Concepts and Tools for Envisioning New York City's Futures

Deborah Balk, [1, 2] Timon McPhearson, [3,14] Elizabeth M. Cook, [4] Kim Knowlton, [7] Nicole Maher, [5] Peter Marcotullio, [6, 8] Thomas Matte, [7] Richard Moss, [13] Luis Ortiz, [3, 9] Joel Towers, [10, 11] Jennifer Ventrella, [11] Gernot Wagner [12]

[1] *Marxe School of Public and International Affairs, Baruch College, NY.*
[2] *CUNY Institute for Demographic Research, City University of New York, New York, NY.*
[3] *Urban Systems Lab, The New School, New York, NY.*
[4] *Barnard College, Columbia University, New York, NY.*
[5] *The Nature Conservancy, Cold Spring Harbor, NY.*
[6] *Institute for Sustainable Cities, Hunter College, New York, NY.*
[7] *Mailman School of Public Health, Columbia University, New York, NY.*
[8] *City University of New York, New York, NY.*
[9] *George Mason University, Fairfax, VA.*
[10] *Parsons School of Design, New York, NY.*
[11] *The New School, New York, NY.*
[12] *Columbia Business School, New York, NY.*
[13] *University of Maryland, College Park, MD.*
[14] *Carey Institute of Ecosystem Studies, Millbrook, NY.*

Correspondence should be addressed to:

Deborah Balk, Ph.D.
Baruch College and CUNY Institute for Demographic Research, City University of New York
https://orcid.org/0000-0002-9028-7898
deborah.balk@baruch.cuny.edu

Timon McPhearson, Ph.D.
Urban Systems Lab, The New School, New York, NY
https://orcid.org/ 0000-0002-9499-0791
timon.mcphearson@newschool.edu

Abstract:

This chapter of the New York City Panel on Climate Change 4 (NPCC4) report discusses the many intersecting social, ecological, and technological-infrastructure dimensions of New York City and their interactions that are critical to address in order to transition to and secure a climate-adapted future for all New Yorkers. The authors provide an assessment of current approaches to "future visioning and scenarios" across community and city level initiatives and examine diverse dimensions of the NYC urban system to reduce risk and vulnerability and enable a future adapted NYC. Methods for the integration of community and stakeholder ideas about what would make NYC thrive with scientific and technical information on the possibilities presented by different policies and actions is discussed. This chapter synthesizes the state of knowledge on how different communities of scholarship or practice envision futures and provides brief descriptions of the social-demographic and housing, transportation, energy, nature-based, and health futures and many other subsystems of the complex system of NYC that will all interact to determine NYC futures.

Keywords:

Futures, Scenario Planning, Climate Change, Complex Systems, NPCC4

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1 Chapter Summary

This chapter provides the first of its kind of assessment for New York City (NYC) of positive future visions, scenarios, and their intersections with current challenges, which can inform new modes and models for equitable climate change policy, planning, and engagement across the diverse social and infrastructural fabric of the city. Here we consider additional aspects of NYC's built, social, and natural infrastructure that were not fully considered in NPCC3 (New York City Panel on Climate Change, 2019) but have become especially salient in the time since. We discuss the many intersecting social, ecological, and technological-infrastructure dimensions of the city and their interactions that must be simultaneously considered to transition to and secure a climate-adapted future for all New Yorkers. We assess current approaches to futures research, visioning, and scenarios across community and city-level initiatives and discuss multiple dimensions of the NYC urban system to reduce risk and vulnerability and to enable an NYC that is adapted to future climate change. In doing so, we synthesize the state of knowledge on social-demographic, economic, transportation, housing, health futures, and many other subsystems of the complex system of NYC that will all interact to determine NYC futures.

1.1 Key Messages

Key Message 1: *NYC is projected to be hotter, wetter, and more flood prone, with multiple types of tropical and winter storms that are likely to increase in frequency, intensity, and severity. At the same time, the population of the city is expected to age. Long traditions of in- and out-migration have shaped the city and are expected to continue to be an important part of its future, anchoring it in the region and the nation. The built environment will largely remain in place, yet changes in land use and land cover, including conversions in impervious and natural areas, are expected. Managing and planning the future NYC to be more adapted and resilient to diverse climate, economic, and social pressures will require understanding these diverse futures that also interact dynamically in real-time.*

Key Message 2: *Future complexity and uncertainty due to climate change demands new ways to plan our cities. Scenario-based planning can incorporate important urban dynamics and complexities and uncertainties common to the non-anecdotal challenges of the Anthropocene that other planning tools cannot, partly by addressing uncertainty over the mid-to-long term. By incorporating scenario planning into NYC futuring exercises, a range of new opportunities for envisioning and shaping health, social, environmental, economic, and population change outcomes can be applied to meet broad or sectoral adaptation and mitigation planning.*

Key Message 3: *Equity and social justice should be explicitly centered in future climate adaptation goals, implementation efforts, and future planning. Planning without centering equity will likely result in unintended negative consequences, such as green gentrification or displacement, which exacerbate inequity. Centering equity in climate adaptation and mitigation actions provides an opportunity to decrease impacts on the most vulnerable.*

Key Message 4: *NYC is dynamic, and the scale and complexity of NYC requires managing interacting socio-economic, ecological-biophysical, and technological-infrastructure components. However, there is often a lack of understanding by planners of the fundamental drivers of behaviors and patterns that are important for planning and designing more resilient, equitable, and adapted NYC and metropolitan region. Inherent in these interdependencies are trade-offs between temporal and spatial scales in planning activities, as well as between sectors; identifying these trade-offs is integral to transparency in planning and adaptation. Incorporating approaches that acknowledge interdependencies in future planning will prevent a siloed understanding of trade-offs and uncertainties.*

Key Message 5: *In the context of climate change risks in NYC and the metropolitan region, changes in key sectors and deployment of technologies have included some which are adaptive and beneficial and others that are unintentionally maladaptive, causing risks and inequities that are costly to reverse. The adaptive or maladaptive potential of such changes have depended on the extent to which their costs, benefits, and risks are balanced and equitably distributed. Local examples considered in this chapter include mechanical cooling, flood protection measures,* *and spatial allocation of the public right of way (ROW, mainly streets and sidewalks). Maladaptation can be caused by ignoring climate risks and equity considerations and by siloed planning, within and among sectors, levels of government, government agencies, non-governmental institutions, and the private sector. Potential for maladaptive and inequitable effects of climate adaptation strategies and other sectoral actions influencing climate risks should be weighed to ensure that near-term actions are not maladaptive in the long term.*

Key Message 6: *Without shared positive visions for the future, it is unlikely that plans made now will achieve the equity, justice, sustainability, and resilience goals desired for the future of NYC and its communities. Participatory processes are critical in co-developing shared visions that bring together diverse perspectives and forms of knowledge, and a sustained engagement process is critically needed to identify the City's climate research priorities and co-produce a future public climate research agenda for the city. Co-produced visions, goals, and strategies can involve perspectives across multiple sectors, scales, and communities to gather the full range of ideas, innovations, and possible actions to address trade-offs and inform transitions toward a climate-adapted future for NYC. However, tools for longer-term (beyond 2050) transitions and pathways to achieve future plans for NYC are currently missing and needed to guide efforts to secure an inclusive climate resilient future for all New Yorkers. In order to track progress towards these goals, periodic and systematic monitoring and evaluation are necessary.*

Key Message 7: *Transitioning the built environment to be more climate resilient while addressing fundamental challenges to equity and sustainability requires policies and investments to retrofit, rebuild, and improve the built infrastructure to support population health. Prioritizing active and sustainable modes, including transit, walking, and cycling can provide multiple, equitable health benefits through increased physical activity, reduced air pollution exposure, more affordable transportation options, and reduced risk of conditions that increase vulnerability to climate change. At the same time, reducing miles driven by private motor vehicles within, into, and out of the city will reduce greenhouse gas (GHG) emissions and expand space available on streets and sidewalks for uses that provide climate resilience and social and equity benefits.*

Key Message 8: *Nature-based solutions are critical for addressing climate adaptation needs in the city and can simultaneously provide co-benefits for public health, society, and natural systems that help create a resilient city. Planning, implementation, and management of nature-based solutions to achieve equitable distribution and holistic resilience in a complex city system is still a developing practice.*

2 Introduction

2.1 Chapter Scope and Context

Prior NPCC reports and other scientific assessment bodies have established that the future climate of New York will very likely be hotter, more flood-prone, and battered by a range of climate induced weather hazards from cold snaps, drought conditions, extreme rainfall, coastal storms, heat waves and potential for overlapping weather extremes (Braneon et al., 2024; González et al., 2019; Gornitz et al., 2019; Orton et al., 2019). Loss of life and damages from these and other climatic hazards are occurring across the globe and the United States, and billions are being spent annually to recover from or moderate future damages. In the US, from 1980 to 2005, the total normalized (inflation adjusted) losses for the 66 major weather events total over $500 billion. Fifty-seven of these disasters occurred during the 1988- 2005 period with total unadjusted damages/costs of over $370 billion (Lott & Ross, 2006). From 1988 to 2017, increased precipitation costs alone were estimated to contribute about one-third (36%) of the cost of flood damages in the country with a cumulative total of approximately $73 billion (Davenport et al., 2021). These recent events suggest that adaptation will be critical to advance with as much political will and financial investment as mitigation efforts in NYC and the broader region. However, in addition to projected climate hazards – including potential exposure of vulnerable populations, critical infrastructure, and ecosystems – there are myriad socio-demographic, economic, infrastructure, and ecological futures that will unfold in the complex urban system of NYC that in turn will impact the city's future risk and resilience to climate change. While there is high confidence in the broad outlines of future climate threats and their impacts, there is a need to develop plans for the future that are robust to uncertainty in the details of exactly when and how in the city's complex human geography these damages will occur.

In this chapter, we discuss the many intersecting social, ecological, and technological-infrastructure dimensions of the city and their interactions that are critical to address in order to transition to and secure a climate-adapted future for all New Yorkers. Here we provide an assessment of current approaches to "future visioning and scenarios" across community and city level initiatives and examine diverse dimensions of the NYC urban system to reduce risk and vulnerability and enable a future adapted NYC. We review methods for integrating community and stakeholder ideas about what would make NYC thrive with scientific and technical information on the possibilities presented by different policies and actions. In doing so, we synthesize the state of knowledge on how different communities of scholarship or practice envision futures and provide brief descriptions of the social-demographic and housing, transportation, energy, nature-based, and health futures and many other subsystems of the complex system of NYC that will all interact to determine NYC futures. For further consideration of energy and energy insecurity, and related issues in the transportation and building sectors, in the context of NYC's future, see NPCC4, Yoon et al., (2024). This chapter is a novel contribution to planning the city of the future through the new NPCC Futures and Transitions Working Group. The NPCC3 inventoried multiple NYC critical infrastructure domains and infrastructure resilience strategies to address climate risks (New York City Panel on Climate Change, 2019). Here we consider additional aspects of NYC's built, social, and natural infrastructure that were not fully considered in NPCC3 but have become especially salient. We provide the first of its kind of assessment for NYC of positive future visions, scenarios, and their intersections with current city challenges that can inform new modes and models for climate change policy, planning, and engagement across the diverse social and infrastructural fabric of the city. We hope the chapter contributes to assessing alternative visions, scenarios, imaginaries, and possibilities for a climate adapted, sustainable, and equitable future NYC.

2.2 Chapter Organization

In this chapter, we examine the state of knowledge on alternative futures and scenarios across sectors and approaches for NYC and assess how current planning and policy can take advantage of multiple tools for transformative climate action to achieve a more resilient, equitable, and sustainable future for the city.

NYC can only be resilient if it articulates inclusive visions, goals, targets, and clear strategies for ensuring an equitable city as well as the means to evaluate progress made towards these goals, strategies and implementation efforts (Blake et al., 2019; Jacob et al., 2010; Solecki et al., 2015; Solecki & Rosenzweig, 2020). Inclusiveness in resilience also requires that justice and equity be centered in all actions designed to address the growing climate challenge in the city (Foster et al., 2019).Thus, there is a clear need for many tools, and a plurality of perspectives, both to envision the future of NYC that is more resilient, equitable, and sustainable, but also to backcast from those visions to interrogate how current planning, policy, and actions at multiple scales are, or are not, creating the mechanisms for transforming and transitioning the city along trajectories that will lead us to the normative futures we aspire to.

The city already employs a wide range of practices to plan for its future and enable transitions for a climate adapted NYC. The concept of transition is a powerful tool with which to understand the dynamics of system change during development. Transitions can be defined as breaks in long-term trends and include both the quantities and rates of change in quantities of interest (National Research Council, 1999). Transitions may occur in any sector (such as energy) or process (such as population change). The community of climate and climate-related research offers additional concepts and tools for predicting the future. These concepts and tools differ largely by discipline with implications for how concepts and tools are used across temporal, spatial, and thematic scale, as well as opportunities for engagement. Yet, scholars have been increasingly interested in the concept of transitions as a way to manage change. There is a growing consensus that continuing to operate in a business-as-usual manner is insufficient for keeping humanity within a 'safe operating space' (Rockström et al., 2009).

In the sections that follow, we review some of the main concepts and tools and what they already tell us about the likely trajectory of the social fabric and climate of NYC. Much of the content of this chapter details methodologies that may be technical for some readers; our goal was not to alienate a broad audience but rather to be as transparent as possible to help move collectively into an interdisciplinary space. Though the focus of this chapter is largely on climate adaptation and resilience, climate mitigation goals and actions are discussed in context of how they can be addressed alongside adaptation strategies.

3 Concepts and Tools for Exploring the Future

This section outlines a number of useful planning approaches, beginning with an overview of the City's major planning exercises to place current efforts in context. Throughout this chapter, we refer to short-term as pertaining to the next decade, medium-term as referring to a period out 30-50 years (and frequently mid-century is used as a reference point) and long-term as referring to the future 80-100 years out, roughly at the end the 21st century. As the NPCC's end-of-century climate projections make evident, there is a commensurate need for long-term scenario planning in order to be resilient to climate challenges anticipated in coming decades, until the end of the century, and beyond.

3.1 Historical Context for New York City Comprehensive and Strategic Planning

Futures planning for NYC has a long history dating back to, at least, 1811, when the commissioners of the City developed the NYC grid to expedite the future of parcel sales and city growth (Jackson et al., 2010). Subsequent planning efforts included a number of important, but *ad hoc* efforts, such as the financing of the Erie Canal and the development of the city's water supply system (Jackson, 1993). The modern city planning era began with the City's 1916 Zoning Resolution.

It was the completion of the 42-story Equitable Building in Manhattan, NYC, in 1915, which set the stage for the nation's first comprehensive citywide zoning resolution. The law governing land use was a response to the perceived lack of sun and air and had enormous future impact on the development of the city as it established height and setback controls and designated residential districts that excluded other incompatible uses. The 1916 Zoning Resolution was amended frequently with major shifts in population and land use.

Eventually, powerful business associations, newspapers, real estate groups and influential residents pressed for an agency to administer the zoning regulations in a systematic fashion. Under Mayor Fiorello La Guardia, in 1936, the New York City Planning Commission was established, headed by Adolph A. Berle, who was shortly replaced by Rexford Tugwell, and included other notable New Yorkers such as Lawrence Orton, Cleveland Rodgers and Arthur V. Sheridan (City of New York Department of City Planning, 1989).

The City Planning Commission provided the structure for the professional application of comprehensive planning principles that replaced the previous haphazard development and zoning decisions driven by politically connected interest groups. The new Department of City Planning, headed by the City Planning Commission, was mandated to develop scientific processes that helped to identify the goals and aspirations for community development. The idea of comprehensive planning emerged in the 1920s and was embraced by Rexford Tugwell, previously a member of Franklin Delano Roosevelt's "Brain Trust" and head of the Resettlement Administration from 1935 to 1937 (Alvey, 2019). Comprehensive planning was based upon the notion that long term goals for a broad array of urban services important for the common good could be developed through consensus (Soomro & Williams, 2021). The comprehensive plan was promoted as the anecdote to "spot zoning".

Despite the promise of a scientific comprehensive plan for the city, however, efforts were met with fierce opposition (Nelson, 2018). For example, Tugwell's idea of a strong government that could deliver a unified vision for the city's growth, was harshly criticized by Robert Moses. Moses rejected the concept of government-sponsored master planning and preferred to pursue projects based upon available funding, the needs of private developers and his own political agenda (Chronopoulos, 2012). He successfully stopped early comprehensive efforts by the City Planning Commission for the next several decades (Alvey, 2019).

NYC underwent dramatic changes, particularly during the 1950s and 1960s. The Lindsay administration, in an attempt to address increasing poverty, white flight, urban renewal failures, and racial inequality, attempted the first comprehensive plan for the city, published in 1969 entitled, "*Plan for New York City: A Proposal*" (New York City Planning Commission, 1969). The focus of the plan was on employment opportunities, housing needs and community improvement, and community participation in development decisions. The plan also attempted to respond to critiques of comprehensive planning as representative of unrealistic and top-down approaches; rationalism involving the search for the 'optimal' strategies that either do not exist or are too difficult to implement (Boyer, 1986; Van der Heijden, 1996). What was different about this plan was that the Lindsay administration divided the city into 62 community districts (now 59) and subsequently held 62 separate public hearings on the plan itself. These meetings were intended to galvanize public support. Each community district was provided detailed information on the then-current trends within their regions, including, *inter alia*, the number of schools, quality of transportation and local development. The plan recommended municipal expenditures of $52 billion at the time (when the total city expenditures were around $8 billion), for projects that would last into the 1970s (Stein, 1976; Tolchin, 1971).

The attempt to garner community support ultimately failed as the plan drew criticism as a top-down approach that presented results to communities as a *fait accompli* with limited ability for local feedback (Gupte, 1973). Also, urban advocates, such as Jane Jacobs, were developing notions of the human, smaller scale, approaches to planning and along with anti-statists rejected "Big Planning" notions that were emblematic to comprehensive planning (Klemek, 2007, 2009). Indeed, the plan was never implemented.

The debate in NYC mirrored the national discussion over urban planning. Some advocated for comprehensive planning while others called for incremental methods (Lindblom, 1959). Incrementalists advocated for planning without radical change but rather for making land use decisions that could be implemented (Slusser, 2007). This often translated into planning for small areas or even individual parcels. When John Zuccotti headed the City Planning Commission in 1973, the notion of comprehensive planning was put aside. Zuccotti, sided with real estate and other non-statists to advocate for incremental methods. In 1975, the City Charter was amended, and the comprehensive plan requirement was repealed. Subsequently, the planning provision in the Charter was replaced by a provision for plans for the development, growth, and improvement of the city and of its boroughs and community districts, giving communities a larger voice in land use decisions (see the New York City Charter, Chapter 8, Section 197a (City of New York, 2023b)). This new mandate helped to stimulate community planning efforts. At the same time, the new charter made provisions for the Uniform Land Use Review Procedure (ULURP) (Eldredge, 2015). ULURP, and later, the Environmental Impact Assessment review, both of which reviewed individual development proposals, became the major tools to assess and regulate the city's land use for the next several decades. The thinking behind these procedures was to allow the affected communities the opportunity to stop a development or find common ground and come to a compromise with the developer. The 197a and ULURP provisions were the compromise that continued efforts to control development but prevent Robert Moses-like large infrastructure projects (Eldredge, 2015). The result of these rules was to make comprehensive planning for the city difficult if not impossible.

During the following decades, NYC underwent further dramatic transformations as its economic base shifted to business and professional services, which along with an international attractiveness and strong national political and cultural status, drove its growth to new heights. It was one of the first identified global cities (Sassen, 1991). During this period, NYC experienced a rebirth as crime dropped and population increased. Planners responded during this era with new future planning approaches, including strategic planning. Strategic planning is a flexible on-going process that attempts to identify major goals, mandates, and challenges for the future. It is a deliberative and iterative process that helps organizations address what they do and why (Bryson et al., 2018). Typically, strategic plans are for the near term (3-10 years), are not as all-encompassing as comprehensive plans and are not mandated by statute. At the same time, strategic plans help decision-makers allocate resources to attain goals. Strategic planning is somewhere in-between incremental and comprehensive planning. The Department of City Planning (DCP), under Mayor Rudolph Giuliani, developed a strategic plan for the "Far West Midtown", which outlined the development of the area from 8th Avenue to the Hudson River and 42nd St to West 24th street, now almost completely built. Subsequently the DCP produced other strategic plans in 2011 and 2018 (City of New York Department of Environmental Protection, 2023b). These strategies helped to outline a vision for a particular area of the city and encourage private development to meet these goals. These strategies often included rezonings.

In the background of growth and global city status, however, were larger processes that were gaining the attention of scholars, practitioners, advocates, and residents. Sustainability and climate change concerns mounted as information on environmental degradation, pollution, biodiversity loss and a changing climate mounted. These trends have brought significant uncertainty to futures and the need to adapt quickly to major changes has become a crucial factor for planning success. Hence futures planning demanded the timely production of accurate information on widespread political, environmental, economic and societal changes (Chermack & Lynham, 2002; Varum & Melo, 2010).

The Bloomberg administration turned the City's attention to environmental concerns through what they termed a "comprehensive sustainability agenda," which included 127 policy initiatives to achieve ten overarching goals to improve the infrastructure, environment, and quality of life in the city (City of New York Office of the Mayor, 2007). *PlaNYC, A Greener Greater New York* was followed by the *NYC Special Initiative for Rebuilding and Resiliency* (City of New York Office of the Mayor, 2013b, 2013a), another citywide report published after post-tropical storm Sandy hit the city. These plans were followed by the next administration, which included many of the same themes in their reports but put a focus on resilience and equity (City of New York Office of the Mayor, 2019).

These publications were not without critics, who argued that the mayors' "plans" were top-down, lacked important social considerations, and were developed without community involvement (Angotti, 2010; Marcuse, 2011; Rosan, 2012). While these documents lacked the elements that detractors mention, they also increased attention on the importance of critical infrastructure, broadened public responsibilities in provision of these services, focused on housing and transit-oriented development and were first steps toward addressing environmental justice for under-resourced communities (Mandelbaum, 2007; Rosan, 2012).

The publishing of the Bloomberg and de Blasio plans also brought back interest in comprehensive futures planning for NYC (New York City Council's Office of Strategic Initiatives, 2020; Soomro & Williams, 2021). The Regional Plan Association, working with a number of other groups, put together a comprehensive citywide planning framework that they claim would provide the rationale for bridging the dislocation of comprehensiveness and community participation for an "inclusive city" (Regional Plan Association, 2018). How comprehensive planning can offer a unified city vision through bottom-up participation remains unclear (Kahila-Tani et al., 2019; Wamsler et al., 2020).

