precipitation and frequency/intensity of extreme events under different SSPs/RCPs and timeframes); extensive research and mapping demographics, community activity nodes, culture, land uses, urban systems and climate vulnerabilities are undertaken prior to the workshop. Products include local climate/population profile and projections, adjacencies and synergies between User Groups and Urban Systems. In the UDCW introductory session the organizers briefly introduce the topic of climate mitigation and adaptation in broad terms, illustrated by a large board with four Urban Climate Factors. The local hosts (local authorities, practitioners' teams, community organizations) present the relevant urban plans and projects in the study area, providing official documentation based on actual ongoing programs and initiatives.
Priorities mapping session	A stakeholder breakout session follows, where tables led by facilitators are asked to discuss and generate lists of priorities; not specifically related to climate, sustainability, or resilience. Job creation, public health, access to services, transportation, affordable housing, crime, open space, quality of life are just some of the themes emerging from past workshops. Provided with sticky notes, participants write each priority to a note for later use.
Study Area Borders and Site Visit session	Determining the Study Area borders is a stakeholder-led process comprising multiple factors. The study area could be established by neighborhood fabric or community character, natural systems or watersheds; and a mix of urban conditions, infrastructure, land uses and urban policy priorities. A site visit, led by local hosts, helps to acquire direct information and deepen relevant topics emerging from the introductory session. The site visit can be designed as an "urban climate walk" (Mills et al., 2018) to link the personal experience of micro-climates in cities to the urban climate effect, so to get participants to be aware of the impacts that cities have on climate at all scales (local to global) by using human senses to detect, analyse and interpret these impacts.
Climate Session	The UDCW organizers describe factors driving local climate, from heat to flooding to GHG emissions linking those to the specificity of Urban Climate Factors in the study area. Using the Urban Climate Factors board as illustration, the organizers work with Stakeholders to "connect the dots" between community priorities not specifically linked to factors driving urban climate. Relevant climate hazard/impact maps developed during the preparatory step are used. An example would be the human and financial cost of hospitalizations due to heat waves (Figure 27).
Evaluating Win-Win Synergies	Stakeholders take their Priorities Notes to the large Urban Climate Factors board and discuss the relationship between each Priority and Urban Climate Factors (Win-Win Synergies, Figure 28). The Value Proposition for Climate Resilient Urban Transformation section analyzes these

	returns on climate-resilient urban transformation investments in the broad sense of the term. In past workshops some examples were: a robust network of energy-efficient public transit supports access regional employment opportunities (linked to 1. Efficiency of Urban Systems); job training to retrofit existing building envelopes for climate-aware energy retrofitting (3. Building Envelope and Surface Materials); building linear parks to connect urban nodes with non-motorized transport, while cooling streets and absorbing stormwater (4. Green and Blue Infrastructure). Through this knowledge-sharing process, climate science evidence and community priorities are intertwined within the proposed planning and design scenarios.
Collaborative Mapping	The synergies between Community Priorities and Urban Climate Factors are mapped in consideration of key social, economic, and environmental drivers. The mapping process is initially analogue to simplify interactions between community and technical expert participants. This process is then integrated into digital mapping and simulation tools to overlap community priorities and city-wide sustainable and climate-resilient city visions with urban design strategies.

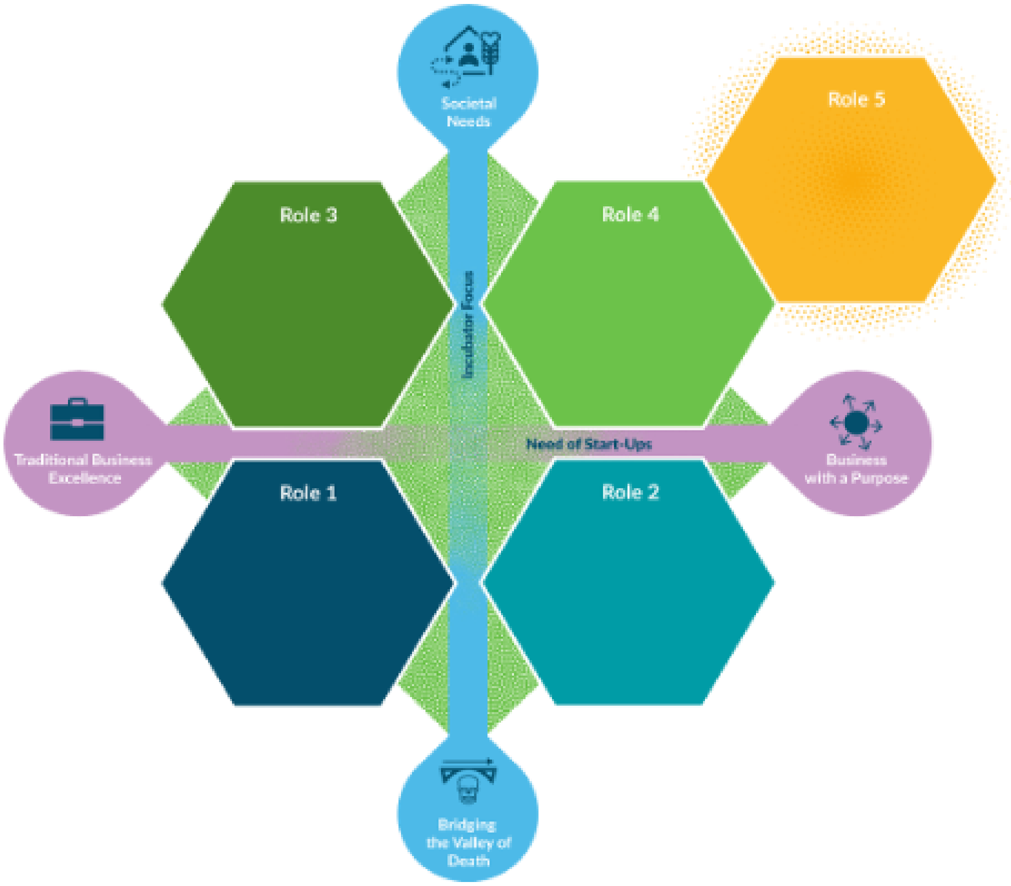


Figure 9. *The role of startups in the ECIA* (source: Mission Innovation, 2021).

