New York City Panel on Climate Change 4th Assessment Climate Risk and Equity: Advancing Knowledge Toward a Sustainable Future - Conclusions

Joel Towers,[1, 2, 3] Robin Leichenko,[4] Christian Braneon,[5, 6, 7] Deborah Balk,[5, 8] Liv Yoon,[9] Gernot Wagner,[10] Jennifer Ventrella,[2] John Kuo Wei Tchen,[11] Bernice Rosenzweig,[12] Philip Orton,[13] Luis Ortiz,[14] Richard Moss,[15] Franco Montalto,[16] Timon McPhearson,[17, 18, 19] Katherine McComas,[20] Peter Marcotullio,[21] Thomas Matte,[22] Nicole Maher,[23] Kim Knowlton,[22] Radley Horton,[24] Sheila Foster,[7, 25] Daniel Bader,[24] Ana Baptista [2, 3]

[1] *Parsons School of Design, New York, NY.*
[2] *The New School, New York, NY.*
[3] *The Tishman Environmental and Design Center, The New School, New York, NY.*
[4] *Rutgers University, New Brunswick, NJ.*
[5] *CUNY Institute for Demographic Research, City University of New York, New York, NY.*
[6] *NASA Goddard Institute for Space Studies, New York, NY.*
[7] *Columbia Climate School, Columbia University, New York, NY.*
[8] *Marxe School of Public and International Affairs, Baruch College, New York, NY.*
[9] *University of British Columbia, Vancouver, BC.*
[10] *Columbia Business School, New York, NY.*
[11] *Rutgers University, Newark, NJ.*
[12] *Sarah Lawrence College, Bronxville, NY.*
[13] *Stevens Institute of Technology, Hoboken, NJ.*
[14] *George Mason University, Fairfax, VA.*
[15] *University of Maryland, College Park, MD.*
[16] *Drexel University, Philadelphia, PA.*
[17] *Urban Systems Lab, The New School, New York, NY.*
[18] *Stockholm Resilience Centre, Stockholm University, Stockholm, SE.*
[19] *Cary Institute of Ecosystem Studies, Millbrook, NY.*
[20] *Cornell University, Ithaca, NY.*
[21] *Hunter College, City University of New York, NY.*
[22] *Mailman School of Public Health, Columbia University, New York, NY.*
[23] *The Nature Conservancy, New York, NY.*
[24] *Columbia University Lamont-Doherty Earh Observatory, New York, NY.*
[25] *Georgetown University, Washington, D.C.*

Correspondence should be addressed to:

Joel Towers, M Arch NPCC4 Panel Co-Chair
Professor of Architecture and Sustainable Design, Parsons School of Design
Co-Director, Tishman Environment and Design Center; and University Professor, New School University
New York, NY
TowersJ@newschool.edu (*ORCID ID: 0000-0003-3503-7607)*

Robin Leichenko, Ph.D. NPCC4 Panel Co-Chair
Dean of Social and Behavioral Sciences
Professor of Geography
Rutgers University
New Brunswick, NJ.
robin.leichenko@rutgers.edu (*ORCID ID: 0000-0003-0607-5874)*

Abstract

This chapter provides an overview of the major themes, findings, and recommendations from NPCC4. It presents summary statements from each chapter of the assessment which identify salient and pressing issues raised and provides recommendations for future research and for enhancement of climate resiliency. The chapter also outlines a set of broader recommendations for future NPCC work and identifies some key topics for the next assessment.

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1 Introduction

The New York City Panel on Climate Change (NPCC) was established to help the city "prepare for and mitigate the expected impact of climate change on New York City's communities, vulnerable populations, public health, natural systems, critical infrastructure, buildings and the economy" (LL42). As an assessment, the NPCC reviews recent advances in biophysical climate science and social science to provide policy-relevant guidance to the city. NPCC4 builds on the prior three NPCC assessments, providing climate projections while deepening areas of prior reports on flooding, health, and equity. It crafts two new areas of emphasis – on energy and energy insecurity, and tools for future visioning and planning – that further understanding of the impacts of climate risks on the human and ecological systems of New York City (NYC).