3.2 The Emergence of Scenario Planning

An alternative approach that has increasingly been recommended as a tool to improve urban decision-making under increasing uncertainty is scenario planning. Scenario planning assumes that the world is unpredictable, and no single plan or strategy can be relied upon to address the future. The scenario approach focuses on identifying trends and uncertainties, so as to allow decision makers to overcome tunnel vision and siloed thinking (Schoemaker, 1995). Scenario planning also makes use of community participation that helps to create alternative representations of the future. Hence, scenario planning has been defined by Roubelat (2000) as a networking process that challenges strategic paradigms and forces organizations to rethink their internal and external boundaries. According to Finn and Miller (Finn & Miller, 2022) the value of scenario planning derives from both its use of scientific data, but more importantly its use of narratives and stories to engage a diverse public in deliberations around critical issues and potential strategic approaches to planning for the future. As opposed to merely, or only, scientific data or quantitative projections of the future, scenario planning relies heavily on the power of narrative and stories to engage participants.

The scenario approach was introduced into planning with adaptational impact assessment (Duinker & Greig, 2007) and formalized with the National Environmental Policy Act (National Environmental Policy Act, 1970), which had state and local spinoffs, including the New York State Environmental Quality Review Act (State Environmental Quality Review, 1975) and the New York City Environmental Quality Review Act (City of New York Office of the Mayor, 1973). These acts required the evaluation of different environmental impacts related to the proposed project as well as community input. The scenario component required the developer to provide a range of alternative schemes with subsequent environmental impact evaluation (NYS DEC Division of Environmental Permits, 2020). Environmental review, however, was only initiated when projects required approval from the City for discretionary actions, such as the issuance of permits, City funding requests, or agency rulemaking, and therefore were not universally applied to all developments.

Scenario planning was adopted widely by the mid 1990's (Chakraborty et al., 2011). The practice has been applied in some international and national contexts and is now being used at the urban scale (Chakraborty & McMillan, 2015). For example, in NYC, scenario planning is currently beginning to be used in the NYC business community (Crain's New York Business, 2022). The use of this approach has been given encouragement by the development of new computer tools that support spatial data and visualization (Klosterman, 2013). Moreover, the approach is the prescribed method in federally funded land use and transportation planning activities such as for Sustainable Communities Regional Planning Grants (City of New York Department of City Planning, 2011) and the Moving Ahead for Progress in the 21st Century program (Rep. Mica, 2012). Also, important for its increasing popularity is that planning groups, such as the American Planning Association (2023) and the Lincoln Land Institute (2023) are now supporting its implementation.

Scenario planning is alike, but not the same as climate scenarios. While climate scenarios include descriptions of historical key events, the focus of scenario planning is typically on the end-state, which is envisioned prior to the analysis (Finn & Miller, 2022). That is, scenario planning employs a backcasting approach to understand how the various futures emerge. Then the process includes development of strategies to help achieve desirable futures and avoid undesirable ones. Moreover, future scenarios need only be "a description of a possible or probable future" and not be quantitatively identified (Chermack & Lynham, 2002). As such, issues to watch out for include adequate consideration of uncertainties, an overemphasis on "picking" a preferred future (Chakraborty et al., 2011), and a lack of effective public involvement (Bartholomew, 2007). Nevertheless, the usefulness of scenario planning in the urban context is increasingly appreciated. Questions remain, however, about how best to move forward and incorporate scenario approaches in both private and public planning exercises.

We next turn to other planning frameworks that are used in the City and climate community.

3.3 Planning the Future Through Scenarios, Forecasts, and Projections

Different scientific and planning communities have adopted specific tools to conceptualize and estimate futures. In this section, we explore the dominant tools the climate community uses to envision the future. We focus broadly on scenarios as a tool for examining the future. Specifically, we review projection scenarios and tools, as well as other exploratory and normative scenarios, visions, and futuring processes that concern (drivers of), adapting to and responding to climate change and its impacts. Scenarios are plausible, coherent narratives about the future of a place or a situation that have a consistent internal logic (IPBES, 2019; Iwaniec et al., 2014; Moss et al., 2010; Reid et al., 2005). Scenario development approaches can consider future projections (prediction or forecasts of what will happen), exploratory scenarios (what can happen), and/or normative future scenarios (what should happen). Some communities of practice use these terms interchangeably while others do not, often creating confusion in interdisciplinary settings. We aim to use terms as specifically as possible here.

Projections of future conditions, sometimes called predictive scenarios or forecasts, extrapolate future conditions based upon predefined models of historic and existing trends. Predictive scenarios typically use quantitative models to suggest a specific outcome at a specific time in the future given a set of trend parameters. Examples of predictive, forecasted scenarios include business-as-usual projections of future land use change (Mustafa et al., 2021), NPCC climate and sea level rise projections (Gornitz et al., 2019), and local or national population projections, such as those from the NYC DCP (2013). Climate projections and international population projections provide a framework for understanding potential future changes with running 30-year averages centered on a decade, such as 2050s, 2080s, 2100s (See NPCC4, Braneon et al. (Braneon et al., 2024)). In order to project the future in 80-100 years, model projections require quantitative historic data, which is a requirement that limits projections to basic demographic or climatic futures.

Exploratory scenarios, and other normative future visions or narratives, are another important tool for cities to anticipate and explore climate adaptations. Exploratory scenarios are often developed in collaboration by many different disciplines and stakeholder communities. Thus, exploratory scenarios can be a tool to integrate diverse forms of data and knowledge about the future, challenge assumptions about anticipated future outcomes, integrate multiple drivers of change, compare alternative policies and pathways to achieve policy goals, and guide decision-making that is flexible and robust (Elsawah et al., 2020). While based on data representing past trends, exploratory scenarios and visions use other methods to imagine the future and thus have more thematic flexibility and ability to explain futures farther out in time.

Business-As-Usual (BAU) projections or scenarios are just that: Based on analysis of current trends using a variety of approaches discussed below to extrapolate emergent trajectories, this method is used both in projections and scenario development. Notably, the BAU conditions are often used as a baseline or reference projection or scenario to compare to more extreme projection assumptions or normative possibilities (Mustafa et al., 2021).

Tools for exploring the future have been widely developed at a global scale and applied by the international scientific community. However, less work has been done at regional or city scales (Reimann et al., 2021; Rohat et al., 2021). City planners and agencies routinely engage in planning exercises for NYC, including developing a range of scenarios and visioning processes. In the remainder of this section, we unpack some of the key aspects of each of these tools, the scale at which they occur, and the themes that they cover.

3.4 Projecting the Future

Prior NPCCs have made great strides in projecting future climate conditions and evaluating how risk is considered and planned for in the City (Solecki & Rosenzweig, 2019). Prior NPCCs have paid much less attention to scenarios and projections of how the built, natural, and social environment is likely to change and interact with changing climate hazard and other environmental conditions, though health concerns were introduced in NPCC2 (New York City Panel on Climate Change, 2015) and equity in NPCC3 (New York City Panel on Climate Change, 2019). Many sectors beyond climate variables – such as changes in the built environment and surface makeup – will influence how resilient or not an NYC urban future may be. Alternatives to climate futures are important for many reasons, not least of which is the opportunity to examine the dynamic interaction between other drivers of risk and vulnerability that are often created by urban development and decision-making (C. Rosenzweig & Solecki, 2018).

Projections of future climate parameters as well as flooding and demographic conditions are critically important – if used together – for understanding the challenges to achieving resilience. Yet, as we describe below, they are often at coarse spatial and temporal resolutions and lack utility without further downscaling efforts to describe potential future risks at the scale of neighborhoods (and potentially by types of households). Owing to their methodological differences and spatial and temporal resolutions (varying from 1-hour stormwater scenarios to decadal population futures), projections of climate and demographic futures are not frequently used together in local planning processes but rely on other approaches such as scenarios (described in the following section) to connect them. It is, therefore, useful to begin this review with the projection efforts themselves.

3.4.1 Climate projections

Since its inception, the NPCC has proposed a risk management framework to mitigation and adaptation (Yohe & Leichenko, 2010). In the selection of emissions scenarios, NPCC's risk management framework suggests that adaptation planning should consider outcomes with particularly adverse consequences, such as those found in projections that may not be likely but present high impacts. In the first report, this approach led to climate projections developed using the high emissions A2 scenario. Climate projections now use Representative Concentration Pathways (RCPs) to identify plausible scenarios for greenhouse gas concentrations (i.e., emissions) in future projections of temperature and precipitation. Subsequent reports use high emissions global climate scenarios such as RCP8.5 to represent the high risks linked with low to no mitigation at global scales throughout the 21st century alongside other scenarios with lower emissions and thus lower climate-related impact (Braneon et al., 2024).

In the IPCC AR6, there is a new framework that has been utilized to design scenarios that combine socio-economic and technological developments, known as the Shared Socio-economic Pathways (SSP) (Riahi et al., 2017). The SSPs are scenarios of projected socioeconomic changes across the globe through 2100 that are consistent with different emissions scenarios. An experiment named the Scenario Model Intercomparison Project developed a set of nine scenarios of future greenhouse gas emissions trajectories (O'Neill et al., 2016). These nine scenarios aggregate into two smaller groups; four scenarios that update the RCPs from the Coupled Model Intercomparison Project Phase 5 (CMIP5), which produce equivalent radiative forcing levels (2.5, 4.5, 6.0 and 8.5 W/m^2) and five new scenarios that were not included as part of the prior RCPs. NPCC4 climate projections follow this approach with the use of the AR6 scenario framework that combines SSPs with RCPs, using the SSP5-RCP 8.5 and SSP2-RCP 4.5 scenarios, which represent greenhouse gas emissions pathways with 8.5 W/m^2 and 4.5 W/m^2 by end of century, respectively. These two scenarios replicate those used in NPCC3.

Climate projections in NPCC were produced with the output of General Circulation Model (GCM) simulations from the Coupled Model Intercomparison Project 6 (CMIP6). An ensemble of 35 models across the two scenarios was used, producing a 70-member matrix of outputs for temperature and precipitation. This ensemble matrix was then used to produce projections of annual mean and extremes temperature and precipitation. GCMs produce information at spatial resolutions ranging from ~0.5° to ~1.5°. In order to develop projections for NYC, the data point over land that is closest to the city was selected to produce single-point projections. These projections are then presented as a range of low end (10th percentile), a middle range (25th to 75th percentile) and high end (90th percentile) estimates for several 30-year time slices of interest (i.e., the 2030s, 2040s, 2050s, 2060s, 2070s, 2080s).

3.4.2 Population projections

Population projections provide fundamental demographic information for socioeconomic and environmental outlooks. Using several different methods and approaches, models to project changes in population sizes, compositions, and spatial distributions cover a range of population trends and produce a set of plausible demographic futures. However, for local areas such as cities, these tend to be short-term (no more than 40 years out) (Balk et al., 2022). For example, the cohort-component model (Burch, 2018) is used by most state and local planning agencies as it is robust (i.e., replicable and verifiable), has simple data requirements (which have improved substantially in recent decades), and is transparent to a wide range of users (O'Neill et al., 2001). This method is based on the current size and age composition of the population and on assumptions of demographic change—fertility, mortality, and migration—rather than simply extrapolating trends in population counts over time. The cohort-component model examines not only change in the total population but also its demographic composition (age, sex) and sometimes other characteristics such as race and ethnicity (see for example, the State of California county-level projections (State of California, Department of Finance. Demographic Research Unit, 2023)). At a city or local level, the cohort-component model often encounters data limitations for population characteristics (or demographic traits) beyond age, sex, fertility, and mortality or cannot be applied at fine-scale geographies (such as neighborhoods or census tracts). Other models examine small-area population projections, such as the Hamilton-Perry Method (Hamilton & Perry, 1962) and methods that proportionally allocate projected city-level population to sub-city districts based on the current population distributions (Smith et al., 2002). Such approaches may be adequate for the short-term of 40 to 50 years (Swanson & Tayman, 2017), but cannot capture long term projections of population at sub-city scale.

The Population Division of the New York City Department of City Planning (DCP), produces short-to-medium term population projections for NYC's boroughs using the cohort-component model (City of New York Department of City Planning, 2013). These projections are part of a larger effort with the New York Metropolitan Transportation Council (NYMTC) (New York Metropolitan Transportation Council, 2020b), which is mandated by federal transportation legislation to produce county-level projections for the 31-county region for its Socioeconomic and Demographic (SED) forecasts to qualify for federal transportation funds, as described in Balk et al. (2022, p. 9). The methods used for the City's 5-borough projection and the NYMTC ones differ somewhat from one another – primarily by use of additional ancillary information in downscaling methods – and therefore both are described here. The cohort-component demographic model used for the projections for both NYC and the 26-county region outside of NYC relies on U.S. census data for the base population input, so projections are typically created soon after decennial data are released. The most recent population projections available on DCP's website are from 2013, which were used for the NYMTC 2050 Socioeconomic and Demographic (SED) forecasts, and DCP was tasked in 2018 to produce interim projections for the NYMTC 2055 SED forecasts, which were adopted in October 2020.

NYC's population projections were produced for each of the city's five boroughs by age and sex with 5-year intervals (City of New York Department of City Planning, 2013). Inputs include average county-level fertility, mortality, and net migration rates. Migration, net of both international and domestic flows, was calculated using a survival-rate method. For all but the youngest age groups, net migration is derived as a residual by applying mortality rates and "surviving" an enumerated population, yielding an "expected" population for each age/sex group five or ten years later. This *expected* population is then compared to the *observed* or actual population; the difference, or residual, is net migration (from which crude migration rates are derived). For the period of the projection, fertility is assumed to be unchanged, while survival rates increase by one-half of the US Census Bureau's national trend. In addition to the demographic model, DCP analyzes the demographic outputs in the context of a housing model to ensure that the resulting population could be reasonably accommodated given the City's current land use and zoning. Through an iterative process, DCP adjusts the crude migration rates to bring the population and housing model in sync. Assumptions on land use, zoning, and housing construction act in essence to limit population growth through adjusting crude migration rates. DCP's final projections are allocated down to transportation analysis zones (TAZ) (see https://www.nymtc.org/portals/0/pdf/SED/2040%20Final%20Draft_TAZ_report.pdf for the criteria upon which more than 3,500 TAZ units are defined), which are akin to census tracts and are based on projections of housing units and land use for these small areas.

Similar to the NYC county-level projections, NYMTC's projections for the 26-county region outside NYC also uses the cohort-component model. The migration rates for this set of counties incorporate a labor induced net migration adjustment to account for projected employment demand. NYMTC's projection with its focus on transportation also includes many additional variables in its model, including those derived from surveys (and other sources) on commuting, transportation, jobs and industry development, and more (New York Metropolitan Transportation Council, 2020a). For the 26-county region, a spatial allocation method was used to downscale population to TAZs, resulting in a final product that is spatially refined. Because NYMTC brings together representatives from many city and municipal agencies, part of the production of the final projection includes engagement with these stakeholders. The publicly available projections represent only one population future scenario: The scenario for NYC was based on a set of assumptions including current fertility levels remaining unchanged, increased survival rates based on national trends, and the adjusted crude migration rates by housing limits. For the non-NYC counties, the scenario was based on a set of assumptions including logarithmically projected fertility rates, increased survival rates based on national trends, and migration rates with labor induced migration adjustments (New York Metropolitan Transportation Council, 2015).

Additionally, DCP produces many tools and resources (City of New York Department of City Planning, 2023a) to interface with census data and showcase population and socioeconomic characteristics of the city from the neighborhood to city scale. While these tools are not intended for medium (20-40yrs)- or long-term (40-100yrs) population projections, they establish current patterns and trends showing spatial variation across the city, and are publicly available and easy to access, making them especially valuable for engagement with communities. DCP's tools include Population FactFinder with profiles of local communities, as well as a map reliability calculator, which shows how ACS data can be used reliably. Since much of the local-area data come from the US Census American Community Survey (ACS) which, unlike the full census head-count data, is drawn from a representative sample, those data are therefore subject to sampling error (Donnelly, 2013, 2020). The tool helps users understand how to reliably use ACS data at small geographic levels. DCP also produces reports of short-term (recent decadal) neighborhood change covering important topics like migration (City of New York Department of City Planning, 2023b) and racial and ethnic composition (City of New York Department of City Planning, 2021a).

To date, the City's projections do not yet include information about land use patterns associated with future climate (such as flood-prone regions) nor do they make assumptions about demographic futures that would be consistent with different emissions pathways and associated climate futures. As discussed in the next section, other tools are used to generate such population futures consistent with socioeconomic development pathways that are linked to different climate futures. These typically conform more to the specification of exploratory scenarios (even if the approaches blend the above methods with longer-term scenarios development) and are implemented at national or regional spatial scales rather than the city scale (see review in Balk et al. (Balk et al., 2022)).

3.4.3 Health valuation

As showcased below (BOX 4), one commonly used tool for evaluating whether a policy or investment in the future should be undertaken, as well as one other construct that can be used to evaluate plans or transitions to the future, is economic valuation of outcomes related to the impact of climate change. These tools are sometimes, but not usually, applied to health outcomes. Health-related costs of climate-related health conditions and deaths are not typically estimated, in and of themselves or as part of evaluating health or other sector policies to reduce the negative impacts of climate change (Limaye et al., 2019). As part of an ongoing Vulnerability, Impact, and Adaptation (VIA) Analysis to study climate change's impacts on decision-making in NYC, a research team is reviewing published reports on the impacts of climate-sensitive events in NY from 2000 to 2020, then evaluating their health-related costs (McPhearson et al., 2024). A wider range of societal costs to NYC for care of climate-sensitive illnesses and premature loss of life are being developed for the city and will be reported separately. The evaluation of health-related costs will inform analyses of potentially avoidable, associated past, current, and future health costs under plausible climate change scenarios (see NPCC4, Matte et al. (Matte et al., 2024)). Such valuations can be forward-looking by accounting for future population shifts (e.g., more older adults) and future climate projections (e.g., more hot days).

3.5 Exploratory and Normative Scenarios

Exploratory scenarios (sometimes called foresighting) explicitly consider emerging trends and uncertainties, while exploring a variety of possible "what if" future pathways and outcomes. Exploratory scenarios are created through identifying key drivers and how they might evolve based upon pathway assumptions, sometimes called storylines (Hunt et al., 2012; van Vuuren et al., 2012). In other words, rather than only examining 'what is most likely' as in predictive scenarios, exploratory scenarios anticipate a range of 'what is possible' based upon potential pathways in different storylines. No specific pathway has priority within the exploratory ensemble in defining the future, rather, exploratory scenarios are used to examine the interplay and influence of drivers. Examples of exploratory scenarios include the Shared Socio-Economic Pathways (SSPs) (O'Neill et al., 2014, 2020) and Millennium Ecosystem Assessment (2005) scenarios.

Normative scenarios are created by first defining a future target—often a desirable future outcome based on values and preferences that align with sustainability and resilience goals about "what should happen." After defining the normative future target, the process to identify the pathways of how to get from the present to this future often occurs through quantitative and/or qualitative backcasting (Vergragt & Quist, 2011) or scenario-discovery techniques (Gao & Bryan, 2017).

Examples of exploratory scenarios include the first ever citywide extreme rainfall driven flood projections for NYC, which it released as part of the first NYC Stormwater Resiliency Plan (2021). The projections include the output of a city-wide modeling effort to map urban flooding according to two rainfall scenarios: moderate and extreme. The moderate scenario corresponds to a 1-hour, 10-year storm (approximately 2 inches) and 2.5 feet of sea level rise above a 2000 baseline, based on the estimates for 2050 made by the NPCC. The extreme scenario corresponds to a 1-hour, 100-year storm (approximately 3.5 inches) and 4.8 feet of sea level rise (NPCC's 90th percentile estimate for 2080) (Gornitz et al., 2019) (see NPCC4, Rosenzweig et al. (B. Rosenzweig et al., 2024)). The NYC Stormwater scenarios released publicly as maps of potential flooding extent and depth provide a first attempt at mapping a source of urban flood risk that, unlike coastal and riverine flooding, is not mapped and accounted for in the U.S. Federal Risk Rating Map (Qiang et al., 2017). The release of these exploratory scenarios to examine potential future flood risk driven by extreme rainfall, however, focus on flooding in right-of-way locations such as streets and sidewalks, while private parcels, parks, and highways were not considered due to a lack of data related to their drainage infrastructure. This omission highlights ongoing data limitations for such detailed climate risk scenarios and both the need for improved data sources to support such model driven scenarios, but also for a plurality of scenario approaches to envision alternative futures for NYC.

3.5.1 Plausible versus desirable futures

In scenario development, it is understood that the future cannot always be accurately predicted and that many futures are likely. Thus, future visions for inclusive climate resilience must integrate perspectives across multiple sectors, scales, and communities to ensure a plurality of ideas, innovations, and actions. Moreover, positive, desirable visions are needed to guide urban planning as a counter to negative discourse on expected urban futures if there are no interventions. The process of positive visioning involves creativity, allows for radical departure from the status quo, and focuses on the pathways needed to achieve desirable outcomes. Building on the more sustainable, low-carbon lifestyle afforded by NYC's compact urban form, walkable neighborhoods, and transit access, a positive future scenario framing can be used to compare multiple, alternative future goals, pathways, and outcomes. Through positive visioning, we can explore both plausible and desirable futures.

Plausible and desirable futures look beyond just what is likely to happen and allow us to consider what is possible. Plausible futures address how we would like to respond, while accounting for the existing context and future projected challenges. In contrast, desirable, or aspirational, futures integrate normative perspectives on what the future should look like (Iwaniec et al., 2020). Desirable or aspirational visions typically have a long-term (multi-decadal) time horizon. The longer time horizon in future visioning is critical to overcome political barriers and allow adequate time and resources for the reconstruction of infrastructure and buildings (e.g., electrification of energy services). Examples include NYC 80x50 roadmap (City of New York, 2016).

Plausible visions can focus on short or longer-term actions. The plausible near-term actions can either be consistent with a desirable long-term vision (e.g., NYC streets master plan) or can lock-in or amplify maladaptive patterns of development (e.g., widening highways (Weinberger, 2022)). Just as some current policies and features are the result of decades of incremental change and are now understood to be maladaptive, near-term, feasible and desirable incremental changes can help build a pathway to a desirable future and avoid or reverse maladaptation.

3.5.2 Shared socioeconomic pathways (SSP) exploratory scenarios

Climate projections use Representative Concentration Pathways (RCPs) to identify plausible futures for greenhouse gas concentrations in future projections of temperature and precipitation. Similarly, the Shared Socioeconomic Pathways (SSP) describe alternative future socio-economic and demographic visions (BOX 1) consistent with those RCPs (O'Neill et al., 2020). Alternative spatial population projections are important for examining potential future changes in land use and land cover, energy use, greenhouse gas emissions, transit, and water availability that will have compounding and differential impacts on climate hazard exposure throughout the city (Güneralp & Seto, 2013; MacManus et al., 2021; R. I. McDonald et al., 2011; Meiyappan et al., 2014; Riahi et al., 2011; Sampedro et al., 2022; Shepard et al., 2012). Each SSP scenario represents a plausible and unique future based on estimates of future fertility, mortality, or education (KC & Lutz, 2014, 2017; van Vuuren et al., 2017) and assumptions about the spatial pattern of development and population distributions. Typically, the SSP's and demographic forecasting have been applied globally, and more work is needed to examine future population scenarios at a regional and city level (Balk et al., 2022; Hauer, 2019; Jiang et al., 2020; Kebede et al., 2018; Rohat et al., 2019; Striessnig et al., 2019). In particular, the SSP-RCP-SPA scenario framework has been used to construct local scenarios of particular outcomes (such as heat-related mortality) in Boston, MA and Houston, TX (Lino et al., 2019; Rohat et al., 2019) and infrastructure in Tokyo, Japan (Kamei et al., 2019).