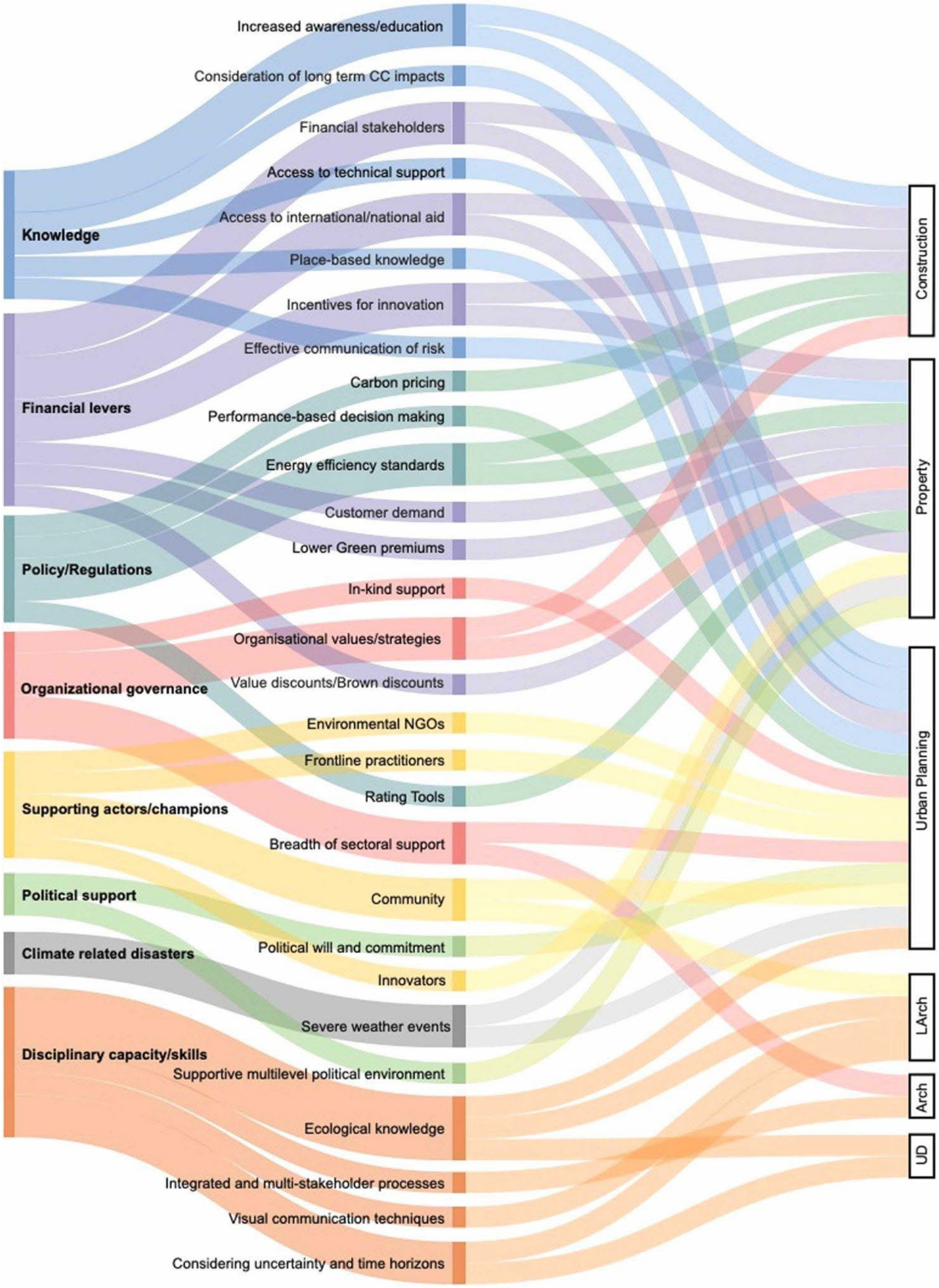


Figure 10 *Facilitators of climate change action across built environment sectors (Source: Hürlimann et al., 2022)*

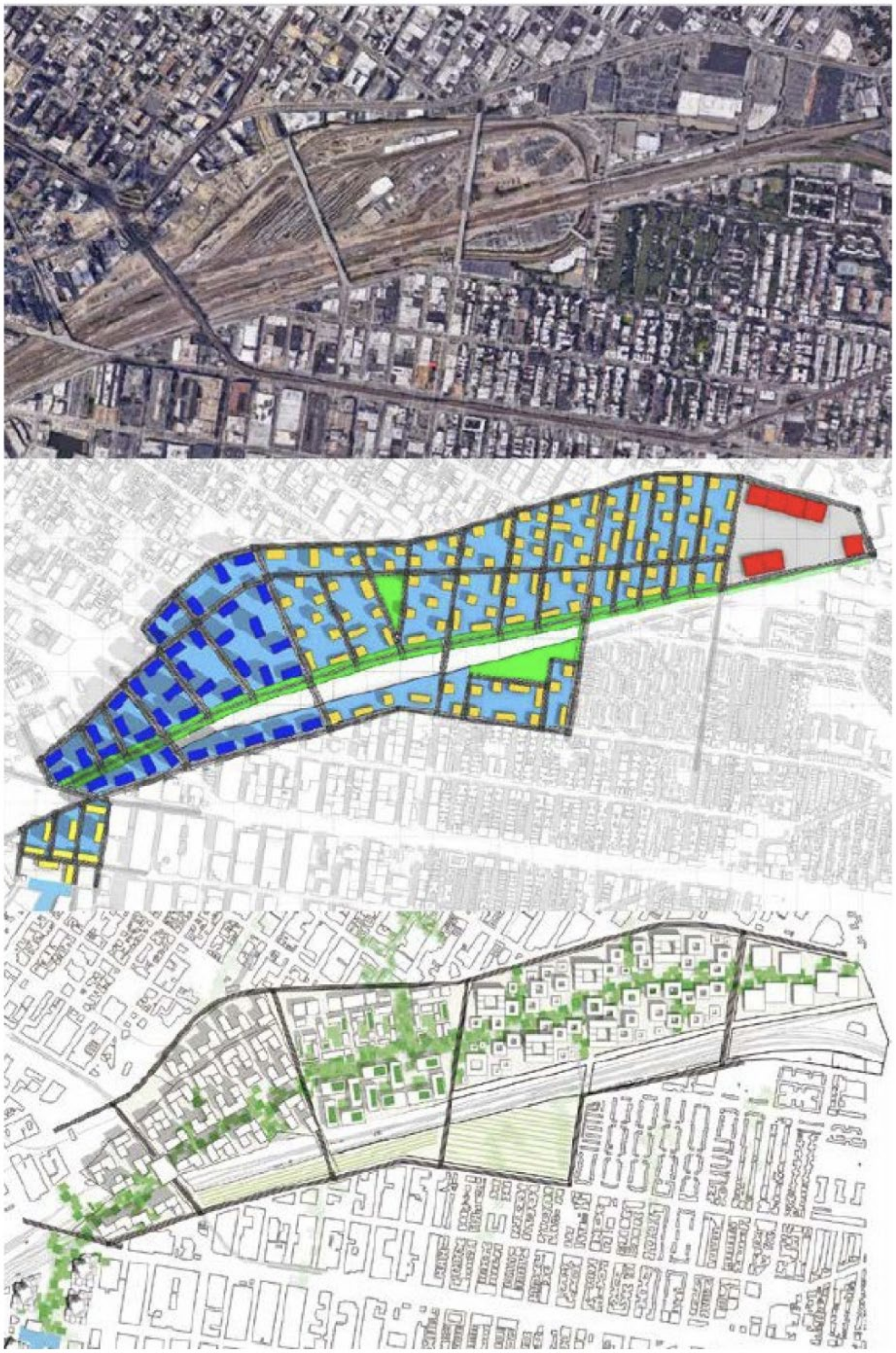


Figure 11. *Current, Future Baseline and Future Best Practice scenarios for the UDCW Sunnyside Yard, NYC* (source: NYIT SoAD Urban Design Climate Lab, 2018).

Table 5

The Power of Design-Led Workshops: Charrettes

A general approach that is applied in complex multi-disciplinary and multi-participatory processes is the design charrette. Fundamental methodologies of a design charrette as described in Condon (2008) and Lennertz and Lutzenhisser (2006) point at the typical projects that are suitable for a design charrette are those that:

- Have high stakes involving substantial public and private investment.
- Take place in a volatile yet workable political environment – situations that are ”hot‟ but manageable.
- Comprehend complex design problems.
- Are real projects including imminent developments.

A typical design charrette process consists of several execution phases (Roggema et al., 2011):

1. **The preparation phase**, both in content, data collection and analysis, as well as becoming familiar with local actors and their experiences and concerns,
2. **The visioning phase**, in which the concepts, complexities, ideas and designs are conceived
3. **The implementation phase**, in which a shared understanding emerges about the future and what is needed to realize this future.
4. **The reporting phase**, in which all visions, implementation and visualizations are collected and presented in an attractive way. This report forms the ‘contract’ of all involved in the charrette.

There are many ways the charrette methodology is applied in practice, depending on the context, the type of problem and the identity of the participating individuals (Roggema, 2013; Biggs et al., 2014a; 2014b), even in an academic context of a conference (Roggema, 2015) this methodology can be applied to explore new governance applications (Roggema, 2016). Condon (2000) defines the key factors for a good charrette process of which the following four are deemed the most important:

1. **Design with everyone**: While becoming a designer requires thorough training and specific skills, the design process as undertaken during charrettes is integrative and contains a variety of possible solutions. This is partly an intuitive activity, making it accessible for many individuals. In this sense,

everyone is a designer;

2. **Start with a blank sheet:** If the group of participants are standing around the table, on which a large map of the site is laid down, overlay the map with a blank piece of transparent paper. Everyone is invited to fill in the future and in a few hours, a shared vision will begin to populate the page;
3. **Provide just enough information:** Too much information causes decision paralysis and too little produces bad proposals. Just enough is mainly arranged through the expertise of the participants and will be provided during the charrette in a concise and accessible manner (maps, schemes);
5. **Drawing is a contract:** All drawings produced during the charrette embody the consensus as experienced and achieved by the charrette team. They form a well-understood agreement, or contract, in images amongst the group. The drawings cannot be broken without consent of the group and function as a very strong commitment.

The following key factors for success are identified after analysis of a range of executed design charrettes (Roggema et al., 2011):

1. **People.** Potential participants, especially the ones that you really want to appear at the charrette, have busy schedules and tight agendas. Therefore, it is essential to communicate the importance of the charrette, do so well in advance, make the charrette as short and convenient as possible and approach each individual personally beforehand.
2. **Right people.** It is not about quantity alone. The strategic key-players in a community, the charismatic group-thinkers and the specific experts in the field are critical in creating a successful team. Intense discussions with people who know the local context well helps to pre-select the right people.
3. **Support.** Local authorities are often busy within their own procedural frameworks and the organization of a design charrette is something that lies outside the core business of a local council. Therefore, it is essential to safeguard beforehand the support of the local authorities. Often, it is necessary to reconfirm this support along the way. To have personal contacts within the organization helps to enlarge the supportive base.
4. **Time.** Potential participants are on a tight schedule. Therefore, it is recommended to organize a short and intense event rather than an outspread one. If the event is short, it increases intensity, and this will lead to better results.
5. **Reason.** A charrette must make sense. To let the charrette play a role in the day-to-day projects and planning processes, the content and especially the outcomes of the charrette must be linked to requirements that are asked in the

regular processes. Only if this link is safeguarded can the charrette solve a problem.

6. **Atmosphere.** The sphere in which the charrette takes place is important because people tend to perform best in a relaxed environment. Therefore, a special venue and a space to “lean back‟ contributes to a pleasant atmosphere. Enough time for locally produced lunches and dinners will also support the working environment.

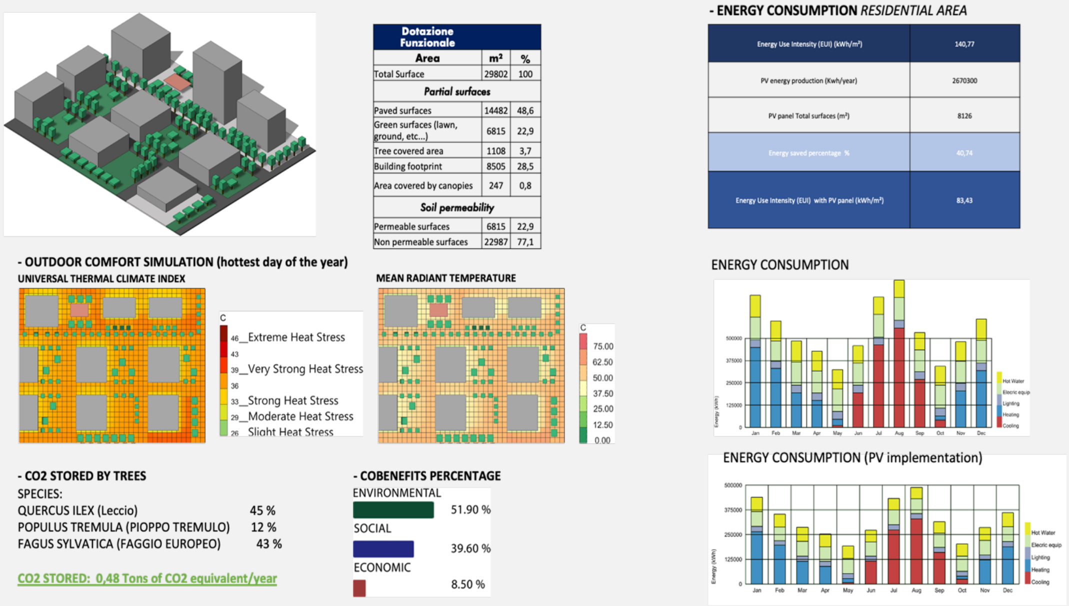
Table 6. *List of simulation tools used during UDCWs*

UDCW simulation tools
GIS TOOLS
Geographic Information Systems (GIS) are becoming increasingly familiar tool in planning and design practice, thanks to their potential of seamlessly integrating any type of information (including those derived from remote sensing sources) into a single analytical geospatial model (Maliene et al., 2011). Innovative GIS-based technologies have the potential to help urban planners address and even anticipate the complexity of contemporary urban growth (Maliene, et al., 2011) as they allow urban planning processes to be data driven more effectively than conventional techniques (Ma and Cheng, 2016). The UDCW GIS tools include a set of algorithms programmed using PostgreSQL and Python, and designed to support evidence-based planning in relation to urban scale issues. To represent and analyze urban areas, the algorithms are based on a 2.5D model (Costamagna, 2011), which combines the two-dimensional features of land cover with selected three-dimensional information (such as elevation, shading, sky-view factor, etc.). The tool can be used to analyse current city conditions (with current and/or future climate) and design scenarios. At the current state of development, the models allow the assessment of the health and economic impact of heat waves and floods (pluvial and coastal), the effect of temperature variations on energy consumption and production, and the CO2 absorption potential from vegetation cover. The tools are based on validated models, such as ENVI-MET for land surface temperature associated with different cover materials, and SOLWEIG (Lindberg and Grimmond, 2011) for the calculation of Mean Radiant Temperature. Impact assessments incorporate widespread models such as Gasparini et al. (2010) for the estimation of mortality rate increase due to heat waves.
3D MODELING TOOLS
Algorithm Aided Design (AAD) tools are increasingly used in architecture and urban design practice for their ability to integrate simulation components within conventional 3D modeling software. This allows them to run complex calculation models, managing data and assessing the effects of planning and design decisions in real time while developing the project. Considering the flexible nature of these digital tools, the accuracy of the results is directly proportional to the amount of information that the designer chooses to integrate in the workflow, according to an “easy to start, hard to master” process logic (Bogost, 2009). In particular, the modular nature of algorithmic design tools allows the tools to be enriched with ever-different elements and data (Mackey and Roudsari, 2017), which, in the case of simulations, materialize in results that can be more or less accurate according to requirements, thus making the computational methodology efficient in different phases of the design process, from the conceptual to the final design. The UDCW 3D modeling tools offer a comprehensive, quantitative, and spatial analysis of the climate-resilient potential of planning and design scenarios at the neighborhood scale, assessing adaptation benefits in relation to heat wave and flood events, and measuring the energy and carbon intensity of different design solutions. Their application requires detailed information about building envelope and HVAC solutions (both for existing buildings and targeted designs for new or retrofitted buildings), as well as technical specification for outdoor paving materials and vegetation types. The tools are based on validated tools such as Ladybug (Mackey and Roudsari, 2018) and i-Tree (Nowak, 2021), incorporate novel custom Python components to assess additional environmental performances based on green building rating systems such as LEED (Nocerino and Leone, 2023).