The relationship between the RCPs and SSPs is visualized in Figure 1. Panel (a) compares RCPs in order of increasing mitigation action (Y-axis) and SSP narratives in order of increasing mitigation challenges (X-axis). The boxes represent the extent to which Integrated Assessment Models (IAMs) were able to successfully reach the RCP target within the greenhouse gas futures described by the SSP (Hausfather, 2018). For example, the numbers in the RCP 2.6/SSP3 box (0/4) indicates that four IAMs tried to achieve RCP 2.6 within the SSP3 narrative, and none was successful. Conversely, the four IAMs associated with RCP 3.4/SSP3 were all successful in reaching the RCP target.

Panel (b) illustrates energy use in 2100 by IAM (along the bottom) for each SSP (along the top). Energy sources embedded within each IAM are color coded in the bars (Hausfather, 2018).

Panel (c) is an overarching view of the SSP-RCP Scenario Framework, which integrates the climate futures described by Representative Concentration Pathways (RCPs), societal futures described by Shared Socioeconomic Pathways (SSPs), and climate policy responses represented by Shared Climate Policy Assumptions (SPAs) into a unified research framework (O'Neill et al., 2020).

Importantly, a future with low mitigation (therefore appearing to the right side of Figure 1, Panel a, as having high mitigation challenges) – which is represented by RCP 8.5 – is only found in one of the SSP narratives (i.e., SSP5). NPCC4 climate forecast includes RCP 8.5, and therefore the population projection should also include an SSP5 future, along with other SSPs (NPCC4 climate projects also use an RCP of 4.5.). Results of research underway that spatially project population out to 2100 for NYC consistent with RCP 4.5 (SSP2 and SSP3) and RCP 8.5 (SSP5) is reviewed in Section 5.

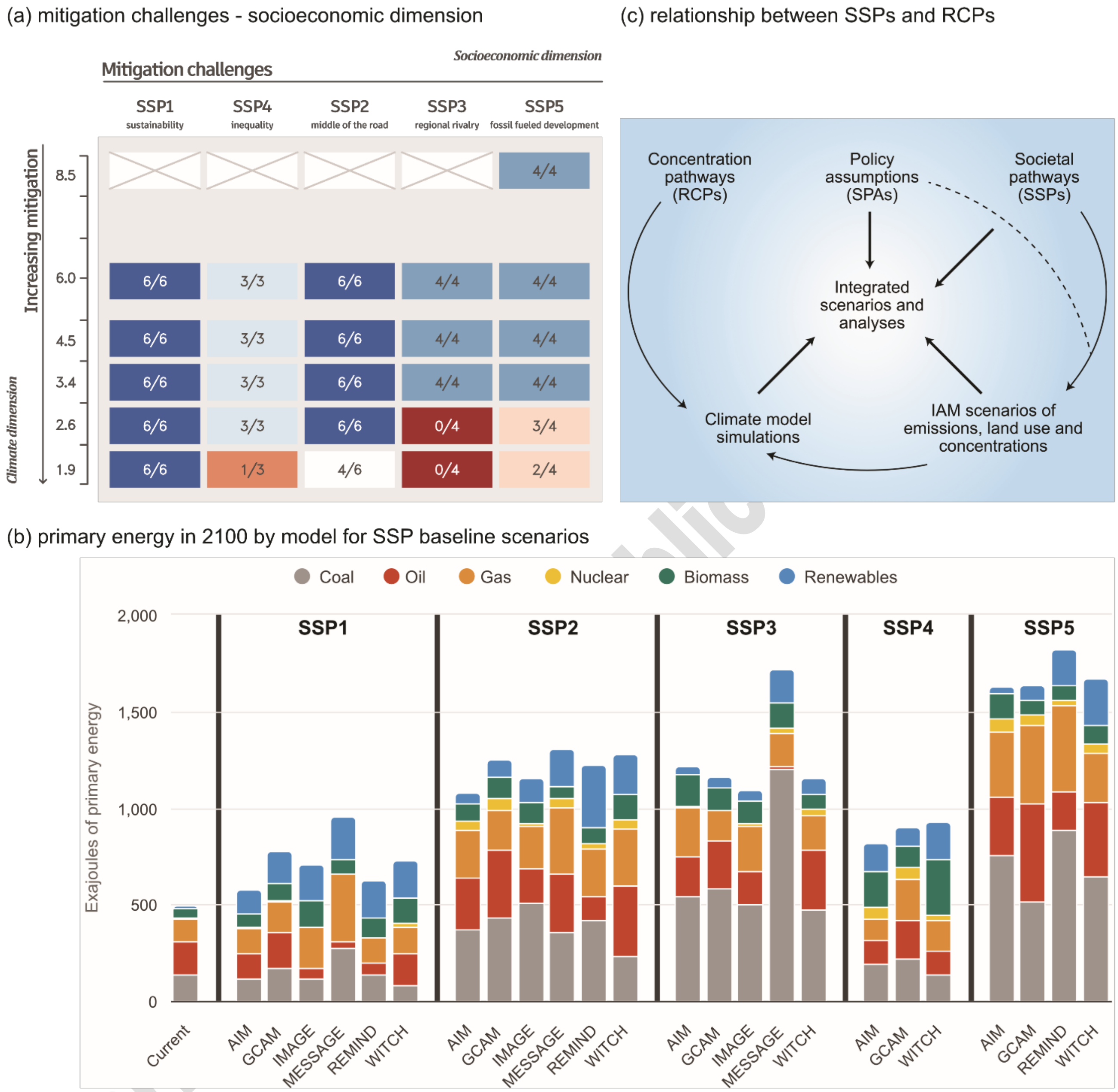


Figure 1: Panel (a).Mitigation challenges evaluated along a socioeconomic dimension. Chart by Carbon Brief (Hausfather, 2018); Panel (b) Global primary energy use by fuel type in 2100. Chart from Carbon Brief (Hausfather, 2018); Panel (c) The SSP-RCP Scenario Framework (O'Neill et al., 2020, p. 1075)

BOX 1: A brief description of five global Shared Socioeconomic Pathways (SSP)

SSP1 is a sustainable future. There is greater investment in education and health, and consequently greater equity; consumption in SSP1 is oriented toward low material growth and lower resource and energy intensity.

In an **SSP2** world, future patterns do not deviate much from historical patterns. Population growth is moderate, leveling off after mid-century. While some countries thrive in economic growth, others do not. Income inequality persists or improves slowly and vulnerability to societal and environmental changes remains.

An **SSP3** world is focused on competitiveness and security. Countries focus on achieving energy and food security goals within their own regions at the expense of broader-based development. Regional conflicts push countries to increasingly focus on domestic or, at most, regional issues. Investments in education and technology decline, economic development is slow, consumption is material-intensive, and inequalities persist or worsen over time. Population growth is low in industrialized but high in developing countries.

SSP4 sees highly unequal investments in human capital, combined with increasing disparities in economic opportunity and political power, leading to increasing inequalities and stratification both across and within countries. Over time, a gap widens between the globally connected knowledge and capital-intensive sectors and society, and fragmented lower-income, poorly educated societies that work in a labor intensive, low-tech economy. Environmental policies focus on local issues in middle- and high-income areas.

SSP5 relies on competitive markets, innovation, and participatory societies to produce rapid technological progress and development of human capital. The path to sustainable development is integrated with global markets and strong investments in health, education, and institutions to enhance human and social capital. These goals are coupled with the exploitation of abundant fossil fuel resources and the adoption of resource and energy intensive lifestyles. Together, these lead to rapid growth of the global economy. Population peaks and then declines by the end of the 21st century. Local environmental problems like air pollution are successfully managed.

Full descriptions in Riahi et al. (2017) and Hausfather (2018).

NYC has used a variety of different exploratory scenarios in some sectors. Notably, the NYC Mayor's Office has articulated a series of visions, actions, and exploratory scenarios in the OneNYC 2050 Building Strong and Fair City report. OneNYC 2050 highlights goals for future just and equitable governance, economy, health, education, transit and housing services, and infrastructure, while acknowledging the impacts of future climate change (City of New York Office of the Mayor, 2019).

Another example comes from the NYC Housing Authority which uses advanced planning approaches driven by concerns about climate impacts and vulnerability. In 2014, NYCHA created an office of Recovery and Resilience within the Capital Projects Division to address damage from post-tropical storm Sandy, build resilience within buildings to similar storms that may occur in the future, and to analyze and advise on future climate hazards for the Authority. In 2020, after an examination of NPCC's climate projections, NYCHA analyzed vulnerabilities and developed a set of strategies with seven key goals including: enhancing resilience into NYCHA's capital budget, fostering the health the NYCHA's urban forests, expanding reliable, efficient cooling in NYCHA apartments, preparing NYCHA structures for heavier, more frequent flooding, protecting critical infrastructure at developments exposed to coastal flooding, preparing for additional hazards including rising groundwater and extreme winds, and investing in social resilience across NYCHA campuses.

The DCP has been working with communities throughout the flood hazard areas of NYC to identify zoning and land use strategies to help to reduce flood risk. This includes proposals to make permanent and improve upon existing zoning rules that were adopted on a temporary, emergency basis following Sandy. These zoning rules were formally adopted in 2021 (Zoning for Coastal Flood Resiliency, 2021). This strategy would enable new and existing buildings to comply with zoning and building code requirements in order to be better prepared to withstand future storms. Additionally, DCP recommended expanding the applicability of zoning rules to include areas that will be subject to high-risk flooding in the future. Doing so would allow buildings that are not currently required to meet flood resilient construction standards to also make resiliency improvements in advance of being mapped within the 1% annual chance floodplain. Finally, DCP also developed guides for flood-resistant building construction in urban areas.

While adaptation is an important climate goal it is clear from current planning in the City and from community-based plans that adaptation must also be implemented with equity as a goal. These two goals can sometimes be in conflict. For example, gentrification, or the displacement of populations from neighborhoods due to rising property values, increasing rents, upzoning, and other core gentrification drivers can also be partly related to greening and climate policies, an increasing concern among vulnerable communities in NYC (see NPCC4, Foster et al. (Foster et al., 2024)). There are examples of community residents who resist green infrastructure in their neighborhood because of concerns that greening may be part of a mix of drivers causing potential displacement. Communities, planners, academics, and the City have noted that resilience planning must include ways in which members of the community can also benefit from climate and greening policies (Amorim-Maia et al., 2022; Bautista et al., 2020; City of New York Mayor's Office of Climate & Environmental Justice, 2023; City of New York Office of the Mayor, 2023; Riverkeeper, 2022).

4 Futures Planning Considering New York City as a Complex System

Transforming NYC to be flexible, adaptive, and resilient requires the capacity to build, design, and plan for complexity (Chester et al., 2023; McPhearson, 2020). Cities have many interacting and interdependent social-economic, ecological-biophysical, and technological-infrastructure systems and NYC is at risk from climate change precisely because of its dense concentration of people, infrastructure, and economies. A key challenge is understanding and governing this complexity, with the additional pressure of climate change (Meadows, 2008) and imagining, planning, and implementing solutions that will be robust in the real-world context of the complex social-ecological-technological systems (SETS) of NYC is critical (McPhearson, Pickett, et al., 2016; Pineda-Pinto et al., 2021). Importantly this is the approach taken in the IPCC's 6th Assessment (Figure 2) to address the complex and cascading impacts of rapid-onset events (e.g., storm surge) and slow-onset chronic events (e.g., everyday flooding) that are likely to occur in cities (Dodman et al., 2022). Since cities are complex systems characterized by irreducible uncertainty, emergent properties, and non-linear behavior that can respond to and learn from changing conditions (Alberti et al., 2018), framing cities as complex SETS provides a conceptual foundation for examining how SETS dimensions interact and affect their individual and collective contributions to climate risk and resiliency.

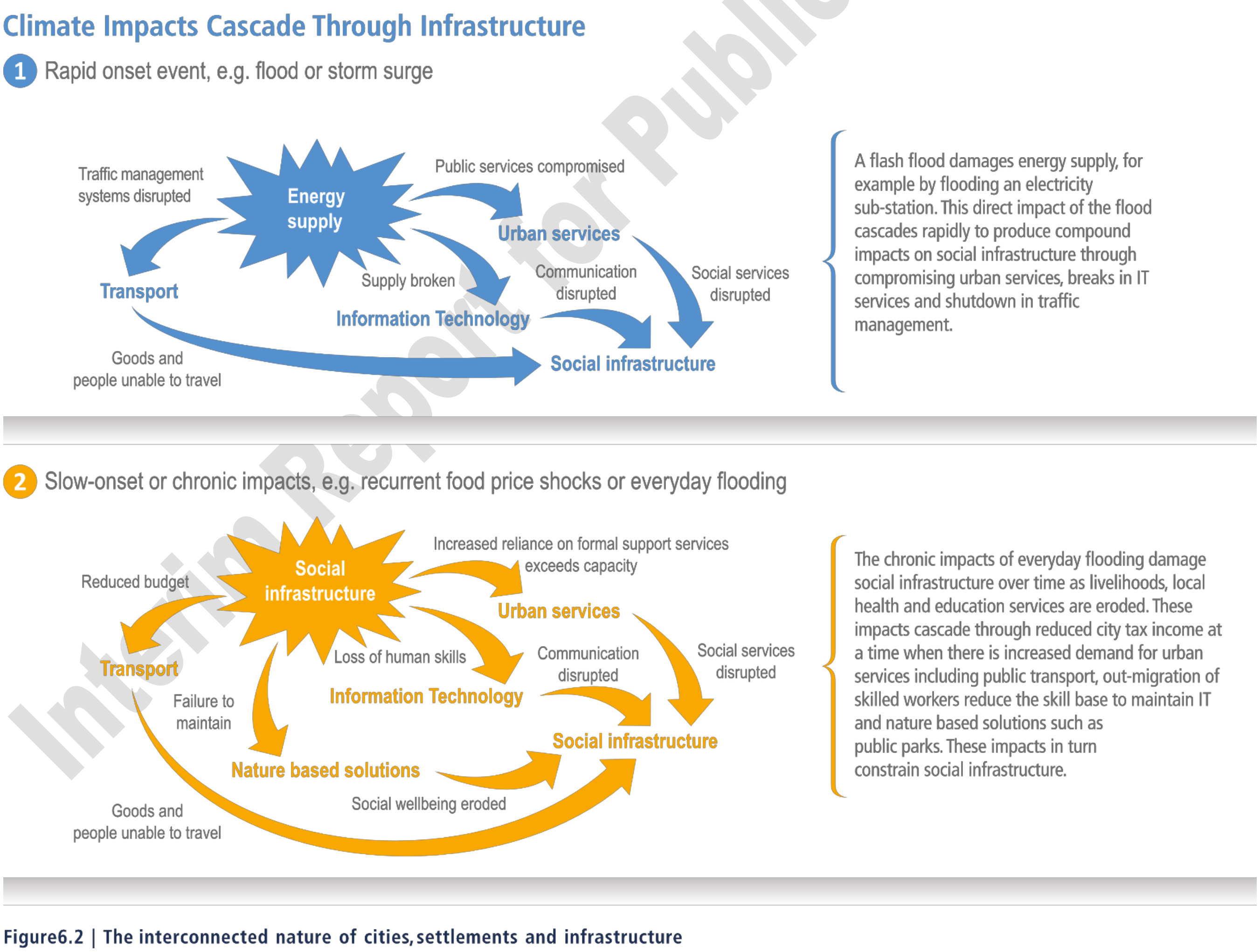


Figure 2: Multiple types of infrastructures including social, built, technological, and natural infrastructures interact to create climate risk and can limit or enable solutions. Source: IPCC Working Group II, Chapter 6 (Dodman et al., 2022, fig. 6.2).

Emerging urban systems science uses models and frameworks to make sense of the real-time dynamics of complex systems. To ensure that climate solutions don't create unintended trade-offs, or maladaptation, it is important to account for the interdependencies among social, ecological, and technological infrastructure components of urban systems (E. M. Cook & McPhearson, 2020; Grabowski et al., 2017; Grimm et al., 2016, 2017; McPhearson, Haase, et al., 2016; McPhearson, 2020; McPhearson et al., 2021, 2022a). Most traditional scientific approaches to improving resilience are siloed, with analytical efforts focused on one or two domains. Yet, as recent events have shown, extreme events can cause cascading impacts across domains. For example, flooding can simultaneously cause power and transportation disruptions, damage ecosystems, impact human health, and damage homes and critical infrastructure. Recent extreme events demonstrated failures or inadequacies not just in the built infrastructure but also in resources, institutions, information, and governance systems—components of the urban SETS—to prepare for, and respond to, events of this magnitude (Eakin et al., 2018). To advance governance for resilience means also advancing our ability to understand such complex urban dynamics and develop near and longer-term scenarios to guide decision-making.

The SETS framework builds on literature that demonstrates that social and ecological systems are linked through feedback mechanisms, and display resilience and complexity. Transitions in these literatures are commonly considered as co-evolution processes that require multiple changes in social-ecological or social-technological systems. Modeling approaches, such as machine learning, spatial projection, and mixed statistical approaches have been developed to explain how different policy mixes influence social–ecological or social–technical change. Complementing recent scholarship in social–technical or social–ecological systems research, the SETS conceptual framework has been used in multiple adaptation and sustainability planning process and policies – in Atlanta, Phoenix, New York, and San Juan (PR) – to examine the interactions and interdependencies between humans, the environment, and technological–infrastructure. It can be a way to analyze the potential of positive seeds of transformation to grow toward larger scale and more substantial changes.

In 2020, the U.S. National Science Foundation issued a call for Sustainable Regional Systems research and argued for SETS as the conceptual foundation to anchor systems approaches that can deliver sustainability across urban and rural interlinked systems (National Science Foundation, 2020). SETS aims to overcome the limitation of a purely socio-technological approach which tends to exclude ecological functions, or of social–ecological approaches which may overlook critical roles of technology and infrastructure, all of which are fundamental constituents and drivers of urban system dynamics. The SETS framework can therefore broaden the spectrum of the options available for more systemic identification of barriers (within existing actions, governance frameworks, economic constraints, and value systems) and generation of solutions for sustainable futures.

For example, processes, challenges, and solutions related to green gentrification can be addressed through a SETS approach. Community concerns are rising about green gentrification where urban greening efforts can be seen as potentially driving displacement of low income and minority populations. This perception is due to well understood impacts of neighborhood greening through tree planting, park development and investment, that can drive increases in real estate values and thus lead to increased costs of rent, taxes, and home ownership (Anguelovski et al., 2022; Keeler et al., 2019). To ensure that urban greening for climate adaptation and resilience does not result in displacement or negative outcomes for equity and justice suggests a clear need for more systemic and convergent approaches to adaptation that couple planning, policymaking, and decision-making across sectors and governance silos. Urban greening thus requires more than ecological investments in a neighborhood (Wolch et al., 2014). A SETS approach suggests that converging priorities for tree planting or park upgrades with solutions to eliminate risk of displacement would mean coupling greening with rent subsidies, low-income housing investments, and other approaches that cut across sectors, agencies, and nodes for decision-making. Plans and policies that couple greening, social policy, affordable housing, and other related dynamics in neighborhoods facing multiple challenges is an ongoing need and challenge for climate adaptation solutions to take up more convergent, systemic approaches to building resilience in NYC.

4.1 Diverse Sector and Cross-Sector Needs: Understanding Trade-offs Between Spatial and Temporal Scales and Thematic Breadth

NYC is part of a larger urban system comprising the greater metro area. Considering relationships and interdependencies at the neighborhood, city, and regional spatial scales, as well as in near- and longer-term timeframes, is essential for advancing resilience and avoiding maladaptation.

Figure 3 shows the spatial and temporal scales for a range of government and community plans to better understand the landscape of NYC resilience plans and identifies the timelines of community-based and government climate adaptation and resilience plans for NYC. The timelines highlight the spatial (neighborhood, city, regional, state) and temporal (short-, mid-, and long-term) scales and the climate hazard(s) each plan addresses (extreme heat, stormwater, coastal flooding, and multi-hazard).

Figure 3: Government-based (Upper) and community-based and non-governmental (Lower) climate adaptation and resilience plans based on their spatial and temporal scales and the climate hazard(s) they address. Note – this is not a comprehensive review of all community-based and government climate adaptation and resilience plans, rather it focuses on selected plans showing recent (from 2019 on) plans or plans still in-use. The timescale was identified by whether the plans included specific targets/deadlines for their strategies. If no long-term time scale was explicitly stated in the plan, they were assumed to be shorter-term. However, it's important to note that many if not all of the shorter-term plans will have lasting and long-term impacts when implemented. (Figure from NPCC authors)

Some planning initiatives by government agencies (shown in upper portion of Figure 3), especially those focused on sectors such as environment, energy, and water systems, have considered regional scale dynamics and has produced plans targeted for the region or state (Pirani et al., 2018; Regional Plan Association, 2018). The timelines of plans in NYC highlight that the included community-based plans mostly address multi-hazard climate impacts, as compared to the government-based plans, which explicitly focus on both individual hazards and multi-hazard planning approaches. Although there are fewer government plans with an explicit multi-hazard focus, many hazard-specific government plans will likely address multiple hazards through stated strategies. When comparing the temporal scales, the community-based plans (shown in the lower portion of Figure 3) generally take a shorter-term focus, compared to the somewhat longer-term nature of some of the government-based plans. The community-based plans that bring together multiple community organizations in a single plan, such as Rise to Resilience, tend to have a longer-term focus. However, long-term planning remains a gap in both city government and community-based planning.

4.2 Community-centered Climate Resilience Planning

Community-based organizations in NYC, such as the NYC Environmental Justice Alliance, The Rockaway Initiative for Sustainability and Equity (RISE), UPROSE, and WE ACT for Environmental Justice, are generating their own climate and sustainability plans that address concerns from transportation to energy to heat resilience. The vast majority of these plans include strategies that are within a short to medium-term time frame. Community-based plans are generally place-based, allowing for a more tailored and contextualized approach to addressing climate resilience based on specific neighborhood characteristics that can complement more general, broader city-level planning efforts. There is an opportunity to further build out and institutionalize the integration and centering of community-based plans in citywide agendas so that they are complementary and mutually reinforcing. Figure 3 highlights a few examples of community-based resilience plans and strategies and BOX 2 describes examples of climate resilience planning and agenda setting by diverse community-centered initiatives throughout NYC since 2020. For a more in-depth description of how these plans are being implemented on the ground, see NPCC4, Foster et al. (Foster et al., 2024).

As an effort to synthesize community-centered resilience goals, Regional Plan Association and Environmental Defense Fund worked with partners and stakeholders to identify climate resilience goals that have been articulated through community-based plans in areas at risk of coastal flooding. As part of this initiative, the team has also identified potential indicators that could be used to measure progress toward those goals. While there are many accepted measures or indicators of sea level rise, increased frequency of extreme events, rising temperatures and targets for greenhouse gas reductions, there are few established measurable targets for resilience to those climate impacts—particularly examined across spatial scales for communities and cities. Without measurable goals, targets, and data at a suitable scale for effectively redressing these risks, government officials and advocates alike are unable to effectively assess, track, and implement solutions. An online map, the NYC Climate Resilience Plan Mapper (Regional Plan Association, 2023) highlights the community-led climate resilience work in the context of government-led and academic plans. This project aims to lay the groundwork for the development of specific resilience performance measures or targets that are evidence-based, community-informed, easily updated, and could be used to support advocacy and decision-making over time. Further, the project also seeks to understand the similarities and differences between how communities, governments, and scientists define resilience goals.

BOX 2: Community-centered climate resilience planning and policy agendas.

These examples of climate resilience planning and agenda setting by diverse community-centered initiatives throughout NYC since 2020 highlight a range of initiatives developed by individual community-based organizations and collaborative coalitions across many organizations, and range in scope from local neighborhood to regional scale and from near-term to longer-term planning.

Community Visioning for Edgemere (Seip, 2022)

Focus: Coastal flooding from storm surges and 'sunny-day' tidal flooding, sea level rise, managed retreat, and development of vacant land and Edgemere Community Land Trust in the Edgemere neighborhood of Rockaway Peninsula, Queens

Process: In collaboration with RISE (Rockaway Initiative for Sustainability and Equity) and CCCE (Collective for Community, Culture, and Environment) and funded by The Nature Conservancy, this grassroots initiative centered the voices of local community members to envision a more sustainable future for their neighborhood through three community visioning and design forums.

Time frame: Near term (six months to five years)

Example strategies: Strategies and actions address a diversity of themes related to food security, recreation and exercise, beautification, economic development, education, arts, and culture.

Rise to Resilience: Our Communities, Our Future. Policies and Investments for a Climate-Resilient New York and New Jersey (Waterfront Alliance, 2020)

Focus: Recommending policies and investments to protect frontline communities in New York and New Jersey from coastal flooding resulting from sea level rise, storm surges, and extreme precipitation events

Process: The Waterfront Alliance and Resilience Task Force reached consensus through a coalition of community-based, environmental, business, government, and research entities in NY and New Jersey coastal region

Time frame: Near- and mid-term to 2050

Example strategies: Comprehensive strategies and actions range from improving cross-jurisdictional climate resilience governance to funding, public awareness and transparent communication, collective action to meet community needs, and economic development to environmental and infrastructure initiatives that restore ecosystem floodplains and increase resilient public infrastructure and housing.

Building an Equitably Green New York City (Riverkeeper, 2022)

Focus: Recommending strategies to bolster the City's Green Infrastructure Program to improve stormwater management during precipitation events and maximize co-benefits and equitable outcomes

Process: Riverkeeper led the development of the recommendations in partnership with community-based organizations such as Bronx River Alliance, Gowanus Canal Conservancy, the HOPE Program, NYC Environmental Justice Alliance, and more, and reviewed by City agencies like DEP, DOT, and Parks

Time frame: Near-term focus on NYC's Green Infrastructure Program 2030 milestone requirements

Example strategies: Some recommendations include prioritizing long-term maintenance and maintenance jobs, increasing interagency coordination, expanding green infrastructure development, changing the rate structure for water, increasing funding, creating public education campaigns, and evaluating all opportunities for stream daylighting.

2023 Extreme Heat Policy Agenda (WE ACT for Environmental Justice, 2023)

Focus: Addressing extreme heat impacts across all of NYC, especially for groups that are disproportionately affected such as people of color, low-income households, and elderly people

Process: WE ACT for Environmental Justice developed the policy agenda and collaborates with government agencies to implement recommendations

Time frame: Near-term (WE ACT sets an annual extreme heat policy agenda)

Example strategies: Policy recommendations range from expanding the Low-Income Home Energy Assistance Program (LIHEAP) to subsidize summer utility bills, to codifying and promoting cooling centers, coordinating emergency planning and communications, increasing green infrastructure and renewable energy, and supporting City policy reform.

Green Resilient Industrial District (GRID) Plan 2.0: A Just Transition Plan for Sunset Park (UPROSE, 2023)

Focus: A plan for a just transition to decarbonizing Sunset Park in Brooklyn that centers local economic development and prioritizes resilience to air pollution, extreme heat, and flooding

Process: In 2022, urban planning firm Integrated Urban Equity Solutions (IUES) updated the 2019 GRID plan, which was originally developed by urban planners in the CCCE for UPROSE and the Protect Our Working Waterfront Alliance (POWWA)

Time frame: Near- to mid-term to 2035

Example strategies: Strategies leverage the unique neighborhood assets and support frontline communities in participating in a just green and clean energy economy. Other focus areas range from building grassroots and institutional capacity, promoting transportation justice, and expanding transformative decision making that is matriarchal, intergenerational, and rooted in ancestral knowledge.

4.3 Multi-Hazard Scenario Planning: Adaptation Scenarios 2021 for Multi-Hazard, Cross-Sectoral and Long-Term Scenario Planning in New York City

An example of multi-sector, multi-scalar city-led planning includes the NYC Adaptation Scenarios for 2100 (E. Cook et al., 2022). Much of the dominant discourse about future forecasts is negative with visions of environmental and societal collapse, and "business as usual" forecasts that challenge planning and policymaking for more optimistic urban futures. Climate hazard projections in NYC can often paint a picture of a future city that is difficult or impossible to adapt to – and thereby may be considered dystopian. Such perceived inevitability of a negative future can become a barrier to action and long-term planning (Iwaniec et al., 2020; McPhearson, Iwaniec, et al., 2016). Ultimately, such dominant discourses may become self-fulfilling with negative future visions driving the city towards a negative future reality. However, research and practice demonstrate the role of *positive* visions that allow exploration of alternative and desirable futures to assist in developing positive plans, goals, and targets and delivering desirable outcomes for cities. Without shared positive visions for the future, it is unlikely that plans made now will achieve the equity, justice, sustainability, and resilience goals desired for the future of NYC and its communities.

In order to create space for positive visions, it is helpful to look to time frames far enough into the future in order to remove the present constraints that often make it hard to imagine desirable, normative futures. Existing planning efforts often focus on goals that are only 10, 20, or possibly 30 years into the future. While these shorter-term planning efforts will have long-lasting impacts, many future aspirations will take even longer to achieve, and short-term planning is not the same as setting long-term goals. Participatory processes are critical in co-developing shared visions that bring together diverse perspectives and forms of knowledge (E. Cook et al., 2022) (see BOX 3).

BOX 3: SETS Convergence Research Network

In Fall 2021, the New York City (NYC) Mayor's Office of Climate and Environmental Justice (MOCEJ) partnered with the National Science Foundation (NSF) Social-Ecological-Technological Systems (SETS) Convergence Research Network to facilitate the NYC Climate Adaptation Scenarios workshop series (E. Cook et al., 2022). Approximately 35 government practitioners from city, state, and federal agencies co-developed six distinct positive future visions for NYC in 2100 that are more just, equitable, and resilient in the face of extreme climate challenges. The envisioned future scenarios addressed: Multiple co-occurring hazards, Coastal flooding, Extreme heat, Winter extremes, Extreme precipitation, and Drought and shifting water demand. The goal of each future scenario was to radically transform the city's social, environmental, and physical infrastructure—including governance, green infrastructure, and water-energy-transit systems—and the City's ability to respond to extreme events.

We used a 2100 timeframe of approximately 80 years from today to create a rare space for long-term planning and positive visioning. Ultimately, the workshop activities were designed to develop long-term future visions that imagine what the future *ought* to be and consider more transformative strategies to achieve those visions without being constrained by the inner workings of the current system. Participants worked in small groups to envision six scenarios for the future of NYC in 2100. Scenario themes were developed in response to practitioner concerns and the City's sustainability and environmental management plans.

Participants envisioned a future NYC that is **resilient to multi-hazard risks from extreme heat, precipitation, and drought** with reliable, resilient, and interconnected infrastructure. The interconnected infrastructure addresses multiple risks and combines green and gray infrastructure solutions. The envisioned future infrastructure, including use of renewable technologies and nature-based solutions, will be interconnected and enable flexibility during co-occurring events. The interconnected systems will allow safer failure or a minimum service provisioning that avoids complete failures. In addition, a social contract would establish an inclusive and transformative governance system built on principles of trust, agility, and accountability. The inclusive governance system will integrate community participation, expertise, and cross-agency collaboration to better address future co-occurring hazards. Finally, this scenario envisioned that all New Yorkers would have equitable access to physical health, mental well-being, and economic stability that is not dependent on zip code, race, and privilege in order to be better equipped in the face of future events.

To ensure a future NYC that is **resilient to coastal flooding and storms**, participants envisioned collaborative governance based on a public-private-civic governance model to facilitate coordination across agencies and cross-sectorial decision-making. This future vision ensures residents are more resilient to future flooding through a variety of mechanisms, including equitable opportunities for relocation, housing, and flood insurance. Finally, this future focuses on a systems approach to developing a retrofitted city that integrates natural elements of nature-based solutions with hard, engineered infrastructure. The retrofitted city is centered on solutions that provide co-benefits and are multifunctional. Through a social-ecological-technological systems approach, the city's design integrates ecological elements and nature-based solutions, together with human health and well-being goals, into the built environment. This 'engineered with nature' approach spans policy, operation, maintenance, research, and design. The primary objectives include flexible or agile buildings or structures that are safe-to-fail, are able to buffer storm surges, sequester carbon, and do not emit contaminants.

Participants envisioned a future NYC that is **resilient to rising temperatures and extreme heat** would eliminate heat-related illness and mortality through a combination of infrastructure and health reforms. The future scenario relies on and maximizes the use of green vegetation and water features to mitigate heat. It ensures excess heat waste (e.g., from air conditioning) is reduced or reused through heat recovery systems to minimize new energy use. This will be achieved through updated building code to, for example, require the use of passive or low-energy building design, reduce the use of absorptive materials, and require green roof installation retrofits.

A future NYC that is **resilient to winter extremes** would minimize community vulnerability and improve preparedness. In addition, the future will maximize public well-being and mental health, ensuring residents are prepared for winter weather and can enjoy its benefits. Finally, the future will rely on investing in zero-carbon infrastructure. A three-pronged approach will be used to meet this zero-carbon infrastructure goal. First, a broad range of infrastructure will be built to withstand the increasing frequency of freeze-thaw cycles. Second, all infrastructure will meet decarbonization standards, including by utilizing fossil fuel-free energy sources, electrifying equipment, and overall regulating retrofits. There will be a particular focus on clean and reliable heating sources to reduce disruptions and increase resiliency during winter extremes. Finally, all infrastructure will also meet design standards that limit ecosystem harm – by phasing out the use of salt on icy sidewalks and roads.

To be **resilient to extreme precipitation**, participants envisioned that residents have agency in decision making to enhance individual and community resilience. New Yorkers would have the information, infrastructure, and ability to be both mobile and stable in the case of an extreme rain event. There would be prioritized and expanded affordable housing in low flood risk areas. In addition, the City will embrace living with water through integrated watershed management and combined natural-green and hard-engineered infrastructure to convey water in times of heavy rainfall. The focus will be on managing stormwater efficiently through integrated ecosystem-based and engineered solutions. Urban neighborhoods will be connected with natural systems and semi-naturalized streetscapes to recreate a natural watershed for stormwater conveyance and recreation. A network of compensated green stewards would help to manage these landscapes, eventually leading to the establishment of land trusts. With fewer cars on the road, transportation spaces like highways and tunnels could be repurposed for water conveyance.

Finally, participants envisioned a future NYC that is **resilient to drought and shifting water** demand that promotes the regional approach to maintain freshwater supply, ensures that all New Yorkers have equitable access to clean water, and minimizes potable water waste to protect water quality and quantity. In particular, landscapes are conserved and managed to be resilient and conserve water. For example, a shift to drought tolerant vegetation helps to protect water supply by reducing outdoor water use and enhances the resilience of the ecological system to severe drought conditions. The future also focuses on stormwater and water reuse infrastructures to ensure resilient water use and quality in the urban environment. Public, residential, and commercial properties will capture greywater and rainwater for on-site use and all water runoff from impervious surfaces is managed for future banking and security.

5 What Do We Know About the Future?

The future climate of NYC is described in the NPCC4 Climate Science Special Report (Braneon et al., 2024) and in this assessment (Balk et al., 2024). In short, NYC will be hotter, stormier and with greater variability in precipitation, and with rising coastal hazards. The spatial distribution of hazards is not evenly distributed across the city – for example, extreme heat is experienced differently and disproportionately. As shown in the NPCC4, Climate Science 2024 report (Braneon et al., 2024), indoor extreme heat exposure is a critical driver of heat related mortality and hospitalization, and yet there is limited work dedicated to monitoring and projecting indoor thermal environments that exacerbate outdoor heat in the present day, let alone to estimate such potential impacts in the future under warmer conditions (Braneon et al., 2024). In this section, we assess the current knowledge about the socio-demographic, built environment, health, and nature-based futures of the city.

5.1 Demographic Futures

Because of the work of the DCP, we know a good deal about the population distribution and composition, change in the recent past and projections a few decades into the future. This section begins with a short discussion of that but then transitions into uses the SSP framework to project population mid-century and beyond.

5.1.1 The population of New York City is getting older and more diverse

The population of NYC in 2020 was over 8.8 million persons, with more than half of the population residing in Brooklyn and Queens. Aging is a national trend, and NYC is no exception. Between 2010 and 2020, the median age increased from 35.5 to 37.3 (38.1) years (5-year estimate. 1-year estimate in parentheses) (Matte et al., 2024; United States Census Bureau, 2021). In 2013, NYC DCP (2013) projected the population in 2040 to reach 9 million persons[1]. According to the 2013 DCP projections, the share of population over age 65 was 12.2% in 2010 and is projected to rise to 15.6% by 2040. Placing this in historical perspective, 7.7% of the city's population was over age 65 in 1950.

Growth in the population of NYC comes largely from natural increase, that is births minus deaths, as the city has a long-standing pattern of migration losses – more people move out of the city than move in – consistent from the mid-twentieth century onward (City of New York Department of City Planning, 2013, 2022). "The net outflow from the city in the past decade totaled just 51,000, but it was a result of a remarkable population churn, with 2.57 million people moving to NYC and 2.62 million people leaving" (City of New York Department of City Planning, 2023b). Population growth is not uniform by race and ethnic composition: "NYC's Hispanic population growth reflected the citywide pattern, with natural increase outstripping net outflows. Asian population growth bucked the trend, with both natural increase and net inflows, resulting in dramatic increases across the boroughs. There were population declines among the White and Black populations as natural increase only partially offset net outflows" (City of New York Department of City Planning, 2023b).

Figure 4 shows the long-standing and increasing diversity of NYC. In the past decade, the Asian population grew by nearly 350,000, accounting for 55 percent of the city's growth, and the Hispanic population, which increased by about 150,000, accounted for about one-quarter of the city's growth over the decade. The White population remained relatively unchanged (declining slightly) whereas the Black population decreased by 84,000. The remainder of the population growth is accounted for by those identifying as two or more races or some other race.

[1] There is inherent uncertainty in projecting the future: DCP's 2013 projection of the 2020 population to be 8.55 million – somewhat lower than the actual 2020 population – and it projected the 2030 population to be around the current-day population, but given the current estimate of the 2022 population of around 8.4 million (City of New York, 2023a) these estimates may turn out to be on target.

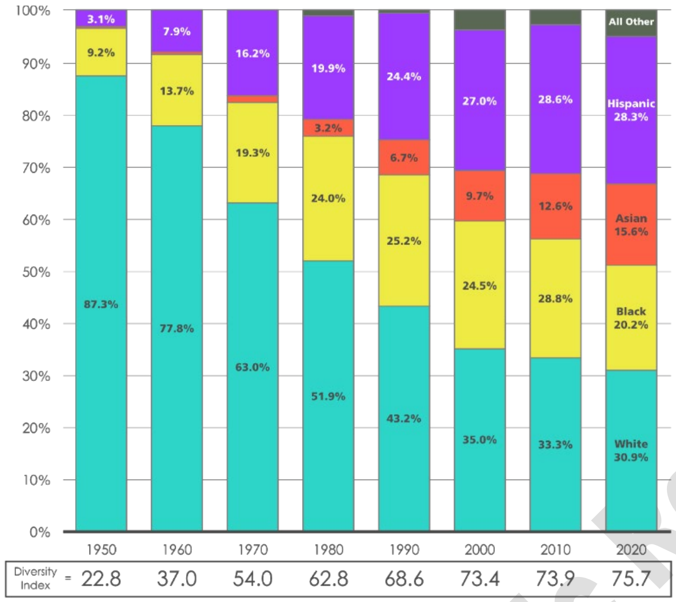


Figure 4: Share of Population by Race/Hispanic Origin, New York City, 1950-2020. Source: NYC DCP (City of New York Department of City Planning, 2023b)

Population aging, migration, and diversity result from larger social processes. Population aging is expected to continue with high certainty into the future and while NYC has long been home to migrants from places throughout the US and abroad, forecasting future migration streams is much harder than projecting future age structure. The NYMTC Socioeconomic and Demographic (SED) projections for 2055 "show both employment and population growing regionwide from 2017 to the 2055 forecast year. Employment, although lagged in the near term to acknowledge the economic slowdown caused by the pandemic, will exceed that projected in earlier forecasts" (New York Metropolitan Transportation Council, 2020b). Growth rates in the region also slow later in the period, due to population aging.

Additional socioeconomic characteristics are important from a climate vulnerability perspective – such as levels and trends in change in income (and wealth) distribution, new, available, and affordable housing units, and job growth. New York University's Furman Center has produced city-wide indicators (2023) (as well as neighborhood level) of housing characteristics, median income and inequality metrics from 2000-2021. In these two decades, they find increases in homeowners (from 30.2 to 33.3%) concomitant with even larger increases in the proportion of households that are rent-burdened (from 23.7 to 30.1%), with substantial increases outside Manhattan since 1980 (Balk et al., 2022). While recent trends are a good indicator of conditions in the near term, apart from using new building permits in the NYMTC forecasts, such socioeconomic factors have not typically been forecast in the medium or long-term.

5.1.2 The spatial distribution of population in New York City

DCP's projections for NYC are for the total population for each borough by age and sex. Projections are not done by race or ethnic composition but are available for the total population down to the transportation analysis zone (TAZ) level, which are akin to census tracts and can be reaggregated in spatial units useful to particular user groups. Apart from their projections, in their recent neighborhood analysis, DCP (2023b) finds that 'Roughly half of neighborhoods experienced net outflows [from 2010-2020]. The vast majority of these still experienced population growth through natural increase, reflecting the citywide pattern of population growth despite net migration losses." DCP also undertakes periodic analysis of the dynamics of racial and ethnic composition of NYC neighborhoods (City of New York Department of City Planning, 2021a). NYC's remarkably diverse population is not evenly dispersed (nor has it ever been) across boroughs or neighborhoods. To understand neighborhood change, DCP also examines decadal change in new construction at the neighborhood level and places these in the context of the change in the racial and ethnic composition of neighborhoods (City of New York Department of City Planning, 2021b), information essential for understanding climate impacts with a racial justice lens despite the short-term nature of the change analysis.

5.1.3 Demographic futures consistent with different SSPs

In thinking about the future climate of NYC, and the ability to adapt to it, it is also important to understand the population futures that are consistent with those different climate futures, and the pathways that jointly lead to them.

Thus, this assessment makes use of new population projections consistent with three SSPs (Jiang et al., 2020) – SSP2, SSP3 and SSP5 – and which were downscaled to 1km spatial resolution (Zoraghein & O'Neill, 2020a, 2020b) for the United States. To project the future, and as an important improvement on global applications, US-state-specific inputs on fertility, mortality and migration are used to project future population and a set of state-specific modelling parameters for urban and rural spatial distributions in downscaling the projections to 1km grid. Adapting these three SSPs to the US states, SSP2 is characterized by medium population growth including medium levels of fertility, mortality, and international migration; SSP3 evolves with low population growth due to low fertility and international migration but higher mortality; and SSP5 sees higher population growth due to high fertility and international migration along with low mortality (Jiang et al., 2020) (See BOX 1 for additional narratives describing these three scenarios).

Table 1 displays the results of those new data for NYC and State. The three scenarios not only produce different expected population totals and age distributions (Figure 5) as well as much different spatial distributions (Figure 6). One of the three scenarios, SSP2 – a "middle of the road" scenario (in terms of the assumptions it makes about demographic futures, and one that resembles recent (2000-2010) historical trends that remain constant over time), envisions that by mid-century the population of NYC will be about the same as present day and modest increases to the end of the century. Another, SSP3, envisions a less populous city, whereas SSP5 envisions an increase of over an additional million New Yorkers. This pattern continues to 2100 where SSP3 produces a much less populous and SSP5 produces a much more populous NYC. Table 1 places these changes in the context of projections for the state as whole. The population of NYC in the present day is under 45% of the state population, and while that doesn't change much by 2050 irrespective of the SSP, by 2100, the relative size of the city's population to the state's varies considerably. According to Zoraghein and O'Neill (2020b, p. 22) paraphrasing their results, SSP3 results in lower relative populations in suburban areas with higher population concentrated city centers; that is, SSP3 parameters result in population loss everywhere but more so outside the city. In contrast, suburban population growth is consistent with SSP5 and sprawling development – where the positive suburban population difference is limited to the surroundings of NYC, emphasizing NYC as the dominant socioeconomic hub of the state. "These effects are accentuated in 2100, where population decline under SSP3 is especially prominent … and in SSP5 the rapid suburban population growth around NYC is noticeable (…which in contrast to the suburbs, show lower populations than SSP2 in the city center)." Uncertainty is inherent in predicting the future: Given the post-World War II growth of NYC's suburbs, as well as recent out-migration related to the COVID-19 pandemic and uptake in remote employment, it is necessary to envision a range of plausible futures such as those from SSP3 and SSP5 scenarios.