Climate resilient district 3D configurator (UDCW Process Steps 2, 3, 4)

The use of computational simulation and AAD tools offers valuable support to designers in integrating climate resilient principles within urban projects and evaluating the impact of design solutions. One of the main advantages of this integration lies in the possibility of importing and managing different sets of data and processes in a single workspace, returning a graphical output of the model and its associated information, which change according to the parameters defined by the planner / designer, influencing the morphological and non-morphological characteristics of the project. The 3D models can be informed with different quantitative and qualitative data, linked to several performance features of the project. The implementation of computational simulation engines allows one to dynamically investigate the effects of design choices on the urban microclimate from the earliest conceptual stages, and consequently to evaluate different design alternatives with respect to the objectives to be achieved.

On the other hand, although the AAD tools embedded into 3D modeling software can streamline the management of data in the planning and design processes, it is also true that users lacking the necessary technical skills or knowledge of the basics of environmental design may find it complex to develop an algorithm that effectively links geometrical input to the large amount of data involved. For this reason, one of the facilitation tools proposed in the UDCW methodology consists of a 3D configurator supporting district to neighborhood scale design.



Dotazione Funzionale		
Area	**m²**	**%**
Total Surface	29802	100
Partial surfaces		
Paved surfaces	14482	48,6
Green surfaces (lawn, ground, etc...)	6815	22,9
Tree covered area	1108	3,7
Building footprint	8505	28,5
Area covered by canopies	247	0,8
Soil permeability		
Permeable surfaces	6815	22,9
Non permeable surfaces	22987	77,1

- ENERGY CONSUMPTION *RESIDENTIAL AREA*

Energy Use Intensity (EUI) (kWh/m²)	140,77
PV energy production (Kwh/year)	2670300
PV panel Total surfaces (m²)	8126
Energy saved percentage %	40,74
Energy Use Intensity (EUI) with PV panel (kWh/m²)	83,43

- OUTDOOR COMFORT SIMULATION (hottest day of the year)

- CO2 STORED BY TREES

SPECIES:

QUERCUS ILEX (Leccio)	45 %
POPULUS TREMULA (PIOPPO TREMULO)	12 %
FAGUS SYLVATICA (FAGGIO EUROPEO)	43 %

CO2 STORED: 0,48 Tons of CO2 equivalent/year

- COBENEFITS PERCENTAGE

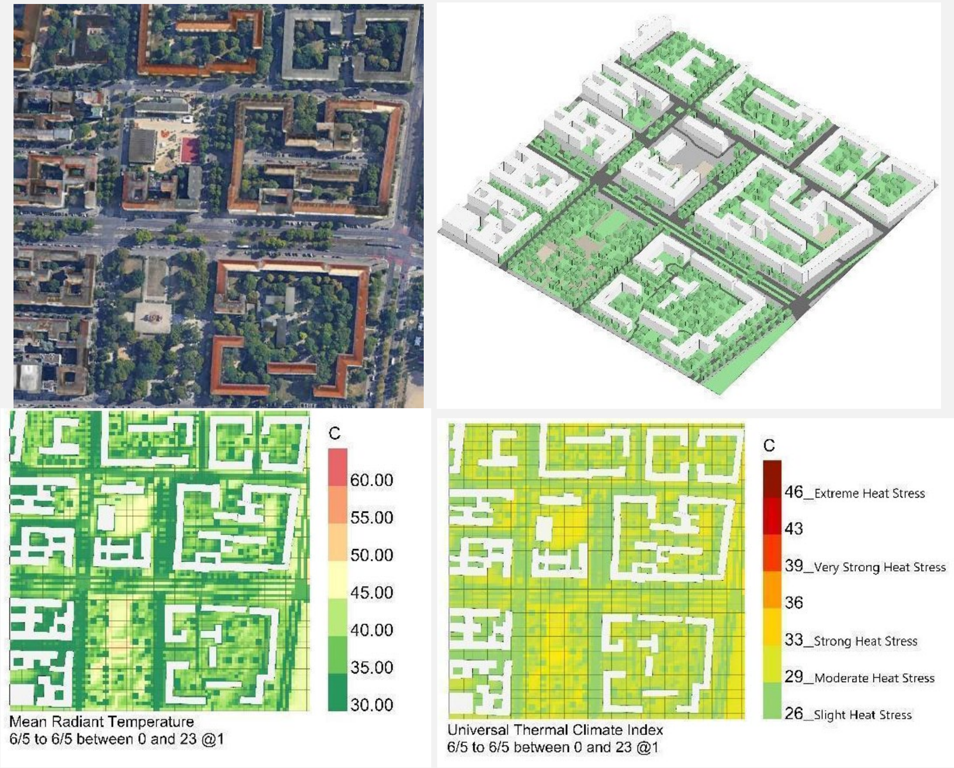
ENVIRONMENTAL	51.90 %
SOCIAL	39.60 %
ECONOMIC	8.50 %

Example output generated by the configurator

The tool aims at optimizing and simplifying the district-scale modeling phase integrating key performance indicators related to climate benefits (mitigation, adaptation) and co-benefits (social, economic, environmental) of different design solutions. The geometries generated by the configurator automatically include all the information required by the UDCW GIS and 3D modeling simulation tools (see box in this section). This helps simplifying the understanding of urban climate modeling principles and consequently to introduce climate resilient solutions enabling the assessment of key performance indicators already at the conceptual stage of design (e.g. massing). Moreover, it allows to easily assess the effects of urban climate factors in different urban contexts.

From a technical perspective, the tool consists of a series of components programmed in Grasshopper (the Visual Programming Language integrated in McNeel-Rhinoceros software), that allow, starting from a certain set of parameters (both geometric and performance-related), the generation of simplified 3D objects representing buildings, open spaces and vegetation components. Once the objects are generated, the performances of proposed design solutions are automatically verified in relation to qualitative and quantitative indicators. By modifying or displacing different geometries in the 3D working environment, simulation results are updated in real time.

The Grasshopper components that comprise the configurator are: Ground Generator, Building Generator, Tree Generator, Road Generator and Canopy Generator. For each of these components the algorithm requires a set of inputs in order to generate the elements to compose the urban space.



Arnswalder Platz area (Berlin) model and microclimate maps generated with the 3D District Configurator.

Public Participatory Geographic Information Systems (PP-GIS) for collaborative mapping (Step 1, 3)

"Collaborative mapping" or "participatory mapping" refers to tools and methods for collecting and implementing spatial data to facilitate collective place-making and action (Burnett et al., 2023). In this type of map-based participation, researchers or experts collaborate with communities and stakeholders to spatially represent their knowledge about a territory.

In the context of participatory mapping, the emergence of PP-GIS (Public Participatory Geographic Information System) presents a method that effectively combines science with public participation. This combination supports spatial decision-making and planning for risk reduction, while also ensuring diverse levels of engagement from communities and stakeholders. PPGIS originated by merging participatory learning and action (PLA) approaches with geographic information technologies (GIT). This merger enables the representation of people's spatial knowledge through virtual, web-based, or physical 2 or 3-dimensional maps (Sieber, 2006).

The purpose of collaborative mapping in climate-resilient design methodology is to facilitate knowledge exchange between experts and non-experts, incorporating tacit knowledge inclusively. The tool is customized on a case-by-case basis to gather community knowledge about a specific neighborhood or district. This knowledge is then analyzed to inform the design of context-specific solutions. Collaborative mapping serves as a means for co-producing knowledge by connecting climate risk data with local concerns and opportunities. It can be applied to assess various aspects, including the quality of urban spaces, environmental pressures, social capital, socio-spatial issues, infrastructure availability, everyday risks, and resident practices.

In contemporary practice, PP-GIS is emerging as a valuable means of evaluating accessibility, distribution, and perceptions of green and blue infrastructure, as well as environmental amenities. This approach facilitates an assessment of environmental and climate justice at an urban scale (Korpilo et al., 2021). In situations involving socio-environmental vulnerability, PP-GIS offers a robust framework for achieving justice outcomes that acknowledge the needs and claims of the most vulnerable and marginalized individuals. Numerous studies and cases, particularly in developing countries, demonstrate the potential of collaborative mapping tools in providing procedural, recognition-based, and distributive justice to communities traditionally excluded from knowledge production and spatial decision-making (Corbett et al., 2016).