Table 1: Projected Population in NYC according to three Shared Socioeconomic Pathway Scenarios in 2050 and 2100 by Borough

	2050			2100		
	SSP2	**SSP3**	**SSP5**	**SSP2**	**SSP3**	**SSP5**
BOROUGH						
Bronx	1,572,273	1,398,464	1,772,284	1,578,596	1,289,855	1,859,701
Staten Island	483,968	442,586	506,137	484,869	307,826	613,835
Brooklyn	2,736,109	2,457,513	3,038,038	2,746,352	2,275,813	3,167,712
Queens	2,444,575	2,202,263	2,700,211	2,450,862	1,925,237	2,893,837
Manhattan	1,713,796	1,535,215	1,922,651	1,720,296	1,468,880	1,972,750
New York City	**8,950,722**	**8,036,041**	**9,939,320**	**8,980,976**	**7,267,610**	**10,507,834**
New York State	**19,376,000**	**17,210,000**	**20,492,000**	**18,685,000**	**10,952,000**	**26,174,000**
NYC as % of State	**46.2%**	**46.7%**	**48.5%**	**48.1%**	**66.4%**	**40.1%**

Table derived from data used in Zoraghein and O'Neill (2020b). Estimates are based on US-national, state-level projections; modification of approach for NYC was underway at the time of publication as part of the City's Climate Vulnerability, Impact, and Adaptation (VIA) analysis.

The different predicted changes are reflected in the proportion over age 65 and expected contributions of fertility, migration, and mortality across the three SSPs (Figure 5 for all NY State). SSP3 projects much higher proportions of those over 65 (and consequently much lower fertility and population totals) and lower proportions in SSP5 (shown Figure 5, panel C). Similarly, in terms of migration (based largely on historical patterns), New York States's growth is due to the continued flows of international migration streams, rather than net internal migration; this largely accounts for the population decline seen in SSP3, even though that future also has low fertility and high mortality trends (Jiang et al., 2020). Note that net internal migration is negative in all three SSPs – that is, the state is assumed to lose internal migrants, on average – but only SSP3 has declining international migration, as well.

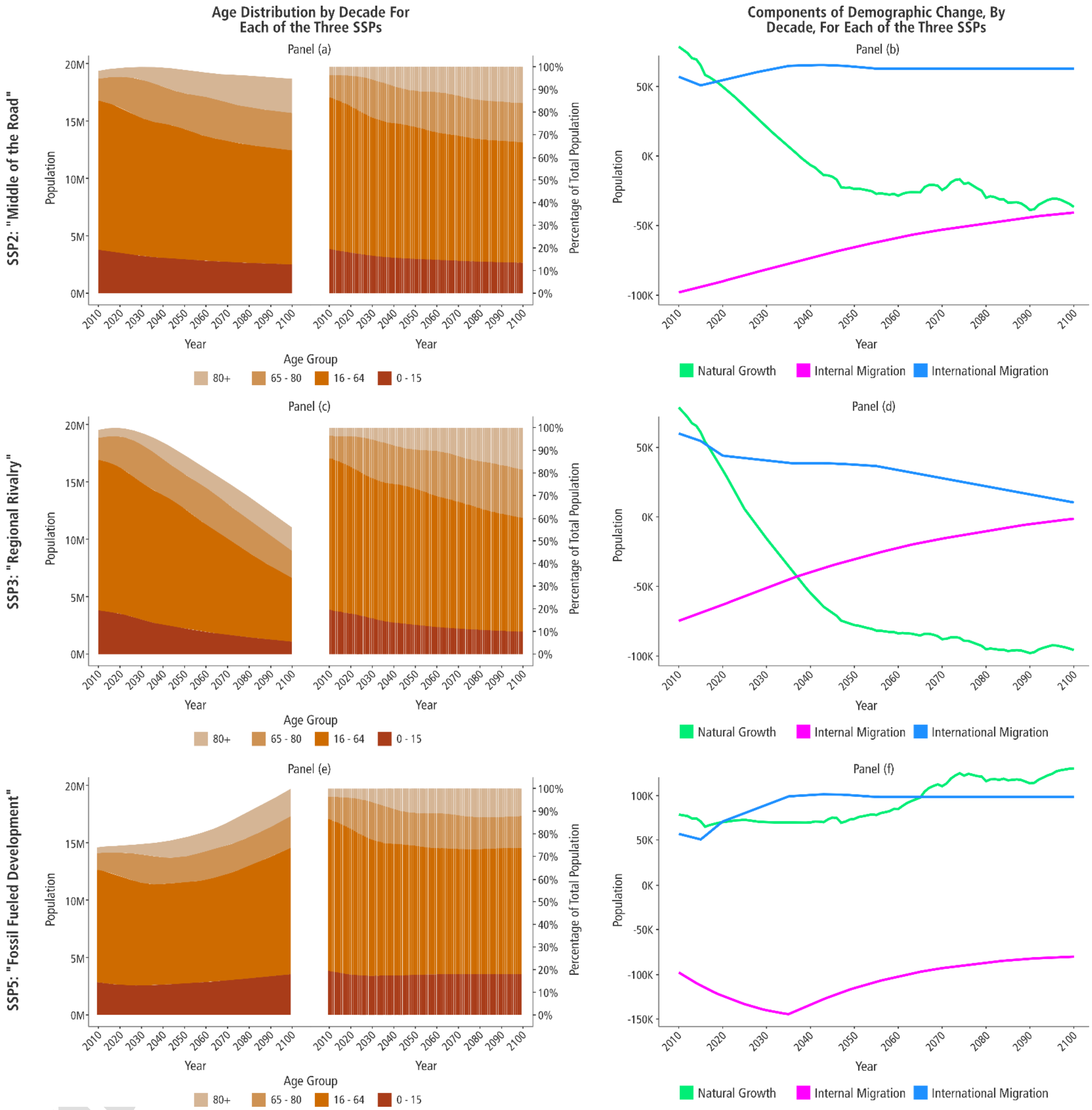
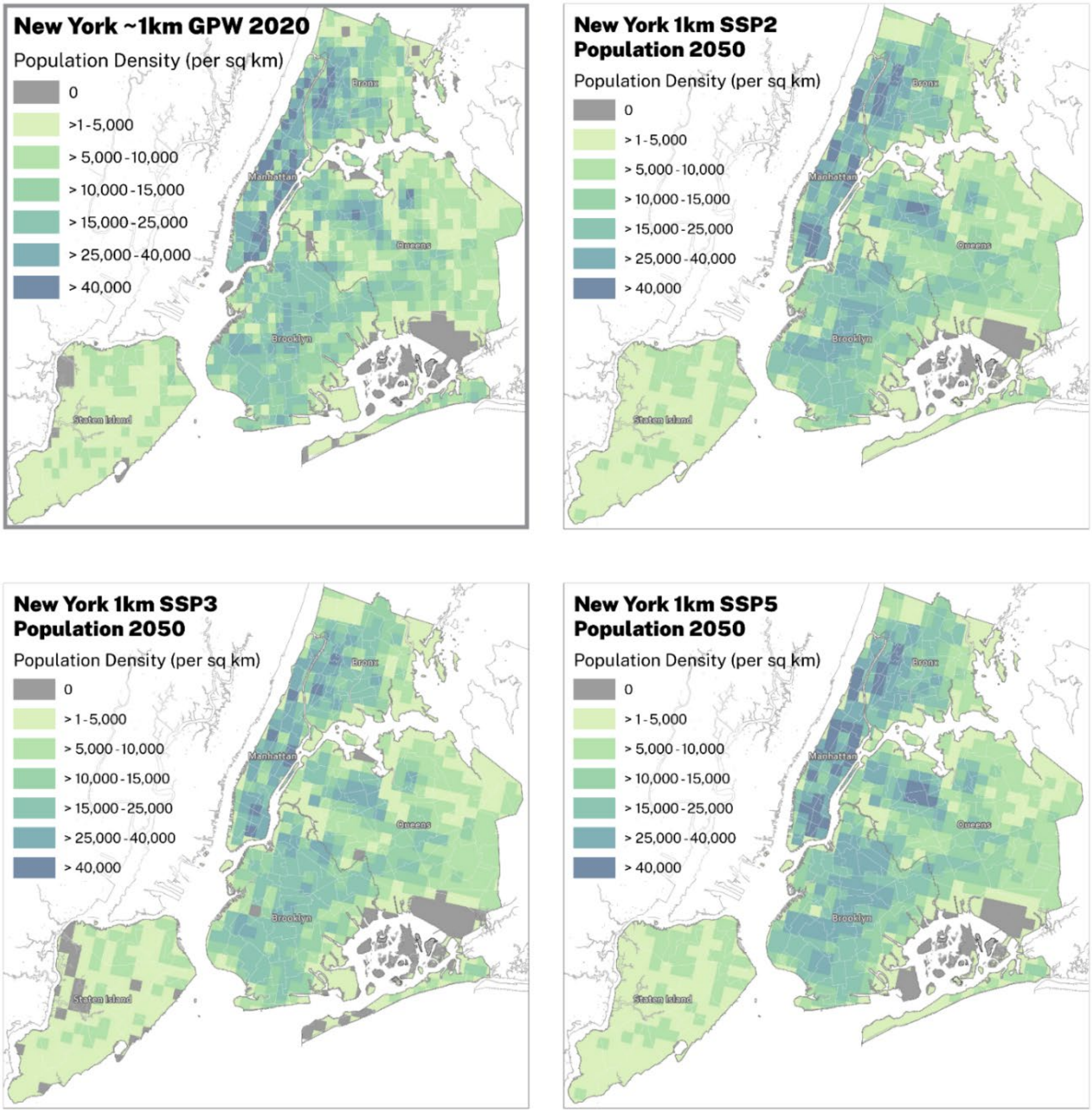


Figure 5: NYS Age distribution by decade and Components of Demographic Change by Decade. Source: Jiang & Zoraghein (Jiang & Zoraghein, 2023)

Differences in spatial distributions of the population are shown in Figure 6. There are many more low-density grid cells (shaded lighter hues) in SSP3 than in either SSP2 or especially SSP5. Population density increases in all boroughs in the SSP5 scenario, with increases in density especially notably in the Elmhurst neighborhood of Queens, while falling in all areas in SSP3 (especially in Staten Island). The patterns to 2100 look quite similar to 2050. These maps are a first look at the spatial distribution of population but drawing on this application of the SSPs to the US, the approach of Jiang and colleagues (2020) and (Zoraghein & O'Neill, 2020a, 2020b) is being adapted to NYC, to include migration flows as well as inputs that are suitable to the diversity of NYC's population as part of the ongoing VIA analysis. The VIA research will produce population projections for NYC that that go out to the end of the century and include race and ethnicity as well as age and gender among its outputs, which will be downscaled to address climate impacts assessments at a fine scale.



Note:
Due to the underlying resolution of the data, population in these diagrams is indicated in NYC's parks (Central Park, Prospect Park)

Figure 6: Population Distribution in 2050 according to three future development scenarios (of the Shared Socioeconomic Pathways, SSPs) New York City and Long Island regions (Zoraghein & O'Neill, 2020b) and compared to 2020 Gridded Population of the World (Center For International Earth Science Information Network-CIESIN-Columbia University, 2018)

5.2 Built Futures

NPCC3 inventoried multiple NYC critical infrastructure domains and infrastructure resilience strategies to address climate risks (Zimmerman et al., 2019). In this assessment, we consider other aspects of NYC's built infrastructure that were not fully considered in NPCC3 but have become especially salient due to the recent crises of COVID-19 and Hurricane Ida. We examine the role of buildings, especially residential structures, and their connection to the energy sector in NPCC4: Energy and Energy Insecurity, and below we consider surface transportation and, more broadly, the public right of way (ROW) to examine opportunities in the ROW for resilient NYC futures. In the case of the public ROW, it is an understudied topic and therefore our assessment concentrates on understanding its historical and current features and the wide range of near and medium-term plans that address aspects of future planning processes.

5.2.1 Historical transformations of New York City's built environment

NYC's current built environment has been shaped over the past 200 years by urban design, economic transitions, population growth and migration, public health challenges, technological innovation that enabled infrastructure improvements, and interactions among these forces. Many changes involved transformation of heavily developed places to new uses. Some of these changes were adapted to the climate and other circumstances of the day but have become maladaptive over time. Others were harmful and/or inequitable when and as implemented. For example, in the early 1800s rapid population growth came before knowledge about communicable disease transmission and control, the construction of water and sanitation infrastructure, and adequate healthy housing resulted in overcrowded neighborhoods and recurrent lethal outbreaks from cholera, yellow fever, typhoid, and other infectious diseases. Notably, residents of basement apartments were observed to be at highest risk. Over time, communicable disease risks abated with the construction of the Croton reservoir, housing codes, and other public health measures (Plunz & Álvarez-Dávila, 2020).

The early 20th century saw rapid, dense, transit-oriented development along new subway lines and the beginning of repurposing waterfront land from piers, warehouses, and industrial use to housing developments. While these publicly and privately financed developments were intended to provide decent affordable housing, they often reinforced *de jure* and *de facto* racial segregation (Rothstein, 2012). More recently, transit-oriented "upzoning" to develop underutilized waterfront and other neighborhoods has often resulted in luxury developments out of reach of households that could most benefit from transit access. Inequities in NYC-area land use policies is considered in more depth in NPCC4, Foster et al. (Foster et al., 2024).

In the early and mid-20th century, bridge and highway construction afforded some NYC residents, those with cars, access to amenities (such as beaches and parks) outside the city. While the motivation behind parkway construction that excluded transit buses is disputed (Kessler, 2021), access was more difficult for those who could not afford cars. Over time, the same car-centric road building promoted suburban land development, including communities segregated by racially restrictive covenants (Sheidlower, 2020), brought traffic congestion caused by car commuters, and highways that bisected neighborhoods and afflicted them with air pollution and noise that impacts the city today. This history demonstrates the potential for built infrastructure, housing, and transportation systems to remake already developed land and the need for foresight and an equity lens to envision futures that avoid unhealthy and maladaptive pathways, as discussed further in the next section.

5.2.2 Streets and the public right-of-way

NPCC3 considered, as part of a broader look at resilience strategies for critical infrastructure, NYC's rail public transportation and its surface transportation assets for moving vehicles and freight (Zimmerman et al., 2019). Plans and progress reports for addressing some of these risks are available (Metropolitan Transportation Authority Climate Adaptation Task Force, 2019). This section extends that assessment by focusing on the public right-of-way (ROW) – mainly streets and sidewalks – (Freudenberg et al., 2021) and how potential future uses can shape either greater resilience or greater vulnerability to climate risks. Realizing a more climate-adapted ROW would require prioritizing the most efficient, essential, accessible, safe, active, healthy, and sustainable transportation modes for moving people – bus transit, walking, and cycling – over the least efficient uses – parking and driving private motor vehicles (Figure 7. We have selected the ROW as a topic of interest because like other topics in this chapter, it requires substantial interdisciplinarity drawing on concepts from multiple sectors to be brought to bear.

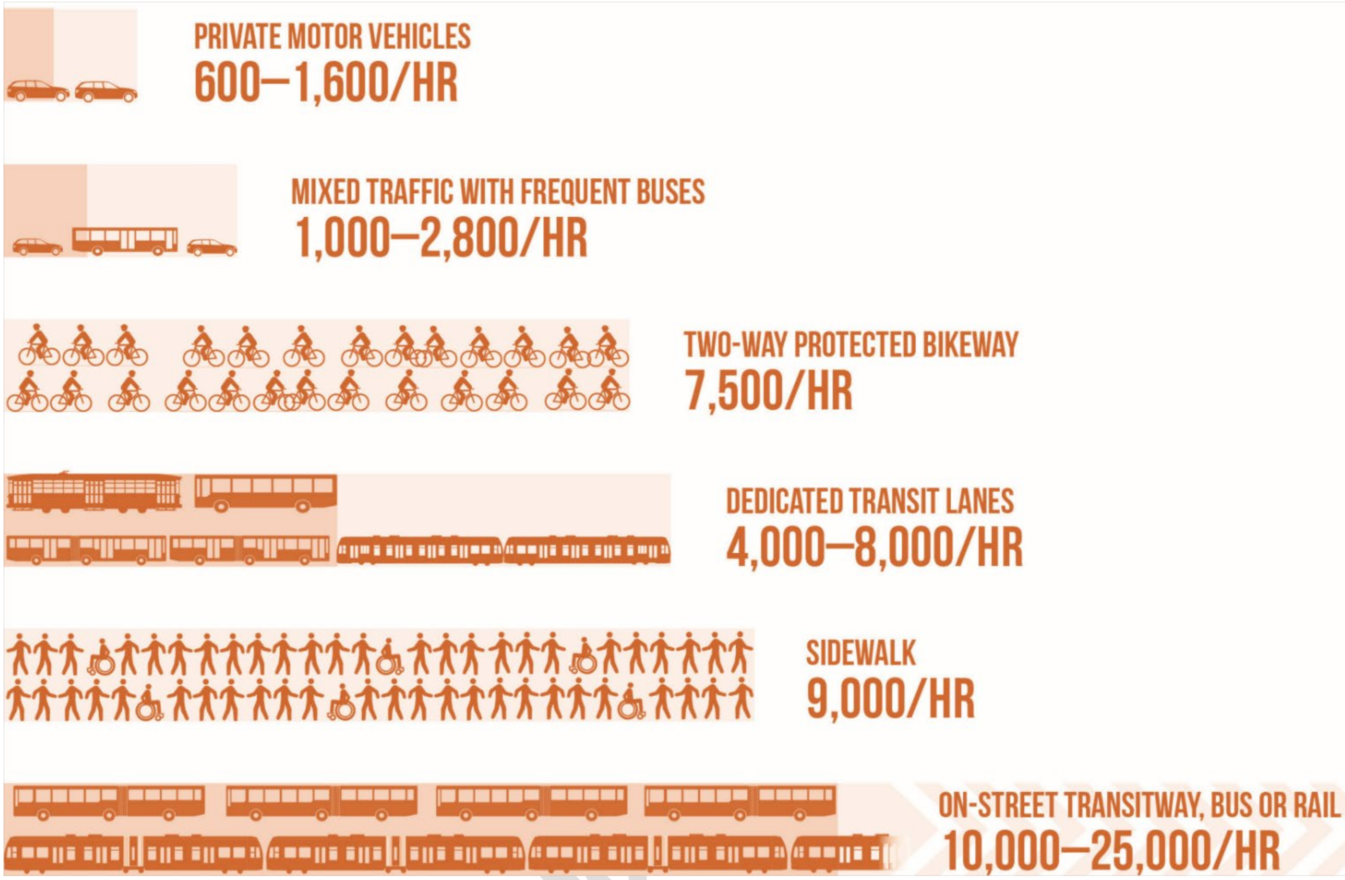


Figure 7: The Capacity of a Single 10-Foot Lane (or equivalent width) by Mode at Peak Conditions with Normal Operations (National Association of City Transportation Officials, 2016)

The urgent need and possibility of much faster and more ambitious repurposing of the ROW was made clear by the recent climate and health crises of flooding from Hurricane Ida (City of New York Office of the Deputy Mayor for Administration, 2021) and the urgent need for safe outdoor spaces for socially distanced gathering, dining, and exercising created by the COVID-19 pandemic.

In a densely developed city like New York, the ROW is a critical asset, comprising approximately 16.5% of the land area of the city (32,000 of 193,700 acres) (Freudenberg et al., 2021) that can be used in ways that are either adaptive and equitable or in ways that are maladaptive and inequitable. Past decisions, beginning a century ago, have shaped the ROW in maladaptive ways to prioritize the movement and parking of private motor vehicles; according to one estimate, NYC devotes enough curb space to park 3 million vehicles (Czebotar, 2021; Freudenberg et al., 2021). Now there is abundant evidence of how built and natural features in the public ROW influence climate risks and how the future of NYC's ROWs can be shaped to reduce climate risks from heat, flooding, and air pollution while providing co-benefits of improved health, greater equity, sustainability, and economic development. Several existing NYC policies, investments, and plans are already beginning to shape a more climate adapted ROW. Other more ambitious plans have been proposed and are supported by successful transformations of other global cities.

Asphalt contributes to climate risks from hot weather and flooding. When exposed to sun, asphalt is a major contributor to the urban heat island (Mohajerani et al., 2017) and higher surface temperatures in turn increase the vulnerability to illness and death during hot weather in NYC (Madrigano et al., 2015). Asphalt and other impervious surfaces in the ROW speed the movement of stormwater as it seeks low points, increasing the risk of dangerous flash flooding for residents of basement apartments, subway users, and even drivers. For a detailed discussion of pluvial flooding, see NPCC4, Rosenzweig et al (B. Rosenzweig et al., 2024). Reducing the amount of ROW devoted to impervious asphalt and replacing it with trees, vegetated bioswales, and materials that are less heat absorbing and more pervious can reduce both risks.

Traffic-related air pollution (TRAP), including $PM^{2.5}$ and nitrogen dioxide (NO_2), exacerbates multiple chronic health conditions, contributes to preventable morbidity and mortality (Bosson et al., 2019; Khreis et al., 2017; Yang et al., 2018). In NYC, TRAP disproportionately impacts communities with higher populations of people who are low-income, Black or Hispanic, and living in places disproportionately impacted by emissions from heavy-duty diesel vehicles (Kheirbek et al., 2016a). Concentrations of TRAP, of which ambient NO_2 is a useful indicator, is highest close to busy roadways and declines rapidly with distance (Brugge et al., 2015). Exposures to TRAP in cities can be greatly reduced by limiting traffic on streets with large numbers of pedestrians and cyclists or by creating low-emission zones in densely populated areas. (Aaron, 2011; Brugge et al., 2015; Pestel & Wozny, 2019; Zhai & Wolff, 2021).

Because NYC's public right of ways are vital conduits for movement of people and goods, freeing space for climate adapted uses requires prioritizing transportation modes that make the most of available street space. Dedicated busways, bus lanes, sidewalks and pedestrian plazas can move roughly 5-6 times more people per hour than a lane devoted to moving private motor vehicles (Figure 7). Parking private motor vehicles occupies valuable space in curb lanes, while enabling the movement of relatively few people. The present allocation of space to private motor vehicles is one reason why traffic congestion has rebounded to pre-pandemic levels (Hinsdale, 2022). Progress reducing traffic deaths has stalled (City of New York, 2013), bus speeds remain slow (Metropolitan Transportation Authority, 2023) and ridership fell in each of the several years prior to the pandemic (Metropolitan Transportation Authority, 2020), while NYC GHG emissions from transportation were little changed from 2010 through 2019, the last pre-pandemic year for which data is available (City of New York Mayor's Office of Climate & Environmental Justice, 2022b).

In addition to freeing ROW space to help cool it, manage stormwater, and provide cleaner air, prioritizing efficient transportation modes would provide multiple health co-benefits (Figure 8). Regular trips using transit, walking, cycling, or combinations of these increase physical activity that provides multiple physical and mental health benefits (Besser & Dannenberg, 2005a; Edwards, 2008a; Gaesser & Angadi, 2021; Heath et al., 2012a; Saint-Maurice et al., 2022; The Community Guide, 2017), helping to shape a future population with a lower burden of health conditions that make people more vulnerable to heat, flooding, and power outages (see NPCC4, Matte et al. (Matte et al., 2024)). Narrower and fewer traffic lanes help calm and slow traffic, reducing injury and death risk of vehicle collisions with pedestrians and cyclists (Lubbe et al., 2022; Smart Growth America, 2022). Dedicated safe space for pedestrians and cyclists could also help support safe routes to school programs for children, with proven health benefits (Centers for Disease Control and Prevention, 2023; Muennig et al., 2014; Stewart et al., 2014). Finally, busways and bus lanes to speed trips and increase ridership will provide a greater return of passenger service for the existing transit bus fleet. Expansion of the battery electric bus service will help reduce TRAP, and it can be facilitated by reducing range losses from congestion and the energy needed for winter heating (Sustainable Bus, 2022; Zhou et al., 2016). In addition to these transportation-related health benefits, increasing greenery that people will encounter every day in the ROW has multiple positive effects on mental and physical health (Keeler et al., 2019). The potential health and environmental benefits of natural features in urban communities is an area of active research.

Other important climate, equity, and development benefits can flow from a re-envisioned ROW in NYC. These include improved access to jobs and services, curbside space to scale up composting and reduce GHG emissions from solid waste management as well as the improvement of waste staging in NYC (see Clean Curbs (City of New York Department of Sanitation, 2016)), reducing combined-sewer overflows (CSO) and non-point stormwater pollution (City of New York Department of Environmental Protection, 2023a), and expanding space for economic, social, recreational, and cultural activity (Freudenberg et al., 2021).

The spatial and temporal scale of changes to the ROW vary from very local and rapid (e.g., street closures and repurposed space during the COVID pandemic) to medium term, such as bus lanes that require community consultation but minimal new construction, to longer term such as removing an urban highway. What history and other cities have made clear is that some rapid near-term change is possible, but that forward-looking, multi-sectoral planning is needed to avoid lock-in of maladaptive uses and enable future transformations.

Several city policies, investments, and plans are already beginning to transform the public right-of-way for climate adaptation. These include: NYC Streets Plan, Green Wave cycling plan, Better Buses Action Plan, NYC Plaza Program, Open Streets, and Pedestrian Mobility Plan (City of New York, 2019; City of New York Department of Transportation, 2023c, 2023b, 2023a). A reimagined public right of way can also support broader visions and goals for NYC's post pandemic future, such as those in Making New York Work for Everyone: reimagining business districts, making it easier to get to work, and generating inclusive, future focused growth (NYCEDC, 2022).

Successful implementations of these approaches in NYC include the 14th Street busway, which improved bus speeds and ridership, reduced traffic crashes and pedestrian injuries, and increased Citi Bike use (City of New York Department of Transportation, 2022; Sam Swartz, 2019) and the pedestrian plaza that revitalized Times Square while reducing exposure to traffic pollution (Aaron, 2011). Other global cities have implemented approaches that could be adapted to the varied local contexts of NYC neighborhoods, such as Barcelona's superblock initiative that limits, shares, or closes some neighborhood streets to through traffic to enhance pedestrian, retail, and commercial activity.

This and other strategies for transforming and capturing greater benefits from the public right of way in NYC have been proposed (Freudenberg et al., 2021; Transportation Alternatives, 2021).

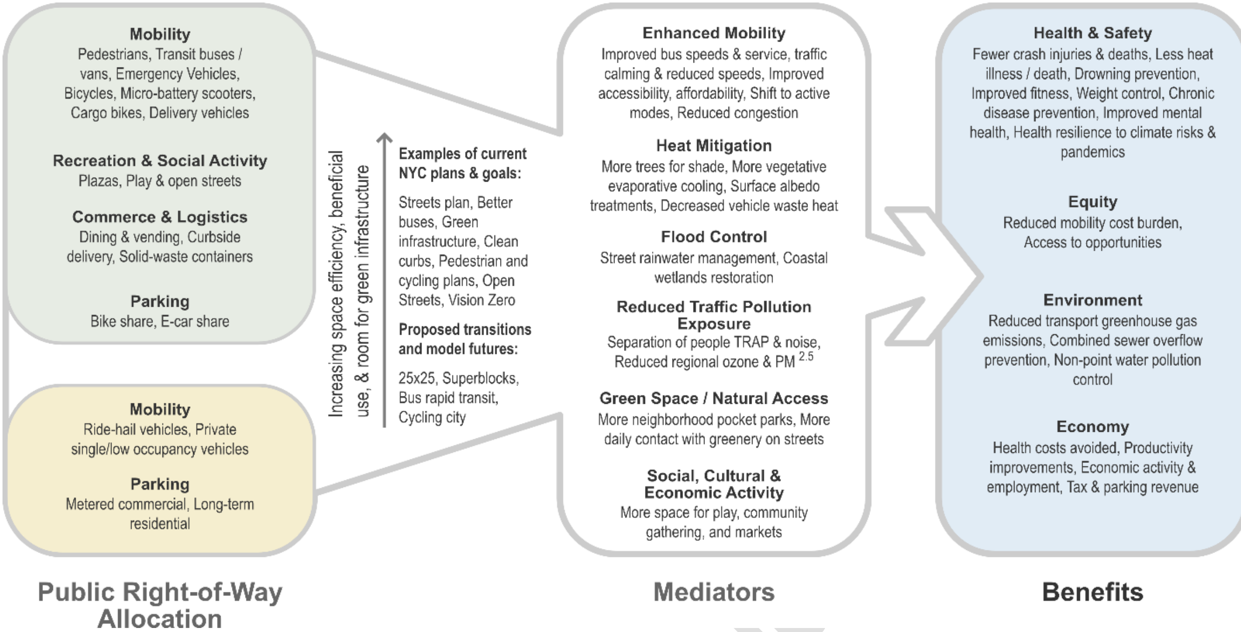


Figure 8: Street space allocation influences how much space is available for beneficial, climate-adapted uses as well as the health, safety, equity, and efficiency effects of our surface transportation system.

5.3 Health Futures

Shaping an urban environment that supports human health and wellbeing, as well as social and economic opportunity and equity should be a central aim of the City's climate planning (Capon, 2017). Pathways to achieve this aim can be informed by methods and tools that quantitatively and qualitatively assess local health impacts, both beneficial and harmful, and their distribution under different policy alternatives and future scenarios (Castillo et al., 2021; Foster et al., 2019; Sohn et al., 2018). Health impacts may be considered "co-benefits" (or co-harms) when other sectors are the primary goal or focus of a policy or planning scenario, such as climate change mitigation, transportation improvements, or ecosystem conservation. Alternatively, policies that primarily have public health and welfare goals can have co-benefits of enhancing climate change adaptation and resilience. Health co-benefits of reallocating space in the public right-of-way are discussed in the preceding section. Other examples of health co-benefits of climate action, and tools to assessment, follow.

5.3.1 Health impact assessment and co-benefits: greenhouse gas mitigation, air pollution, and active mobility

Reducing local air pollution emissions and concentrations provides important health co-benefits from reducing local greenhouse gas emissions. Measures of air pollution can be estimated using the US EPA's Benefits Mapping and Analysis Program Community Edition (BenMAP) tool (Sacks et al., 2018) in conjunction with local and regional air pollution emissions and atmospheric modeling. For example, fully implementing NYC's 2014 strategy of reducing greenhouse gas (GHG) emissions 80% by 2050, was estimated to annually avoid between 160 and 390 premature deaths, relative to a 2012-2014 annual average, and health-related costs valued at $3.4 billion (Johnson et al., 2020). Similar methods can also be used to estimate potential health co-benefits of sector-specific actions, such as phasing out the most polluting heating fuels either prospectively or retrospectively using ambient monitoring data (Kheirbek et al., 2014; Zhang et al., 2021). Clean air scenarios can also be evaluated to estimate health benefits of idealized, hypothetical futures, such as sustaining air pollution improvements observed during COVID-19 restrictions or eliminating traffic related PM2.5 emissions. By analyzing both air quality change and health data at neighborhood scale, these analyses also show that the most vulnerable and disadvantaged communities are most harmed by current emission levels and their spatial distribution and have the most to gain from cleaner air (Figure 9) (Johnson et al., 2020; Kheirbek et al., 2014, 2016b; Perera et al., 2021).

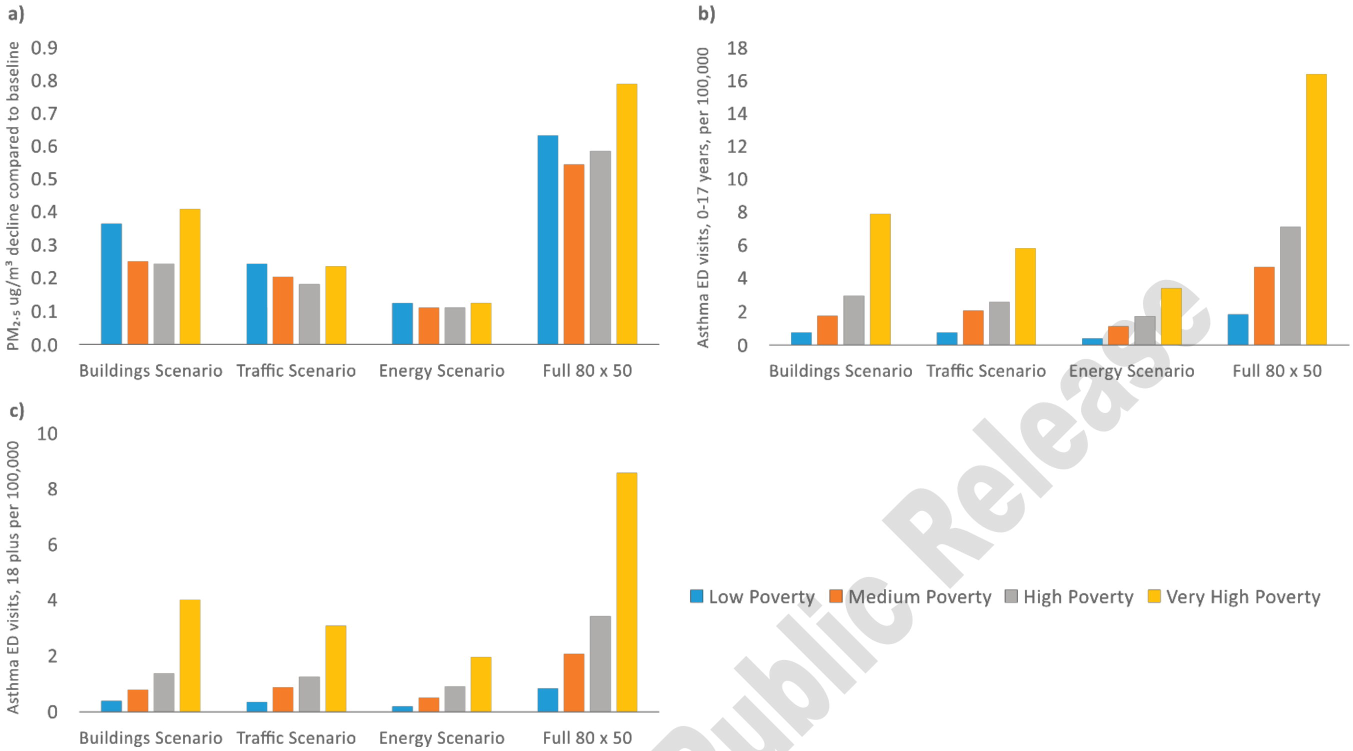


Figure 9: Median decline in zip code tabulation areas (ZCTA) average ambient annual average PM2.5 (a) and avoided asthma ED visits, age 0-17 years (b) and age 18 plus (c) under the sector=specific 80x50 strategies, alone and in combination stratified by neighborhood poverty. Adapted from Johnson et al., Figure 3 (Johnson et al., 2020).

Health impact assessment is a tool that can engage community stakeholders in ways that enhance procedural equity and shed light on distributive equity of proposed actions (Foster et al., 2019; Sohn et al., 2018). Often overlooked in health impact assessments focused on clean air benefits of climate action are the health benefits that transportation, land use, and urban planning strategies can provide through shifting from driving to more active modes of getting around such as walking and cycling (Mueller et al., 2015). Benefits of regular physical activity during trips to access jobs, school, services, and other essential needs include improved self-reported health, greater fitness, weight loss or less weight gain, reduced risk of chronic physical and mental health conditions, and reduced death rates (Gaesser & Angadi, 2021; Heath et al., 2012b; Saint-Maurice et al., 2022; The Community Guide, 2017, 2023). Active mobility need not involve cycling or walking alone; transit trips almost always involve physical activity beneficial to health, like walking (Besser & Dannenberg, 2005b; Edwards, 2008b) or cycling (Dutch Cycling Embassy (DCE), 2023; Nello-Deakin & Brömmelstroet, 2021) to and from stations and stops, with a shared motorized segment in the middle. Physical activity benefits of shifting trips from driving to transit and other active modes can provide health benefits far surpassing those from strategies focused on air quality improvements alone, such as electrifying cars to reduce tailpipe emissions. While health benefit pathways depend on local context, this importance of physical activity benefits has been shown in health impact assessments conducted in the Northeast, (Harvard T.H. Chan School of Public Health, 2021; James et al., 2014) in London, and Delhi (Woodcock et al., 2009).

NYC has long had many walkable neighborhoods (City of New York Department of Environmental Health, 2023) and has expanded its cycling infrastructure (City of New York Department of Transportation, 2019). However, faster, more comprehensive implementation of safe street designs is needed to reduce fatal pedestrian and cyclist crashes (New York Police Department, 2023) and to make adjustments in shared walkways and bike paths for an increasingly older population. Reducing private vehicle trips in favor of transit, cycling, and walking could also make more efficient use of the public right-of-way to move people, (Global Designing Cities Initiative, 2016, p. 14) freeing up space for additional trees, bioswales, and other green infrastructure, reducing local urban heat island effects, and better managing stormwater runoff, all of which may make investments in ROW even more compelling.

5.3.2 Heat, mechanical cooling, and health: applying maladaptation criteria to the local context

In NYC during the latter part of the 20th century, there was a substantial decline in excess mortality associated with higher temperature during the warm season (Petkova et al., 2014). This trend occurred nationally in association with increasing access to residential air conditioning (Barreca et al., 2013). Globally increased air conditioning prevalence from 1972-2009 was associated with reduced heat-related mortality in a comparison among several high-income countries, but the findings suggest that other adaptive strategies such as investments in green infrastructure and social connectedness may have played a more important role (Sera et al., 2020).

Without air conditioning, indoor temperatures can be much higher than outdoors, a difference that persists for up to 3 days after the temperatures have cooled off outside (Vant-Hull et al., 2018) due to thermal inertia of the building, highlighting the importance of understanding the interplay of the built and demographic character of cities. This may play a role in the delayed effects of up to 3 days documented in studies of NYC heat-exacerbated deaths (Matte et al., 2016; Metzger et al., 2010). Elevated indoor temperatures may also play a role in deaths and illnesses that occur when the outdoor temperature is moderately hot but not extreme (City of New York Department of Health and Mental Hygiene, 2022a). Those who die of heat stress in NYC are most often overcome by heat in dangerously hot homes without a working air conditioner (City of New York Department of Health and Mental Hygiene, 2022a, 2022d). Vulnerable New Yorkers most often stay at home during hot weather, even if unable to stay cool because of a lack of air conditioning (Lane et al., 2014). Other health benefits of mechanical cooling are discussed in NPCC4, Matte et al.,(2024).

Air conditioning already accounts for a substantial share of residential and commercial energy use in the US (17%, 12%) (Biardeau et al., 2020). By contrast, among energy uses in NYC's multifamily buildings, space cooling accounted for just 4% of greenhouse gas emissions in 2014 compared to 15% in commercial buildings. Across all NYC buildings, energy consumption for space heating (42%) and domestic hot water (15%) accounted for more GHG emissions that space cooling (8%) (City of New York, 2016). The need for heating and cooling will likely shift with increased climate impacts requiring increased cooling (and likely decreased heating) as well driven by population and demographic change. Air conditioning use increases peak electric demand during hot weather, and potentially outages, which are associated with health risks. The NPCC3 noted the potential for heat waves to severely stress the electric grid (Zimmerman et al., 2019). As recently as June 2021, it was reported that the major electricity outage threat during a heat wave was narrowly averted, but many neighborhoods were affected by localized outages and voltage reductions (Noor, 2021). Waste heat from building air conditioning may contribute substantially to the urban heat island, especially in dense cities (Gamarro et al., 2020; Ohashi et al., 2007) potentially adding to the risk of outages. More information on the health risks of power outages is provided in NPCC4, Yoon et al.(2024).

Substantial lock-in risks and vulnerabilities that accompanied the health benefits of mechanical cooling have already occurred over several decades in NYC, but the benefits and risks are inequitably distributed. Nearly all commercial and institutional buildings are mechanically cooled and roughly 90% of households have at least one air conditioner, but the proportions without access vary more than four-fold across neighborhoods. Households in low-income communities, and non-Hispanic Black people are more likely to lack air conditioning or report being unable to pay the added electricity cost (City of New York Department of Health and Mental Hygiene, 2022c; Lane et al., 2014; Madrigano et al., 2018). In a warming climate, the increased energy cost burden will fall hardest on these populations (City of New York Department of Health and Mental Hygiene, 2022b; Ortiz et al., 2022). The health and equity effects of energy cost burden and insecurity are addressed in more detail in NPCC4, Yoon et al. (Yoon et al., 2024).

Mechanical cooling in many large NYC buildings has been accompanied by maladaptive building design changes. During a warm weather power outage, glass façade high-rise buildings gain heat faster than comparable brick buildings (Urban Green Council, 2014). Limited operable window area and potential for passive ventilation may lock in the need for more mechanical cooling. Even when opening windows can maintain thermal comfort, a lack of screens in many modern buildings provides access for mosquitos that can transmit diseases like West Nile virus (see Section 3.5 in NPCC4, Matte et al.) (Matte et al., 2024). Raising air conditioning set points to avoid wasteful over-cooling while maintaining safe indoor temperatures can substantially reduce cooling energy use (Ortiz et al., 2022).

Other co-benefits (or costs) can be considered in building design. For example, energy efficient building design can also be bird-friendly design because increased glass on building facades increases both heating and cooling energy requirements and fatal bird strikes (Klem et al., 2009; Morris & Barges, 2023; Sheppard & Phillips, 2015). With Local law 15 (Local Law 15, 2020), NYC is already a leader in this space requiring new construction, and significantly altered buildings to use bird-friendly materials. Additionally, shade trees, green roofs, and other nature-based features can provide cooling through shading and evapotranspiration serving as key sources of heat adaptation through cooling that has potential to support reduced health-related impacts of heat exposure (Crown et al., 2023), and thus reduce the need for potentially maladaptive responses in the short-term.

5.4 Nature and Nature-based Futures

NYC is a complex social-ecological-technological system in which the ecological dimension is a fundamental driver of human health and well-being and a critical component of climate adaptation and mitigation strategies (Keeler et al., 2019; R. McDonald & Beatley, 2021; R. I. McDonald et al., 2023; McPhearson et al., 2022b). Nature and nature-based solutions have potential to provide many climate adaptation services in cities (stormwater management, urban heat island relief, flood, and erosion protection) and simultaneously provide health, social, economic, and ecological co-benefits that improve the well-being of people and support biodiversity and the function of ecosystems. In this section, we provide a brief assessment of how nature and nature-based solutions can contribute to a healthier, more resilient, equitable, and sustainable future for NYC.

As NYC prepares for increased climate change impacts, nature and nature-based solutions (NBS) can play an important role in addressing the twin crises of climate change and biodiversity loss, connecting people to nature where they live, and increasing the resilience of both people and nature. The International Union for Conservation of Nature (IUCN) defines NBS as "actions to protect, sustainably manage, and restore natural or modified ecosystems that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits" (IUCN, 2020). NBS encompasses both natural ecosystems and engineered solutions that incorporate or mimic characteristics of nature to achieve the services needed by the city. Cities around the world are using NBS in innovative ways to address some of urban planning's biggest challenges (Keeler et al., 2019). One advantage to NBS over traditional engineered solutions is that they can be multi-disciplinary efforts designed to address more than just one issue and create feedbacks among urban social, ecological, and technological systems providing multiple co-benefits (McPhearson et al., 2023; Treglia et al., 2022). Because urban NBS exist in a developed urban area where the natural processes on which they depend have been disrupted, natural areas require strategic long-term management to maintain desired benefits for people and ecosystem function (Pregitzer et al., 2018; Swadek et al., 2021) and engineered NBS require a dedicated workforce trained to design, install, and maintain them (Just Nature NYC, 2021).

Natural habitats (forests, wetlands, grasslands, streams) within NYC have intrinsic value, provide valuable ecosystem services that benefit people, and support local, regional, and global biodiversity (Cullman et al., 2023). Nature-based solutions of the engineered variety are diverse and can include parks and other green spaces, street trees, green roofs, community gardens, living shorelines, rain gardens, and bioswales. In addition to the measurable benefits of heat reduction, stormwater management, and carbon sequestration provided by green and blue infrastructure in the city, some of the most important services provided by nature are those that support human health and well-being that cannot be replicated by engineered solutions (e.g. Keeler et al., 2019). Streets and ROWs that are shaded by dense tree canopy create opportunities for active mobility and recreation. Engagement in urban environmental stewardship such as tending to green spaces like building a bioswale or working in a community garden can build community identity and social resilience (Campbell, Svendsen, et al., 2021; McMillen et al., 2019).

While the utility and efficiency of NBS for climate adaptation and social and ecological co-benefits has been widely documented (Bridges et al., 2015, 2018; IUCN, 2020), operationalizing them to achieve holistic resilience benefits in an equitable way is still a developing practice (Andersson et al., 2021; Wickenberg et al., 2021; Wijsman et al., 2021). Meeting our current challenges will require planning where and how to implement these strategies in a complex city system (Hoover et al., 2023; McPhearson et al., 2022a). Inclusive engagement of communities who will experience the benefits and burdens of decisions highlights their values and explicitly centers equity and justice to avoid unintended consequences that could exacerbate inequity (Grabowski et al., 2023).

One example of an ongoing effort to address NYC's needs for equitable application of NBS is the Forest for All NYC coalition working to advance the Urban Forest Agenda (NYC Urban Forest Task Force, 2021). The coalition is composed of over 126 diverse organizations including environmental justice and community groups, City agencies, NGOs and other groups working to support and equitably expand the urban forest to benefit all New Yorkers. Coalition goals include equitably expanding tree canopy cover citywide to 30% by 2035, advocating authentic engagement with local communities, and elevating local needs and leadership. Equitable expansion of NBS in NYC has tremendous potential to transform the function of NYC systems and the well-being of its inhabitants. Just as it takes time for a newly planted tree to expand its canopy and provide heat-reducing shade, authentic community engagement to identify the right solution for the right place takes time. Investment in solutions that integrate social, ecological, and economic attributes will be instrumental in transitioning NYC into a more healthy, resilient, sustainable, and equitable city.