PP-GIS has been incorporated into the UDCW for evaluating urban space quality, environmental conditions, socio-cultural capital, and integrating climate-related considerations. Collaborative mapping exercises within UDCW are tailored to the specific design objectives and area characteristics. These exercises involve mapping abandoned areas, spaces affected by socio-spatial factors (such as unsafety or segregation), and environmental issues (such as waste, illegal dumping, fire risk, and high pollution), as well as gathering information about meeting spaces, leisure areas, and local initiatives. Stakeholders' engagement, including residents, local administrations, and third sectors, drives the development of these participatory exercises in various cases (see www.uccrn.education). In the Naples case, an online platform was established as an interactive tool to foster spatial learning and democratic discussion (Figure 39). This approach shifts the knowledge transfer process from a science-policy axis to a co-production approach where community knowledge, technical analysis, and urban planning converge (Visconti, 2023).

PP-GIS serves as a practical tool to identify local priorities and establish a baseline for aligning climate-resilient priorities with community needs. The potential lies in integrating the daily dimension of urban spaces into comprehensive urban regeneration initiatives that enhance neighborhood livability, promote sustainable lifestyles, and advance social inclusion and equity. Furthermore, the evidence-based data co-produced by experts and citizens holds the potential to influence urban policies and redirect local urban agendas toward community-driven resilience objectives by providing a platform for decision making and inclusive planning (Visconti, 2023).

Table 7. *Focus and Output of UDCWs*

Focus	**Output**
Urban Systems' Users	Population Scenarios • The future “Business as Usual” (BAU) Baseline scenario for the UDCW project area, a hypothetical scenario based on proposed development, projects in the development pipeline, rezoning plans and “market driven” full build-out assumptions. For this projected “maximum build-out” scenario, each building lot is built-out to its fully allowed maximum Floor Area Ratio (FAR) per these plans. Specific layout of open spaces is based on city/district strategies in place in the city/are. The projected development is converted to additional population, based upon the city’s standard urban density ratios. Urban Systems Inventory and Footprint: Current and Future (based on user groups and population projections) • Amount of land needed by converting urban systems to physical footprint (hectares) • GHG emissions for urban systems (CO2eq) Synergies and Adjacencies: Connections and Flows • Connections and flows between different urban systems, and between systems and user groups • Flow type, intensity, and direction • Synergies between different urban systems, and between systems and user groups
Scales	Aspirations and policy mandates across multiple scales:

	• Buildings, district, city and region, • Connections and flows between spatial scales, boundaries and jurisdictions • Flow type, intensity, and direction • Synergies between different urban systems, and between systems and spatial scales
Programming Design Typologies, Simulation and Modeling	Emerging site planning and building typologies and metrics responding to climate aspirations including: • Mixed use, residential, commercial, institutional, manufacturing, infrastructure • Energy hubs, food hubs, waste hubs, water treatment, intermodal hubs
Urban Climate Factors	Study Area evaluation according to these urban form and urban function principles for configuring climate resilient neighborhoods: • Efficiency of Urban Systems • Form and Layout • Building Envelope and Surface Materials • Green and Blue Infrastructure
Site Opportunities and Constraints	Analyzing and configuring interconnected microclimates and urban systems within the study area to achieve reduced energy loads, cleaner air and enhanced civic life. These elements include: • prevailing winds, solar impact, floods vulnerability, urban heat "hot spots", • viewsheds, area topography, natural systems, biodiversity, • community culture, "soft sites" for potential development, existing landmarks, active public realm, circulation corridors, current and future activity nodes, intermodal hubs, • opportunities for circular economy, production and distribution hubs for energy, waste, food.
Urban Climate Goals	Current, and future scenarios for integrated climate mitigation and adaptation (Figure 31), based upon: • GHG emissions and footprint: Scopes 1, 2 and 3 based upon the GHG Protocol for Cities • Heat and flooding outcomes at district and sub-district scales The three scenarios include: • Existing Condition: Reflecting current climate and development patterns. • Future Baseline BAU: Hypothetical scenario based on municipal planning regulations and "market driven" full build-out assumptions. • Future Best Practice: Full build-out based on climate adaptive development considering evidence-based "best practice" urban climate factors.

The UDCW Case Studies included in this Element have been carried out thanks to the support of a large group of partners engaged by the local hosts and by UCCRN Regional Hubs, also in connection with existing funding programmes who supported the implementation of preparatory and workshop activities.

- Paris, Nov. 2022 - Typology: "Design Studio"; Partners: C40, Marie de Paris, Atelier Georges, UCCRN European Hub. Universities: Gustave Eiffel, New York Institute of Technology, National Science Foundation, University of Naples Federico II, University of Mons.
- Durban, Feb. 2019 (SAF Hub) - Typology: "Capacity Building"; Partners: NASA-GISS, National Science Foundation, GIZ, UCCRN European Hub, UCCRN Durban Knowledge Hub, Ethekwini Municipality: Strategic Spatial Planning, Branch (SSPB), Development Planning Department (DPD), Development Management Department, Environmental Health, Primary Health Care Area Office, Urban Design, Architecture Department, Strategic Development Manager, Architecture Department, Biodiversity Impact Assessment Branch, Environmental Planning and Climate Protection Department (EPCPD), Climate Protection Branch, EPCPD.

- NYC – Gowanus, Brooklyn, 2019 - Typology: Design Studio. Partners: Urban Land Institute (ULI), Urban Climate Change Research Network, American Institute of Architects New York Chapter, SUGI Belmont Forum, National Science Foundation, New York Institute of Technology, Consulate General of Switzerland in New York, Fifth Avenue Committee, Gowanus by Design. Universities: New York Institute of Technology.
- Napoli, Oct. 2018 - Typology: Design Studio. Partners: Urban Climate Change Research Network, UCCRN European Hub, SIMMCITIES Project; CLARITY Project. City of Napoli: Environment Department; Urban Planning Department; Social Housing Department. Universities: University of Naples Federico II, New York Institute of Technology, Polytechnic of Milan, Université Paris-Est Marne-La-Vallée, PUC Santiago de Chile.