5.5 Benefit-Cost Analysis

Benefit-cost analysis (BCA) is a planning tool used by federal, state, and local governments, including NYC (City of New York Mayor's Office of Climate & Environmental Justice, 2022a), to evaluate whether a proposed policy, project, or regulation should be pursued. The deciding criterion is whether benefits are greater than costs. The big question in applying BCA in practice, especially with an eye toward equity considerations: benefits and costs for whom? This question must be considered across generations, with discount rate assumptions front and center, as well as equity considerations within generations. Key in the application of BCA is for all assumptions to be fully transparent. BOX 4 lays out a set of best practices and guidance for applying BCA to climate mitigation and adaptation projects (for related discussions, see NPCC4, Foster et al. (Foster et al., 2024) and NPCC4, Rosenzweig et al. (B. Rosenzweig et al., 2024)).

Challenges to monetizing benefits and costs in applying BCAs have led to the development of many other alternative decision mechanisms, including 'multi-criteria analysis', 'robust decision making', 'socially tolerable risk', 'maxi-min' to maximize the lot of those worst off, 'mini-max' to minimize the maximum downside risk, and related methods. Multi-criteria analysis, for example, is just that, adding criteria other than maximizing (monetized and monetizable) net benefits as decision tools. 'Robust decision making' comes close to recommendation #1 in BOX 4 below: focus on risks and uncertainties, in a BCA framework. While some of these analyses, like those focusing on 'fat tails' and extreme risks (i.e., predicting the probability of extreme outcomes and being "fatter" making those outcomes more likely), pose fundamental challenges to standard BCA analysis. Strictly speaking, fat-tailed distributions make BCAs literally impossible (Weitzman, 2009) yet no other decision criterion comes close to the overall rigor and internal consistency of BCAs when *properly* applied. One downside is that unquantified and perhaps even unquantifiable risks and uncertainties might indeed dominate, which requires developing proper frameworks to deal with true 'unknown unknowns'. Practically, it might mean treating the outcome of a BCA as the 'lower bound' of large potential range of outcomes.

BOX 4: BCA guidance and best practices.

Be explicit about risks, uncertainties, and biases

BCA, in the broadest sense, is merely an attempt to compare like with like, typically by translating benefits and costs of any (policy) action — or the lack thereof — into dollars and cents. Therein begin the problems: calculating 'cents' would immediately imply false precision, false accuracy, or worse — leading to a fundamental confusion of precision with rationality (Brookes & Wagner, 2021). Users of this tool must be careful not to fall into that trap.

Every BCA is biased. The question is which way these biases go. For individual public works projects such as local adaptation measures, benefits are sometimes overestimated while costs are often underestimated. The latter is due to the inherent delays and cost overruns. For example, costs are based on third-party bids, which are incentivized to lower their costs. Delays, inflation, additional regulatory burdens, and other reasons, meanwhile, lead to increased costs. Adaptation benefits, too, might be underestimated largely due to missing quantifications of 'indirect' benefits. Underestimates of both benefits and costs now leads to the need to trading off the relative biases, a task made more difficult because even the signs of biases might change with the type of projects analyzed (Flyvbjerg & Bester, 2021).

For climate mitigation BCAs, the biases often go the other way — with costs of cutting emissions often overestimated (sometimes, substantially so) while societal benefits are underestimated. The latter is largely due to difficulties and delays in quantifying expected climate benefits and other risks and uncertainties. The former might be even more important: Biased cost estimates are due to the rapid nature of technological change and improvements in mitigation technologies and processes. The overall result is a bias toward inaction (Wagner et al., 2021).

Any BCA tools developed need to allow for presenting risks, uncertainties, and biases — at the very least by presenting 'high' and 'low' estimates in addition to 'best'/'average' results. Ideally, BCAs would span full-fledged uncertainty analysis, relying on probability density functions rather than point estimates. That process, too, might introduce false precision by forcing guesstimates of uncertainty ranges that are unmeasurable. Sometimes then, these biases necessitate moving (well) beyond BCA as a decision-tool. When examining risks and uncertainties, and the appropriate step could be to look toward direct 'risk-risk tradeoffs' (Zeckhauser & Wagner, 2019) a BCA emphasizing the probability of extreme impact risks (sometimes called tail risk).

Efficacy, cost-effectiveness, and equity

One danger of applying BCAs is elevating narrow interpretations of (economic) efficiency above all else, including important distributional considerations. That would be a mistake and misapplication of the concept — and also presents an important stumbling block in socializing and getting broader buy-in for BCAs. A SETS approach could also benefit BCA. Though BCA do well in terms of efficacy and cost-effectiveness, they could more explicitly include equity and co-benefits (such as in health and nature outcomes) as part of the BCA calculations.

A first step to avoid this fallacy is to explicitly split efficiency into efficacy and cost-effectiveness, and to add equity as an explicit additional criterion, at least in any narrative describing the analysis. Enlightened BCAs can span all three, with 'equity weights' explicitly incorporating effects of inequality (Anthoff et al., 2009). City-level applications might pose additional challenges, but that does not excuse their absence in BCAs. If anything, it calls for a shared understanding of the need to incorporating equity considerations into BCAs and standardized approaches across city agencies to do so.

Applying equity weights and putting distributional impacts front and center are important in lending BCAs much-needed legitimacy. Case in point is the U.S. Interagency Working Group on the Social Cost of Greenhouse Gases, which ended in U.S. government agencies agreeing to disagree, and for U.S. EPA to go it alone with its own SCC (U.S. Environmental Protection Agency, 2022). The separation of efficacy and cost-effectiveness, meanwhile, might be less important in the final analysis. BCA clearly spans both.

Train, engage NYC agency staff to help conduct BCA analyses

Some agencies like DOT already conduct their own BCAs. Other agencies outsource theirs. Since many agencies are now considering how to mitigate and especially adapt to climate change, thus establishing capacity and consistency across agencies' effort may be an important city-wide objective. BCAs, and the framing they provide, could be one important parts of this process.

6 Limitations of Future Scenarios and Approaches

Despite the variety of scenarios and current approaches for envisioning the future of NYC and its many transitions, they also have recognized limitations. Among these limitations are shortcomings in the degree of understanding about who and where future New Yorkers will be living and working; lack of a longer-term perspective on lessons from relevant policies in the recent past with place-based implications; lack of comprehensive comparisons between approaches; and the need to consider these projected futures in an integrated way across the multiple sectors and dimensions of NYC's urban systems. While it is a sizeable challenge to describe integrated, multi-sectoral, plausible pathways to positive futures for NYC, providing details of how future events might unfold can limit anxiety toward worrisome future events and reduce the perceived likelihood of negative outcomes (Jing et al., 2016).

Discussing uncertainty allows us to better understand the range and parameters around different futures. Low probability events (such as catastrophic flood expected to occur once in a 1000 years) with high magnitude and potential for damage cannot be predicted but can be projected recognizing that such projections come with high uncertainty due to the low probability nature of such events. Another challenge inherent in projecting or envisioning the future is that it may include events or disturbances that we have yet to experience, or even imagine. The COVID-19 pandemic and Hurricane Ida (in which the City for the first time issued a flash flood warning), are other examples of events that in the past many planners would have considered unlikely, but nonetheless have now occurred. Lastly, unforeseen and unintended consequences of plans add another layer to uncertainty and while the magnitude of such consequences can often not be forecasted, narratives around such consequences can often be articulated.

6.1 Climate Actions and Plans Can Be Adaptive or Maladaptive

Plans and actions to enable resilient futures can be adaptive or maladaptive. Maladaptation describes actions that lead to increased vulnerability or risk to climate impacts or diminish welfare. The IPCC describes responses to climate change that unintentionally "create lock-ins of vulnerability, exposure and risks that are difficult and expensive to change and exacerbate existing inequalities" as maladaptive. Understanding the processes leading to maladaptation can help prevent it. Whether an action is maladapted or not can depend on social or environmental context, scale, or time. In some cases, maladaptive responses to hazards have exacerbated inequality in the distribution of impacts, for example shifting risk from one community or group to another.

There are a variety of causes of maladaptation, including lack of knowledge. For example, early in the 20th Century, health officials recommended substituting the new automobile technologies to replace horses. Horses created excrement and often died on city streets, creating safety and health hazards. Health officials argued the automobiles were a good, healthy solution to urban horse use (McShane, 1994; Melosi, 2000; Tarr, 1971), only to see rising injuries, deaths, traffic congestion, and other problems caused by the flooding of cars into cities. Similarly, unintended consequences of segregated land use zoning, which was originally put forth to keep residents away from industrial locations, included it becoming a tool for creating segregated suburban communities (Jackson, 1985). Alternatively, maladaptation can also occur through plans, policies, or investments that consider sectors and climate risks in isolation or that ignore climate risks for what are seen as more urgent planning priorities. In the local context, this has involved, for example, policies that subsidize and encourage driving, parking, and car ownership, removing electric streetcars, widening surface streets and building urban highways without considering implications for health, safety and equity and, more recently climate risks, equity, and mitigation goals. Maladaptation can also result if climate risks are not considered in "non-climate" policies that influence climate risks, such as those governing zoning, building codes, and affordable housing.

For example, building walls to keep floodwaters out of low-lying areas can be a critical source of coastal flood protection but may also be maladaptive over longer time frames because sea walls can give a false sense of security, encourage additional development in flood-prone areas, limit public access to the water, exacerbate erosion, negatively impact coastal habitats, and may be built to design guidelines that become quickly outdated as sea level rise and storm surge projections change over time (Dodman et al., 2022). Structural mitigations like floodwalls can also result in "resilience gentrification" resulting in greater inequality (Gould & Lewis, 2021). Floodwalls and tide gates are generally designed for a single purpose, and as such, may fail to meet the complex needs of a city. Indeed, NYC's flood reduction strategy must address multiple compound flood hazards including storm surge, regular tidal flooding, groundwater flooding, heavy rainfall and compound flooding (see NPCC4, Rosenzweig et al.(B. Rosenzweig et al., 2024)), but it must also balance flood protection with other resiliency needs such as sustainable economic development, social equity and affordable housing, and biodiversity and the protection of nature that together will support resilience of the city long term.

Several evidence-informed criteria can be applied to assess whether actions are adaptive or maladaptive within the local context of NYC and its diverse communities. One example, the use and expansion of mechanical cooling in several types of NYC buildings, was considered in Section 5.3.2 . Elsewhere in this assessment, measures are described to reverse or reduce maladaptation in other sectors, including the public right of way, mechanical cooling in buildings, and flood protection. For most adaptation strategies, recognizing inherent feedbacks among system components (such as between use of air conditioning to reduce heat risks that may also increase energy use and increase carbon emissions) will be critical to ensure intended adaptation approaches do not become or enhance maladaptation in other systems, contexts, or timescales. Similarly, trade-offs are likely to exist for all adaptation strategies, including spatial trade-offs such as where adaptation in one location may increase and thus drive maladaptation in other locations. Whether maladaptation occurs thus depends on whether a particular strategy or climate adaptation action is examined for larger potential trade-offs, cross-sector impacts, and longer-term effects versus short-term outcomes.

6.2 Uncertainty

There are many uncertainties that must be accounted for in estimating and planning for the future. Like weather forecasts, these include temporal and spatial factors and pertain to the social and ecological themes as well as climate-related factors: It is more difficult to predict the future, the farther one goes, and predicting changes that will occur in precise locations (specific neighborhoods) is much less certain than in larger spatial units (all of NYC, or the greater metropolitan area). The IPCC has been a leader in thinking about ways to address uncertainty in the future climate, examples from which are shown in BOX 5.

In addition to understanding climate futures, each sector, and within those particular themes (or variables of interest), produces models that generate futures that quantify or qualify uncertainty in different ways. Typically, there are trade-offs between spatial and temporal uncertainty, which make futuring exercises at a long-term sub-city scale challenging. Furthermore, models used to predict the future have their own uncertainty associated with the data and estimation techniques. While we have identified many of these areas of uncertainty in this chapter, future work on understanding and communicating uncertainty inherent in city scale issues remains to be done.

BOX 5: How the IPCC contextualizes uncertainty

"Impacts at high levels of warming are particularly uncertain, as all methodologies require extrapolation and insufficiently incorporate possible tipping elements in the climate system (from IPCC WGII Ch.16 (O'Neill et al., 2022)).

"Unlike known or identified risks, emergent risks are characterized by the uncertainty of consequences and/or probabilities of occurrence. The International Risk Governance Council (IRGC) suggests three categories of emergent risks: (1) high uncertainty and a lack of knowledge about potential impacts and interactions with risk-absorbing systems; (2) increasing complexity, emergent interactions and systemic dependencies that can lead to nonlinear impacts and surprises; and (3) changes in context (for example, social and behavioural trends, organizational settings, regulations, natural environments) that may alter the nature, probability and magnitude of expected impacts." (O'Neill et al., 2022).

Figure 16.1 illustrates the elements covered by the chapter, which can be summarised as four key questions

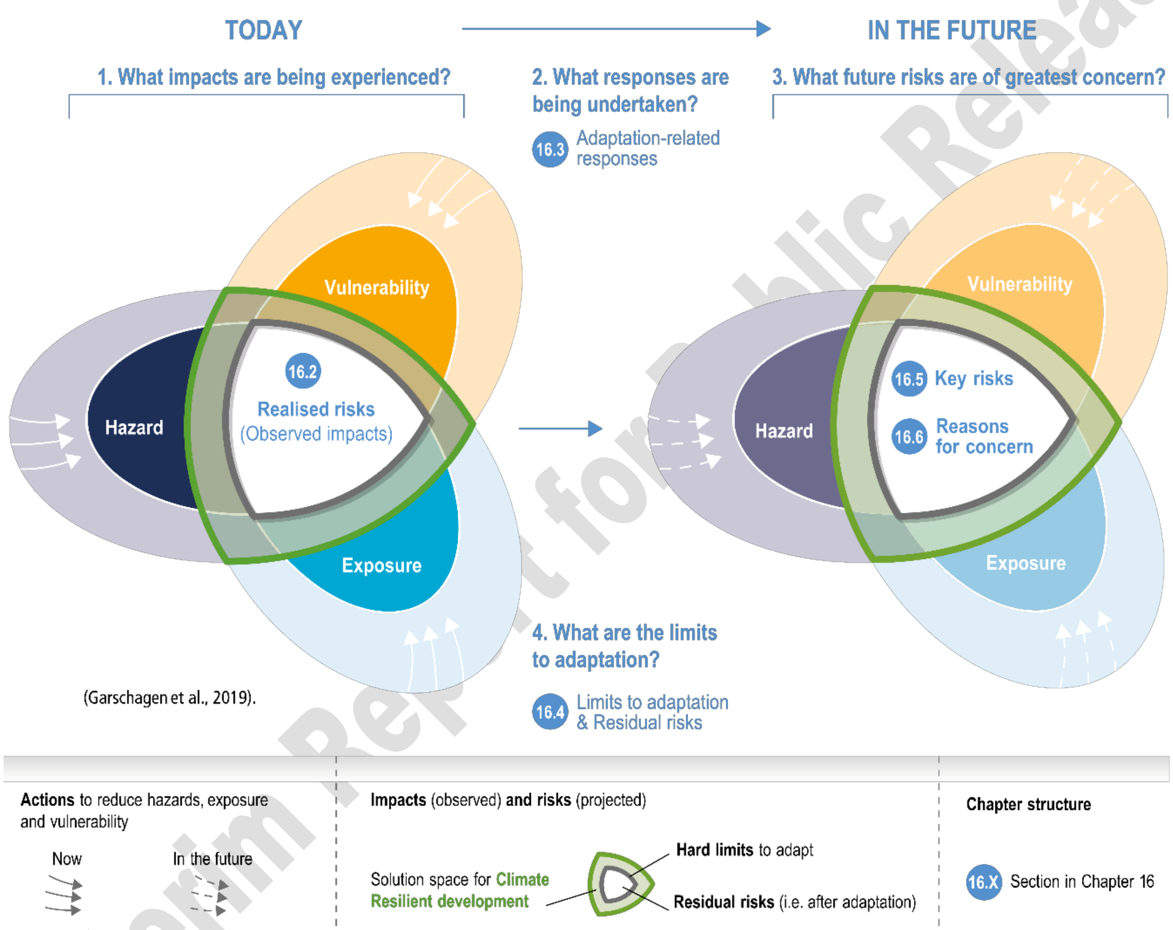


Figure16.1 | Illustrative storyline of the chapter highlighting the central questions addressed in the various sections,from realised risks (observed impacts) to future risks (key risks and reasons for concern), informed by adaptation-related responses and the limits to adaptation. The arrows illustrate actions to reduce hazard, exposure and vulnerability, which shape risks over time. Accordingly, the green areas at the centre of the propeller diagrams indicate the ability for such solutions to reduce risk, up to certain adaptation limits, leaving the white residual risk (or observed impacts) in the centre. The shading of the right-hand-side propeller diagram compared with the non-shaded one on the left reflects some degree of uncertainty about future risks. The figure builds on the conceptual framework of risk–adaptation relationships used in SROCC (Garschagen et al., 2019).

Figure 10. Realized risks (observed impacts), future risks (key risks and reasons for concern), adaptation-related responses, and the limits to adaptation. Chapters identified here refer to IPCC6, WGII. Source: O'Neill et al., (2022, p. 2419)

The challenges of managing these risks are amplified by the complex interactions between climate and urban scenarios, owing to the smaller spatial–temporal scales of urban areas in climate change modelling relative to global climate models (GCM) and shared socioeconomic pathways (SSP); geographical or geomorphological variations in city location; uncertainties arising from incomplete assumptions about socio-economic pathways at urban scales affecting demographic characteristics of cities, etc.

7 Sustained Engagement Through New York City Climate Knowledge Exchange

Sustained engagement is a foundational component of sustained assessment and may contribute to building communities of practice and establishing a public agenda for climate research. Through the sharing of knowledge about ongoing efforts across the City, sustained engagement with city government agencies, community groups, academics, and others can help to foster informed decision-making, build community capacity and empowerment, and inform the development of effective communications tools. Sustained engagement helps to identify current gaps in knowledge and practices and create a process for discourse and knowledge sharing about how to effectively plan for adaptation in the short and medium term.

In 2020, the Mayor's Office of Climate and Environmental Justice (MOCEJ) initiated the Climate Knowledge Exchange (CKE), a sustained engagement process to identify the City's climate research priorities and co-produce a future public climate research agenda for the City. In Year 1, the CKE brought together over 170 participants from city agencies and NGOs in small discussion groups. Using a combination of thematic analysis from the discussions, document review of existing community based and government plans and analysis of survey data, MOCEJ developed an agenda for future climate resiliency and adaptation research: 1) Living with Climate Change, 2) Managing Resiliency, 3) Climate and the Built Environment, and 4) Climate Communication, Education, and Engagement. For more details on each research priority, see the State of Climate Knowledge 2021 Report (City of New York, 2022). Participants also identified future areas of improvement for the climate knowledge exchange process, including create sustained partnerships and build awareness of ongoing efforts, raise funding to support community participation in research initiatives, improve information sharing and knowledge development, recognize multiple ways of knowing, and evaluate outcomes of the CKE process and research.

These improvement areas helped to inform Year 2 of the CKE, which took a step back from Year 1 to refine the design of the engagement process to achieve the CKE's broader objectives using the Theory of Change (TOC) framework. A TOC is a tool for planning, implementing, and evaluating an initiative, and typically includes a statement of the problem being addressed, an overarching end goal, and short, medium, and long-term pathways to achieve the end goal. Through a series of three workshops in 2022, participants co-produced a TOC for the CKE. The five key goals identified, and informed by Year 1 improvement areas, were: Sustained funding is achieved; information is accessible to all; networking and partnerships with stakeholders are created and maintained; multi-way exchanges to empower and elevate communities are established; and Brave spaces for listening and learning are fostered. A full description of the workshops and outcomes is available in the State of Climate Knowledge Exchange 2022 Workshop Summary Report (City of New York, 2022).

The city continues the CKE, currently in Year 3, as a forum for sharing information, research, and initiatives amongst a diverse group of city and state agencies, community organizations, nonprofits, and academic institutions. The CKE is one model of sustained engagement processes, and going forward, others may also be adopted.

8 Conclusion and Future Research Needs

This chapter has illustrated how interacting dimensions of the complex nature of NYC, including intersecting social, ecological, and technological-infrastructure system domains, are essential to address in order to transition to a climate-adapted future that protects all New Yorkers. We reviewed a range of approaches to futures and scenario development processes as part of the emergence of scenario planning to guide decision-making for climate adaptation and mitigation in the city. We also reviewed community-based planning and opportunities to integrate community and stakeholder ideas about what would make NYC more livable, equitable, and resilient. By assessing these current approaches to future visioning and scenarios across community and city level initiatives and examining these diverse dimensions of the NYC system to reduce risk and vulnerability, we find that city as well as a multitude of community organizations are engaged in a wide range of adaptative planning; although these are largely oriented to near-term objectives and strategies and are mostly framed around sectoral concerns.

While long-term visioning has been part of the City's planning efforts in the past, no current plan, let alone a demographic forecast, matches the end of century dates of the climate projections, and represents a gap in long-term planning need to guide NYC decision-making that looks beyond the near term to actions now that will impact the city later this century. The future NYC will be increasingly older, and there is little to suggest that it will not continue to thrive as a diverse city. But whether the NYC of 2100 is more or less populous than today is unknown. Further, whether future New Yorkers increasingly live in flood-prone neighborhoods or heat-prone housing – let alone whether such risks will be born unequally according to race and ethnicity, or socioeconomic or nativity status – remain unknown. Yet these unknowns are modifiable by tools, planning and policy; and planning for a range of possible outcomes is increasingly necessary. Thus, there is need for increased multi-sector, multi-hazard long-term planning initiatives, and future research can help to evaluate, assess, and monitor the progress of these planning initiatives, as well as the capacities and collaboration of community-based organizations and government entities to implement the plans.

Though the are many tools that could drive policymaking and decisions about how to prioritize investments, BCA remain influential in deciding what gets built (or invested in), how, and by whom. BCA of policies and future investments still have not typically included valuation of costs associated with climate-sensitive health conditions. Including health-related costs in these analyses can more fully capture the benefits of avoidable health costs and be more forward-looking by accounting for future population shifts and future climate projections. Additionally, health impact assessment can be a useful tool for estimating health co-benefits of climate actions and assessing their distributional equity. Such tools are already well established, but their application to climate adaptation and mitigation is still new and therefore underutilized.

Many aspects of the built environment (such as infrastructure) have been addressed by prior NPCCs. In this chapter, we took a novel look at NYC's public ROW (streets and sidewalks) and found that this valuable shared resource has the wide potential to be transformed to better support climate adaptation, health, and equity. Near-, medium-, and long-term changes to how streets, sidewalks, and other public spaces that are part of the public ROW are designed, governed, and managed at different spatial scales can begin to reverse maladaptive uses and enable a more sustainable future, yet aspects of the public ROW need to be incorporated in a range of planning and knowledge-gathering initiatives. This chapter did not review issues in the housing sector in any detail, and notes that housing quantity and quality remains an important issue for future NPCCs to address fully.