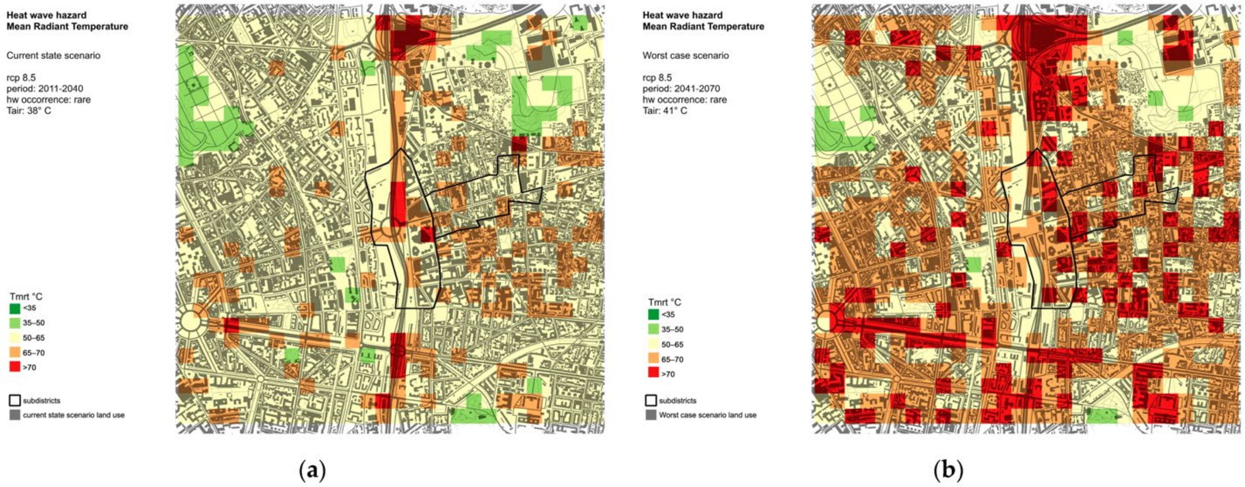
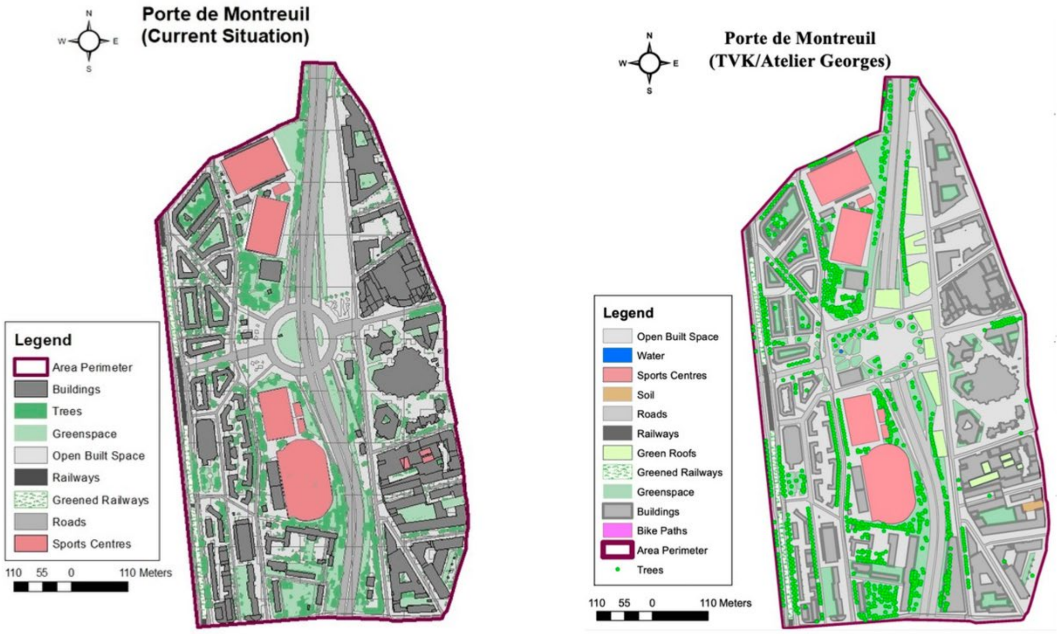


Figure 11. *(a) Tmrt of current-state heat wave in the Porte de Montreuil district (RCP8.5 20112040 rare event, 38 °C); (b) Tmrt of BAU worst case scenario heat wave in the Porte de*

Montreuil district (RCP8.5 2041–2070, 41 °C).



(a) (b)

Figure 12. *Land use of current state scenario (a) and planned land use within the business-as-usual scenario (b).*

Figure 13. *Paris Urban Design Climate part of the Urban demonstrator "Sensecity" (July 2022).*

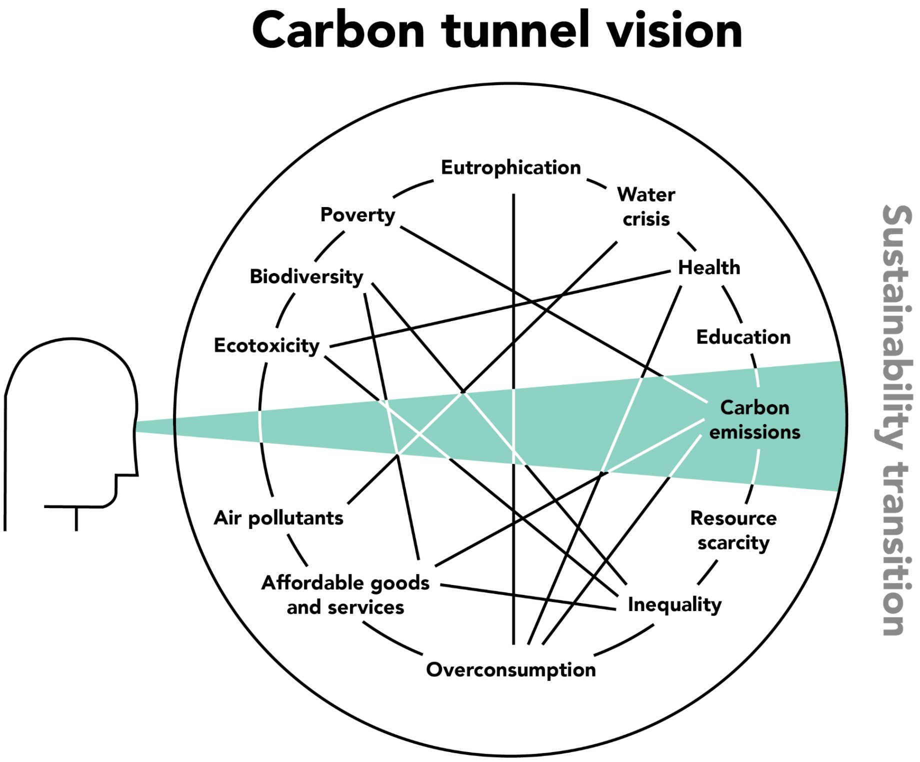


Figure 14. Decades of state-led negotiations about climate action contributed to the establishment of a mainstream vision prevalently focused on carbon emissions reduction, also referred to as Carbon tunnel vision (Source: Konietzko, 2022) which inevitably leads at overlooking the systemic complexity that links several socio-economic and environmental global and local development goals. In planning and urban design, prioritizing emerging needs across identified development challenges helps delivering transformative and systemic climate resilient strategies and measures.

Box. 1

Best Practice Example: Maximizing the Value of Renewable Energy Infrastructure in Turin
Multi-Criteria Decision Making (MCDM) tools are particularly helpful in evaluating new climate infrastructure such as renewable energy systems. Planners tasked with siting new infrastructure share the common goals of maximizing environmental, economic, and socio-cultural desirability. However, decision-making sub-criteria vary for each project and stakeholders need a means of assigning relative value judgements for each of these criteria (Feyzi et al., 2019).

For example, the city of Turin used Multi-criteria Spatial Decision Support System (MC-SDSS) to help stakeholders in urban energy planning to identify and evaluate different energy retrofit scenarios. The tool enabled the stakeholders to consider a range of criteria, including environmental, economic, technical, and social factors of various scenarios, and visualize and compare the impact of various decisions through charts, maps, and other indicators (Moghadam et al., 2018).

Case Study 3.1 Durban Urban Design Climate Workshop

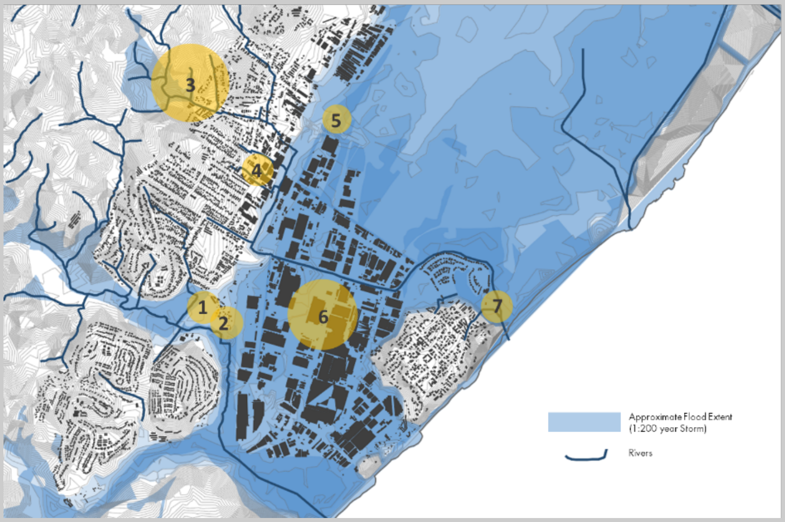
In 2019, the UCCRN proposed a district-level UDCW program for isiPhingo in Durban, South Africa to facilitate participating City Teams to incorporate climate change actions and initiatives into the isiPhingo Rehabilitation Programme. The sessions' goal was to develop implementation actions that considered varied governmental, developmental, socio-economic, and ecological conditions. A further goal was to build capacity across multiple stakeholder groups, particularly Municipality staff and students at the local University of KwaZulu-Natal, to implement mitigation, adaptation, resilience, and transformation actions to respond to climate change.

Community engagement session: outlining synergies between community and climate priorities for the Isipingo central business district (CBD).

In the design phase, GIS tools were used to test district-wide concepts to evaluate the effectiveness of climate-adaptive solutions (green surfaces, water, shading systems) for the resilient regeneration of urban spaces.

Application of GIS tools in Durban. Tmrt analysis of current state vs design scenario (2050 regional scale climate projections provided by NASA-GISS through the Earth Exchange Global Daily Downscaled Projections NEX-GDDP dataset).

The UDCW sessions allowed city officials from eThekwini Municipality to integrate and scale up mitigation and adaptation principles by reducing energy consumption, strengthening resilience, and enhancing human well-being. The workshop demonstrated that through efficient urban planning and design, urban districts can work synergistically with construction and landscape configurations to create interconnected, protective, resilient, and attractive urban areas.



Water Issues / Challenges:

1. Human Health and Safety Concerns Caused by:
   - Flash Floods
   - Toxic runoff
   - Difficulty accessing food and clean water during flooding
2. Damage to infrastructure and community/industry property
3. Decrease in Water Quality / Ecosystem Damage

CHALLENGING AREAS

1. **TRANSIT CAMP** – Area frequently flooded (endagering residents). Located on former wetland site.
2. **MALFUNCTIONING WEIR:** Only 10% Flow to Canals
3. **SIGNIFICANT RUNOFF FROM UPSTREAM**
4. **CBD** - Impervious surfaces, lack of building-level stormwater management plans, frequently blocked and aging sewers , polluted runoff
5. **ILLEGAL CONTAINER DEPOT WITHIN WETLANDS**
6. **CANALS** – Inadequate flow for estuary health, causes flooding of industrial sites, severely polluted.
7. **ESTUARY** - Insufficient Flow, garbage and sewage, sand blockage of outlet

1. **Relocate Transit Camp /** Restore Wetland Ecosystem Services
2. **Isipingo Inlet Weir Restoration** (Restore a consistent flow of clean water to canals and downstream estuary ecosystem)
   - There is a gabion weir on the river that is supposed to route water into the inlet under baseline conditions. Under flood conditions, the water flows over the river into the Mbokodweni River. The challenge is that the river changes flow and continues to flow on a different path into the Mbokodweni River. Invasive water plants are a factor causing the flow into the Mbokodweni River.

3. **Develop Water Retention Sites Upstream of CBD** (Attenuation Facilities Already in Planning)
   - Purpose is to capture water and allow for slow release
   - When possible, the sites will be utilized for some social benefits (e.g. park)
   - Opportunity for commercial mixed use development and high-density housing
   - Central bowl can be developed; surrounded by roads
   - Desire for water from detention basins to gravity flow to canals (12 meter elevation difference?)

4. **CBD Green Infrastructure Design Interventions**
   - Require building parcels to implement their own stormwater management measures including rooftop and site rainwater collection, detention, and/or reuse
   - Municipality to make use of 9 ha area freed up within CBD for rain gardens / infiltration zones

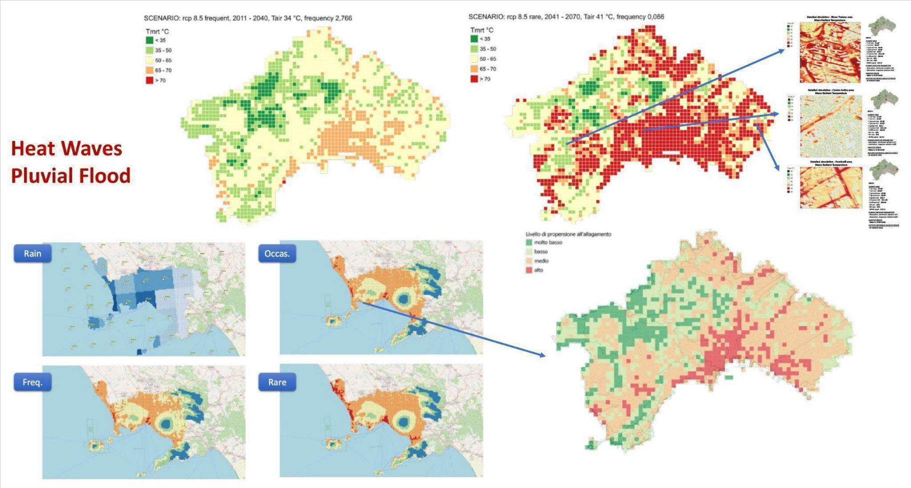
6. **Canal System Upgrades (opportunities to improve design and operation)**
   - Sluice gates to control illicit discharges from industry upstream.
   - Closing gates and taking advantage of the head; allowing more flow into the estuary To be further studied)
   - Modifying slope to increase hydraulic gradient towards the estuary (To be further studied)
   - New canal running through the site with the container depot
   - Removal of invasive water plants, drying, and use for animal feed.
7. **Restoration of a healthy estuary Ecosystem**

Water management issues and planned/potential projects in isiPhingo area.

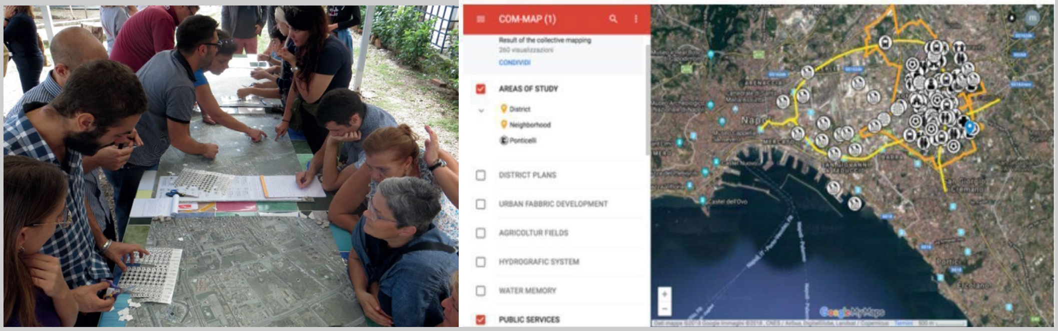
Recommendations from the 2019 UDCW were revisited in January 2023 in a one-day workshop to illustrate how a climate-resilient approach to urban design can support the ongoing initiatives of the Transformative River Management Programme (TRMP), supported by the Cities and Climate in Africa (CICLIA) programme. The TRMP is an ongoing programme investing in the city's rivers as a core component of transformative adaptation.

Case Study 3.2 Napoli Urban Design Climate Workshop

Napoli is a major climate change hotspot. Extreme temperature and precipitation events significantly increased in recent years and slow-onset variations in seasonal temperatures are also dramatically impacting urban energy use.