People and nature co-exist in NYC, but NBS are often siloed despite acknowledgment of their many co-benefits including those on physical and mental health. Furthermore, the benefits of nature are not evenly distributed across the city. Thus, investment in NBS alongside other engineered and social approaches to adapting to increasing climate impacts may have broad potential. Examples of these adaptations can include increase investments and plans for natural area restoration, conservation, and protection alongside new hybrid and green infrastructure installations including expanding tree canopy and installing green roofs and bioswales. As noted above with health impacts assessment and BCA, NBS must include intentional equity dimensions in their implementation in order to ensure that they not do not reinforce or exacerbate historical inequities and that they work to making NYC more sustainable for all.

Systems approaches such as that of the SETS framework are needed to ensure adaptation and mitigation decisions do not occur in siloes; rather they consider a range of futuring options that accommodate feedbacks to other sectors and subsystems. For example, mechanical cooling, while maladaptive in some applications, has helped reduce heat health impacts among vulnerable populations. Yet long-term investments in cooling the city to protect residents from high heat impacts need to consider nature-based and other systemic solutions to cool the city, while recognizing the need for mechanical cooling to reduce heat impacts during high heat events. Overall, maladaptive and wasteful uses in NYC buildings should be reduced to avoid increasing energy use and emissions as access is expanded.

It is increasingly clear that equity and social justice are critical to inclusive climate adaptation goals, implementation efforts, and future planning. Centering equity in climate adaptation and mitigation actions provides an opportunity to decrease impacts on the most vulnerable while creating more inclusive processes that center community voices in climate adaptation and mitigation planning, policymaking, and investments decisions. This means that tools for planning must allow for explicit attention to equity concerns.

Prior NPCCs have noted the need for regular and meaningful indicators of climate impacts in perpetuity. This NPCC finds equal imperative in the City's commitment to regular and meaningful monitoring of adaptation progress. Such meaningful and transparent indicators, and related fora for exchange such as the CKE, are important so that the agencies of city government, and other civil actors, as well as the public can observe and engage in the city's progress toward a more sustainable and equitable future.

As part of the first NPCC Futures and Transitions Working Group, this chapter has contributed to imagining, visioning, and planning the future of NYC. It introduced frameworks that would allow for longer demographic projections consistent with socioeconomic futures that are plausible given a range of climate futures and social-ecological-technological systems (SETS) that model complex urban dynamics with a range of cascading influences and feedbacks. These new frameworks offer longer-term scenarios to guide the decision-making today and, with continued use, in the future. Going forward, much work remains to be done to assess the alternative projections, visions and scenarios, and their inherent uncertainties, but so doing will build the necessary tools for a climate adapted, sustainable, and equitable future NYC.

9 Traceable Accounts

Key Message 1	NYC is projected to be hotter, wetter, and more flood prone, with multiple types of tropical and winter storms that are likely to increase in frequency, intensity, and severity. At the same time, the population of the city is expected to age. Long traditions of in- and out-migration have shaped the city and are expected to continue to be an important part of its future, anchoring it in the region and the nation. The built environment will largely remain in place, yet changes in land use and land cover, including in impervious and natural areas are expected. Managing and planning the future NYC to be more adapted and resilient to diverse climate, economic, and social pressures will require understanding these diverse futures that also interact dynamically in real-time.
Description of Evidence	The Climate Science Special Report (Braneon et al., 2024) lays out the future climate conditions for NYC. Projections of population, which describe future aging patterns and the total size of NYC's population in the short and medium term, are produced by NYC's Department of City Planning (2013) to 2040 and New York Metropolitan Transportation Council (NYMTC) (New York Metropolitan Transportation Council, 2020b) to 2055. Historical evidence shows that NYC has become increasingly diverse in terms of its racial and ethnic composition since 1950 (City of New York Department of City Planning, 2023b). See KM8 for evidence on changes to the natural environment.
New Information and Remaining Uncertainties	Population futures that match the temporal scale of the climate projections, out to 2100, do not yet exist, and therefore those uncertainties remain hard to describe (Balk et al., 2022). Evidence from work done for US States (Zoraghein & O'Neill, 2020a, 2020b) indicates that the total population of NYC at mid- and end of the century could be larger, smaller or about the same size as it is now, depending in part upon which climate future is used to inform that future population trajectory. Such projections for NYC, that will include spatial downscaling in order to assess future impacts of climate hazards, are underway as part of Task 4 of the NYC Vulnerability, Impacts and Adaptation Assessment (VIA) project; these will project the population by race/ethnicity and age out to 2100.
Assessment of Confidence based on the Evidence	The evidence that NYC will remain diverse, continue to be a home to migrants (both domestic and international), and that its population will become older (as will the rest of the country) is very high with strong evidence. Levels of each of these compositional characteristics is less certain, as is the spatial distribution.
Key Message 2	Future complexity and uncertainty due to climate change demands new ways to plan our cities. Scenario-based planning can incorporate important urban dynamics and complexities and uncertainties common to the non-anecdotal challenges of the Anthropocene that other planning tools cannot, partly by addressing uncertainty over the mid-to-long term. By incorporating scenario planning into NYC futuring exercises, a range of new opportunities for envisioning and shaping health, social, environmental, economic, and population change outcomes can be applied to meet broad or sectoral adaptation and mitigation planning.
Description of Evidence	Scenarios, as future tools, have consistent internal logic and coherent narratives useful in addressing complexity and uncertainty (Díaz et al., 2019; Iwaniec et al., 2014; Moss et al., 2010; Reid et al., 2005). While these tools have been deployed at the global scale, less work has been done at regional or city scales (Reimann et al., 2021; Rohat et al., 2021). Historically, localities have focused on predictive scenarios or forecasts, that extrapolate future conditions based upon predefined models of historic and existing trends (City of New York Department of City Planning, 2013, 2023b) and are relatively short-term projections (Balk et al., 2022). Moreover, most of these plans focus on land use zoning needs based upon economic and population growth (see review in Balk et al.(Balk et al., 2022)).
New Information and Remaining Uncertainties	Planners have started employing scenarios in local development analyses (Finn & Miller, 2022). While scenarios promise to provide new insight, issues to watch out for include adequate consideration of uncertainties, an overemphasis on "picking" a preferred future (Chakraborty et al., 2011), and a lack of effective public involvement (Bartholomew, 2007).
Assessment of Confidence based on the Evidence	Localities could use scenario planning in a variety of development plans (High Confidence). Questions remain, however, about how best to move forward and incorporate scenario approaches in both private and public planning exercises.

Key Message 3	Equity and social justice should be explicitly centered in future climate adaptation goals, implementation efforts, and future planning. Planning without centering equity will likely result in unintended negative consequences, such as gentrification or displacement, which exacerbate inequity. Centering equity in climate adaptation and mitigation actions provides an opportunity to decrease impacts on the most vulnerable.
Description of Evidence	Historical evidence shows that NYC has become increasingly diverse in terms of its racial and ethnic composition since 1950 (City of New York Department of City Planning, 2023a). Persons of color are more likely to lack air conditioning or report being unable to pay the added electricity cost amplifying the burden of future heat in communities of color (City of New York Department of Health and Mental Hygiene, 2022d; Lane et al., 2014; Madrigano et al., 2015). For example, gentrification, or the displacement of populations from neighborhoods due to rising property values, increasing rents, upzoning, and other core gentrification drivers are an increasing concern among vulnerable communities in NYC (Foster et al., 2024). Additional evidence is reviewed in the NPCC4, Foster et al (Foster et al., 2024).
New Information and Remaining Uncertainties	Health impact assessment can be a useful tool for engaging community stakeholders in ways that enhance procedural equity and shed light on distributive equity of proposed actions (Foster et al., 2019; Sohn et al., 2018). Future population projections by race/ethnicity and that are spatially specific would also help the city guide response with an equity lens (Balk et al., 2022).
Assessment of Confidence based on the Evidence	Counterfactuals (that is, the ability to show the results had a given plan not been implemented) is hard to observe at a city scale, yet evidence from a variety of plans and programs with equity goals is a helpful precondition for equity goals to be met. Very high confidence and strong evidence.
Key Message 4	NYC is dynamic, and the scale and complexity of NYC requires managing interacting socio-economic, ecological-biophysical, and technological-infrastructure components. However, there is often a lack of understanding by planners of the fundamental drivers of behaviors and patterns that are important for planning and designing more resilient, equitable, and adapted NYC and metropolitan region. Inherent in these interdependencies are trade-offs between temporal and spatial scales in planning activities, as well as between sectors; identifying these trade-offs is integral to transparency in planning and adaptation. Incorporating approaches that acknowledge interdependencies in future planning will prevent a siloed understanding of trade-offs and uncertainties.
Description of Evidence	Cities have many interacting and interdependent social-economic, ecological-biophysical, and technological-infrastructure systems and NYC is at risk from climate change precisely because of its dense concentration of people, infrastructure, and economies. Transforming NYC to be flexible, adaptive, and resilient requires the capacity to build, design, and plan for complexity (Chester et al., 2023; McPhearson, 2020). To ensure that climate solutions don't create unintended trade-offs, or maladaptation, it is important to account for the interdependencies among social, ecological, and technological infrastructure components of urban systems (E. M. Cook & McPhearson, 2020; Grabowski et al., 2017; Grimm et al., 2016, 2017; McPhearson, 2020; McPhearson et al., 2021, 2022b; McPhearson, Iwaniec, et al., 2016).
New Information and Remaining Uncertainties	Recent extreme events demonstrated failures or inadequacies not just in the built infrastructure but also in resources, institutions, information, and governance systems—components of the urban SETS—to prepare for, and respond to, events of this magnitude (Eakin et al., 2018). There also remaining uncertainties in best practices for identifying and comprehensively assessing trade-offs across sectors and spatial and temporal scales to inform future decision-making (Zeckhauser & Wagner, 2019) . More research is needed on approaches that focus on identifying trends and uncertainties that would allow decision makers to overcome siloed or short-term planning as needed (Balk et al., 2022; Schoemaker, 1995).
Assessment of Confidence based on the Evidence	To advance governance for resilience means also advancing our ability to understand such complex urban dynamics and develop near and longer-term scenarios to guide decision-making. There is high confidence that without significant investment in transparency and cross-sectoral collaboration, there will continue to be siloed planning initiatives and unintended tradeoffs that will hinder future resilience and adaptation. There is high confidence and moderate evidence through a quickly emerging body of literature that a social-ecological-technological systems (SETS) approach can improve ability to examine

	complexity of cities and examine trade-offs across sectors and scales. This body of literature is expanding globally, as well as for NYC empirical case studies.
Key Message 5	In the context of climate change risks in NYC and the metropolitan region, changes in key sectors and deployment of technologies have included some which are adaptive and beneficial and others that are unintentionally maladaptive, causing risks and inequities that are costly to reverse. The adaptive or maladaptive potential of such changes have depended on the extent to which their costs, benefits, and risks are balanced and equitably distributed. Local examples considered in this chapter include mechanical cooling, flood protection measures, and spatial allocation of the public right of way (ROW, mainly streets and sidewalks). Maladaptation can be caused by ignoring climate risks and equity considerations and by siloed planning, within and among sectors, levels of government, government agencies, non-governmental institutions, and the private sector. Potential for maladaptive and inequitable effects of climate adaptation strategies and other sectoral actions influencing climate risks should be weighed to ensure that near-term actions are not maladaptive in the long term.
Description of Evidence	Abundant and robust evidence shows that key technologies in NYC have been deployed in ways that have been both adaptive and maladaptive and inequitable; evidence-informed approaches can inform potential for adaptive and equitable sectoral transitions. Mechanical cooling of residences has greatly reduced deaths caused by hot weather in NYC and nationally (Petkova et al., 2014) (Barreca et al., 2013) and provides other health benefits (Matte et al., 2024). Widespread but inequitable access contributes to greater heat vulnerability in low-income and non-Hispanic Black populations (City of New York Department of Health and Mental Hygiene, 2022c; Lane et al., 2014; Madrigano et al., 2018). Much larger sources of building energy consumption include space heating, provision of hot water, and space cooling in commercial buildings (City of New York, 2016). Building designs vary in their adaptation to hot weather (Urban Green Council, 2014)). Evidence concerning maladaptive and adaptive uses of the ROW is considered in KM 7. Evidence concerning maladaptive and adaptive flood protection measures is considered in NPCC4, Rosenzweig et al (B. Rosenzweig et al., 2024).
New Information and Remaining Uncertainties	Emerging and future developments in mechanical cooling technologies, the potential efficacy of scaling urban heat island mitigation measures, future energy transition challenges (Yoon et al., 2024), and proposed new policies (City of New York Office of the Mayor, 2023) add uncertainty to forecasting future benefits, costs, and inequities that mechanical cooling might create. Uncertainties concerning the public right of way are considered in KM 7. Uncertainties concerning flood protection measures is considered in NPCC4, Rosenzweig et al (B. Rosenzweig et al., 2024).
Assessment of Confidence based on the Evidence	There is high confidence that mechanical cooling, use of the ROW, and flood protection have been deployed locally in ways both adaptive and maladaptive and that it is feasible to begin transitions to more adaptive uses.
Key Message 6	Without shared positive visions for the future, it is unlikely that plans made now will achieve the equity, justice, sustainability, and resilience goals desired for the future of NYC and its communities. Participatory processes are critical in co-developing shared visions that bring together diverse perspectives and forms of knowledge, and a sustained engagement process is critically needed to identify the City's climate research priorities and co-produce a future public climate research agenda for the city. Co-produced visions, goals, and strategies can involve perspectives across multiple sectors, scales, and communities to gather the full range of ideas, innovations, and possible actions to address trade-offs and inform transitions toward a climate-adapted future for NYC. However, tools for longer-term (beyond 2050) transitions and pathways to achieve future plans for NYC are currently missing and needed to guide efforts to secure an inclusive climate resilient future for all New Yorkers. In order to track progress towards these goals, periodic and systematic monitoring and evaluation are necessary.
Description of Evidence	Shared positive visions of the future can help to address the barriers to action of dystopian or negative framings of the future (Iwaniec et al., 2020; McPhearson, Iwaniec, et al., 2016). Co-production processes that bring together a range of perspectives and stakeholders have already been employed in NYC (City of New York, 2022; E. Cook et al., 2022). An analysis of government and community-based plans in this chapter indicated that most plans have short or mid-term timelines, and very few focus on the long-term (Figure 3).

New Information and Remaining Uncertainties	There are remaining uncertainties as to how to effectively engage community members and community-based organizations and more meaningfully learn from and integrate their expertise into planning initiatives while addressing redundancies in community engagement across sectors or agencies (E. Cook et al., 2022). More research is needed on effective methods to evaluate progress on co-production and community engagement in planning.
Assessment of Confidence based on the Evidence	Without improved processes such as those that are co-produced or others that are integrated into resilience planning, there is high confidence that we will continue to replicate historic trends and mistakes in resilience planning without the multiple perspectives and innovations that co-production processes generate.
Key Message 7	Transitioning the built environment to be more climate resilient while addressing fundamental challenges to equity and sustainability requires policies and investments to retrofit, rebuild, and improve the built infrastructure to support population health. Prioritizing active and sustainable modes, including transit, walking, and cycling can provide multiple, equitable health benefits through increased physical activity, reduced air pollution exposure, more affordable transportation options, and reduced risk of conditions that increase vulnerability to climate change. At the same time, reducing miles driven by private motor vehicles within, into, and out of the city will reduce greenhouse gas remissions and expand space available on streets and sidewalks for uses that provide climate resilience and social and equity benefits.
Description of Evidence	Extensive evidence shows that active transportation modes, including public transit, promotes regular physical activity that confers multiple health benefits (Besser & Dannenberg, 2005a; Edwards, 2008a; Gaesser & Angadi, 2021; Heath et al., 2012a; Saint-Maurice et al., 2022; The Community Guide, 2017) (Besser & Dannenberg, 2005b; Edwards, 2008b) (Dutch Cycling Embassy (DCE), 2023; Nello-Deakin & Brömmelstroet, 2021). Studies also show that policies promoting motor vehicle traffic cause congestion in densely populated areas, increase exposure to air pollution (Bosson et al., 2019; Khreis et al., 2017; Yang et al., 2018) and increase crash risks for pedestrians; these risks are inequitably distributed (Kheirbek et al., 2016a; Lubbe et al., 2022; Smart Growth America, 2022). Such policies also limit space available for safe, healthy, active modes. Spatial allocation of NYC's public right of way (ROW, mostly streets and sidewalks), has prioritized the movement and parking of private motor vehicles (Czebotar, 2021; Freudenberg et al., 2021) over more spatially efficient modes (National Association of City Transportation Officials, 2016). The amount of paved impervious surface required contributes to climate risks from heat and flooding (Mohajerani et al., 2017) (Madrigano et al., 2015; B. Rosenzweig et al., 2024). Potential strategies and examples of adaptive transition of the ROW have been described and demonstrated in NYC and elsewhere (Freudenberg et al., 2021) (Aaron, 2011; Brugge et al., 2015; Pestel & Wozny, 2019; Zhai & Wolff, 2021) (City of New York, 2019; City of New York Department of Transportation, 2023c, 2023b, 2023a) (City of New York Department of Transportation, 2022; Sam Swartz, 2019).
New Information and Remaining Uncertainties	Emerging changes in the transportation sector within and around NYC create opportunities, implementation challenges, and some uncertainty about the potential for transitions that provide health and environmental co-benefits. These include the advent and implementation of congestion pricing (Slevin, 2019), electrification of buses (Sustainable Bus, 2022; Zhou et al., 2016), state and national subsidies promoting battery electric private vehicles, which share most maladaptive features of fossil fueled vehicles (Kelly & Zhu, 2016; Requia et al., 2018), and the expanded use of delivery apps and motorized two wheeled vehicles (Cohen, 2023; DiMaggio et al., 2020).
Assessment of Confidence based on the Evidence	Despite challenges and uncertainties, there is high confidence that sustainable and active transportation investments and policies, including reallocation of space on streets and sidewalks can advance NYC health, equity, and environmental goals.
Key Message 8	Nature-based solutions are critical for addressing climate adaptation needs in the city and can simultaneously provide co-benefits for public health, society, and natural systems that help create a resilient city. Planning, implementation, and management of nature-based solutions to achieve equitable distribution and holistic resilience in a complex city system is still a developing practice.
Description of Evidence	Nature-based solutions have the potential to provide many climate adaptation services in cities and when strategically designed to do so, have the potential to simultaneously provide health, social, economic, and ecological co-benefits that improve the well-being of people and support biodiversity and the function of

	ecosystems (Campbell, Cheng, et al., 2021; Keeler et al., 2019; R. McDonald & Beatley, 2021; R. I. McDonald et al., 2023; McPhearson et al., 2022b).
New Information and Remaining Uncertainties	Measuring the delivery of social-cultural benefits and the avoidance of disservices is still a developing and evolving practice that needs to be more fully developed to measure whether NBS deliver promised co-benefits and avoid unintentional disservices (Andersson et al., 2021; Campbell, Cheng, et al., 2021; Hoover et al., 2023; Wickenberg et al., 2021; Wijsman et al., 2021). The Forest for All NYC coalition is an ongoing collaborative effort with great potential that incorporates procedural and distributional equity in an effort to advance equitable expansion of the Urban Forest in NYC so that it can benefit all New Yorkers (NYC Urban Forest Task Force, 2021).
Assessment of Confidence based on the Evidence	Because measuring effectiveness is a developing field, with some early evidence (e.g. Campbell et al. (Campbell, Cheng, et al., 2021)) there is medium confidence that if NBS are designed and implemented with social-cultural benefits and avoidance of disservices like green gentrification as central to their project goals, that they can be successful and contribute to holistic resilience for the city. The Forest for All NYC coalition, established in 2021, is new enough that there are not yet measurable outcomes of the anticipated social and cultural benefits.

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Acknowledgements

NPCC Member Futures & Transitions Workgroup Co-chairs

Deborah Balk, PhD (NPCC panel co-chair / Workgroup co-chair), City University of New York, Baruch College and CUNY Institute for Demographic Research, New York, NY.

Timon McPhearson, PhD (Workgroup co-chair), Urban Systems Lab at The New School, and Cary Institute of Ecosystem Studies, New York, NY.

NPCC Futures & Transitions Workgroup Panel Member and Scientific Contributors

Christian Braneon, PhD, (NPCC panel co-chair) CUNY Institute for Demographic Research, City University of New York, The Earth Institute at Columbia University, Carbon Direct, New York, NY.

Elizabeth M. Cook, PhD, (Scientific contributor) Barnard College, New York, NY.

Radley Horton, PhD, (NPCC panel member) Lamont-Doherty Earth Observatory, Columbia University, New York, NY.

Kim Knowlton, DrPH, (NPCC panel member) Columbia University Mailman School of Public Health, New York, NY.

Nicole Maher, PhD, (NPCC panel member) The Nature Conservancy, Cold Spring Harbor, NY.

Peter Marcotullio, PhD, (NPCC panel member) City University of New York, Hunter College, New York, NY.

Thomas Matte, PhD, (NPCC panel member) Columbia University, Mailman School of Public Health, New York, NY.

Richard Moss, PhD, (NPCC panel member) Pacific Northwest National Laboratory Joint Global Change Research Institute, University of Maryland, College Park, MD.

Luis Ortiz, PhD, (Scientific contributor) George Mason University, Fairfax, VA.

Joel Towers, MArch, (NPCC panel co-chair) Parsons School of Design, The New School, New York, NY.

Gernot Wagner, PhD, (NPCC panel member) Columbia Business School, New York, NY.

Fellows & Interns

Daniela Tagtachian, PhD Candidate, Sociology Program, CUNY Graduate Center City University of New York, New York, NY.

Jennifer Ventrella, PhD Candidate, Public & Urban Policy Program, The New School, New York, NY.

Interagency Climate Advisory Team (ICAT) Members

Peter Lobo, Department of City Planning

Michael Marella, Department of City Planning

Erica Maurer, Department of City Planning

Novem Auyeung, NYC Parks

Allan Zaretsky, Director of Climate and Social Resiliency Planning & Policy, NYC Housing Preservation & Development

Jarrod Sims, Mayor's Office of Management and Budget

William Pappas, Risk Analysis Program Manager, NYC Emergency Management

External Advisors[2]

Leiwen Jiang, Population Council

Eric Ketchum, Department of City Planning

Other Contributors

Hayley Elszasz, PhD, Climate Science Advisor, Mayor's Office of Climate and Environmental Justice, New York, NY.

Janice Barnes, PhD, Managing Partner, Climate Adaptation Partners, New York, NY.

Leo Temko, MSc, General Partner, Climate Adaptation Partners, New York, NY.

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Figures List

[2] Individuals who reviewed and provided substantive input on partial or complete drafts of this article, listed alphabetically.

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