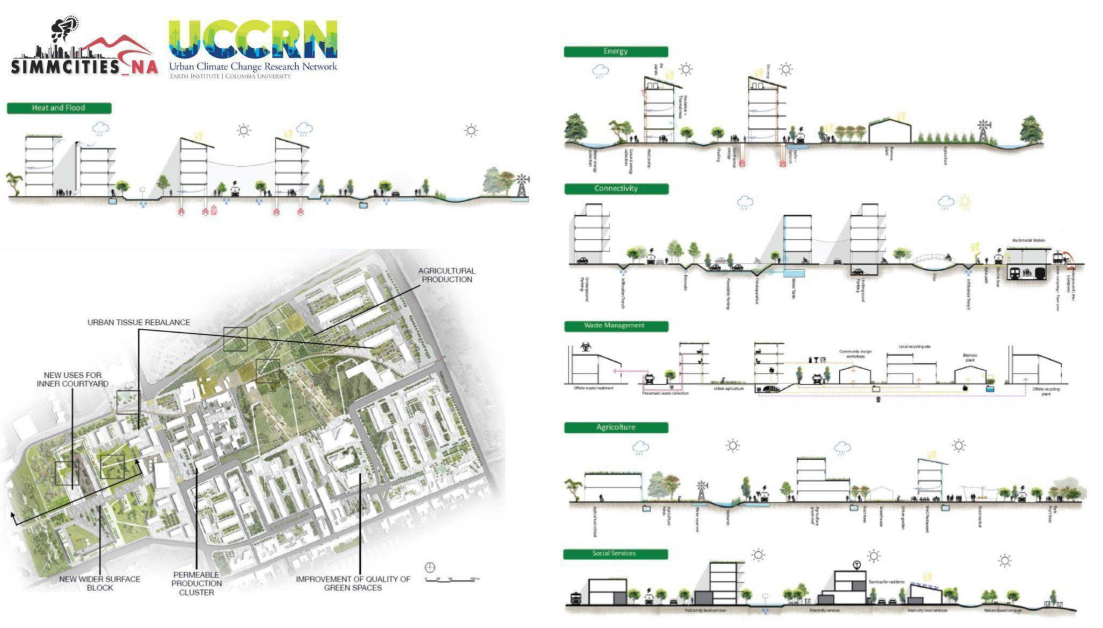
Example of Heat and flood reference scenarios for the city of Naples used for the climate analysis mapping phase of the UDCW(250m resolution).



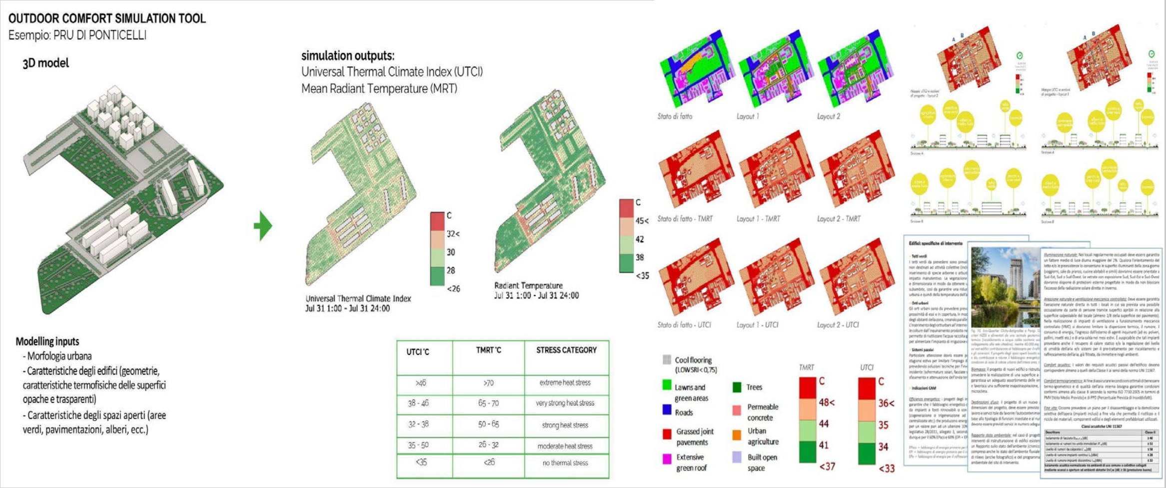
Collaborative mapping exercise in Napoli for the Ponticelli district Redevelopment plan and open source digital map elaborated by UDCW facilitators.

The first UDCW took place in 2018, involving international students and teachers from University of Napoli Federico II, New York Institute of Technology, Polytechnic of Milan, Université Paris-Est and PUC Santiago de Chile, focusing on the Ponticelli district, performing urban climate analyses through GIS and parametric design tools, and engaging local communities and stakeholders in a collaborative mapping exercise.

The results of the UDCW have been presented to Napoli public officials. The interest raised helped to expand the UDCW towards a capacity building platform (with workshop sessions held in 2019 and 2020) intended to deliver multi-scale analyses, guidelines and simulation services, bridging the strategic level (SECAP) with city planning (PUC) and urban design (PRU) scales to support the climate-resilient transformation of the city.



Ponticelli district masterplan and urban sections drafted following the collaborative mapping phase.



OUTDOOR COMFORT SIMULATION TOOL
Esempio: PRU DI PONTICELLI

3D model

simulation outputs:
Universal Thermal Climate Index (UTCI)
Mean Radiant Temperature (MRT)

Modelling inputs
- Morfologia urbana
- Caratteristiche degli edifici (geometrie, caratteristiche termofisiche delle superfici opache e trasparenti)
- Caratteristiche degli spazi aperti (aree verdi, pavimentazioni, alberi, ecc.)

UTCI °C	TMRT °C	STRESS CATEGORY
>46	>70	extreme heat stress
38 - 46	65 - 70	very strong heat stress
32 - 38	50 - 65	strong heat stress
35 - 50	26 - 32	moderate heat stress
<35	<26	no thermal stress

Excerpt of design guidelines for the Ponticelli district in Napoli developed as UDCW output.

A set of user-friendly analysis tools showed the effects of heat and flood risk on buildings' layout and morphology, surface materials, vegetation and public spaces. The expected outcome from the 2023 and 2024 UDCW sessions is the development of the Napoli SECAP, an operational framework to support the short- to mid-term implementation of all local plans.

Case Study 3.3 Paris Urban Design Climate Workshop

The Paris Urban Design Climate Workshop took place in 2021 within the "Climate-Resilient Urban Design" (CRUD) project, combining teaching, scientific research, climate analysis, urban planning and design interventions to construct proposals for climate change adaptation. Led by Université Gustave Eiffel's Urban Engineering Department and the UCCRN, the project centered in *Porte de Montreuil,* a densely populated Paris suburb. International university teams worked for a year with professional partners, public structures and civil society organizations within the project zone.

The "climate analysis mapping" phase identified areas exposed to rising temperatures (See the additional resources, Figure 11, for heatwave risks in Porte de Montreuil). In the second phase, "Best Practice" and BAU scenarios were developed for 2050 (See the additional resources, Figure 11, for land use scenarios).

(a) (b)

Current land use (a) and proposed scenario (b) for the Porte de Montreuil district.

In phase 3, all partners came together at Université Gustave Eiffel and met local actors and associations, participated in an international symposium, and established masterplans for "Best Practice" scenarios at the project site scale. Student teams focused on circular cities, zero carbon city, green and blue corridors, 15-minute city and presented at Montreuil Town Hall.

International students and teachers during the workshop at Université Gustave Eiffel.

Students meeting a community garden association in Porte de Montreuil saying: “yes to the garden, no to concrete”.

Detail of the “best practice” design scenario in the Porte Montreuil area.

Based on the proposals from the workshop, a fourth phase measured their effectiveness in the “Sensecity” environmental chamber (see additional resources, Figure 13), quantifying their cooling benefits in terms of air temperature and thermal comfort (UTCI). Effectiveness of different cooling solutions was quantified with data to be evaluated for future developments of the project.

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