Navigating present and future climate risks and related socio-economic challenges facing the city will require tradeoffs and compromises forged through constructive and scientifically informed public dialogue. To plan and act, community-based organizations, businesses, city government, and other stakeholders will need to continue to integrate scientific and technical information with community values and knowledge. Scientific and technical information are critical to addressing the challenges the city faces and to understanding the technologies and measures that are available to meet them. Scientific and technical information can provide insights and guidance that inform, for example: how to update codes and standards (e.g. Climate Resiliency Design Guidelines) so that new and renovated structures are resilient and efficient; how to identify where, and what kind of flood protection should be prioritized; how to estimate the service loads public infrastructure for stormwater management, sanitation, electric power, and water supply will need to bear; and how to plan public health strategies to manage cascading and compounding extreme events (e.g. co-occurrence of storms, power failures, and heat waves). Community perspectives and local knowledge[1] provide an essential compass to help navigate issues such as growing economic opportunities, improving social welfare, planning transportation systems, and improving access to nature-based solutions that contribute to multiple dimensions of well-being. Local knowledge offers complementary information and expertise to bio-physical and social science, ensuring that, as the city prepares for the future, it does so in a way that increases civic participation, social cohesion, and community stewardship, all indicators of resiliency. Evidence suggests the integration of different forms of local knowledge (e.g. NOAA's Urban Heat Island mapping program) can

[1] Local knowledge (LK) refers to the understandings and skills developed by individuals and populations, specific to the place where they live. It can contribute to effective land management, predictions of natural disasters, and identification of longer-term climate changes, and LK can be particularly useful where formal data collection on environmental conditions may be sparse (IPCC).

improve decision-making associated with climate risk management and community stewardship of, and commitment to, climate resiliency initiatives (Anthony, 2023; Carmona et al., 2023; Hurlbert et al., 2019).

2 Chapter Summary

This chapter provides an overview of the major themes, findings, and recommendations from NPCC4. It presents summary statements from each chapter of the assessment which identify salient and pressing issues raised and provides recommendations for future research and for enhancement of climate resiliency. The chapter also outlines a set of broader recommendations for future NPCC work and identifies some key topics for the next assessment.

2.1 Climate Science

New York City faces many challenges due to climate change and its interactions with social vulnerabilities and uneven urban development patterns and processes. In its assessment, NPCC4 confirms new sea level rise, temperature, precipitation, and extreme events projections of record for use by NYC, and presents a new methodology related to climate extremes.

Sea level is projected to rise for centuries and remain elevated for thousands of years. Glaciers and ice sheets combined are now the dominant contributors to global mean sea level rise. Coastal locations in the NYC metropolitan region continue to experience higher rates of relative sea level rise as compared to the global mean.

Surface and air temperature varies throughout NYC as a function of time of day, season, and the underlying characteristics of the built environment. The number of days with minimum temperatures below freezing has been steadily declining since 1900. The total number of hot days in the city and the frequency and duration of heat waves are expected to increase as this century progresses. Although the increase in total annual precipitation is projected to be relatively small, global climate models project somewhat larger increases in the frequency of extreme precipitation events.

2.1.1 Recommendations for Future Research

- Indoor heat exposure is the most common cause of both heat-related and heat-exacerbated deaths in NYC. In order to better understand indoor heat exposure and address its impacts (e.g., morbidity, mortality), there is a need for research to quantify the climate and infrastructure drivers of indoor temperature extremes.
- More research is needed on the meteorological factors that contributed to extreme precipitation events like the remnants of Hurricane Ida that adversely impacted the NYC metropolitan region.
- Projected sea level rise for NYC will exacerbate the destructive hazards posed by storm surges and cause more frequent high-tide flooding. More research is needed on both the baseline storm surge hazard (e.g., extreme wave heights, expected damages) as well as its potential future changes (e.g., inundation area and extent).
- The compound effect of climate hazards and stressors (e.g., pluvial flooding, high wind speeds, and storm surge) can play an important role in exacerbating climate impacts. More research is needed on compound extreme events (e.g., tropical cyclone-blackout-heatwave events).

2.1.2 Recommendations for Climate Resiliency

- Although many improvements have been made to protect neighborhoods and secure critical infrastructure in future floods, many neighborhoods remain vulnerable to coastal flooding. Long-term planning needs to examine plausible scenarios at the upper tail of the projected sea level rise distribution, and meaningfully engage communities in planning processes.
- In order to better understand indoor temperature change and address its impacts, there is a need for (1) operational monitoring of indoor temperatures to map the spatial distribution of indoor hazardous heat as well as (2) better communication and warning systems when hazardous indoor conditions can be expected.
- Consideration of water management under drought currently relies on estimates of imbalances between annual supply and evaporative losses, but droughts are a manifestation of the non-linear interaction between supply and demand as the climate risks faced by water users vary over time and by sector of use. There is a need for more comprehensive assessment of drought vulnerability that accounts for projected changes in cross-sectoral demand as well as projected climate impacts.

2.2 Flooding

NYC faces risk from four types of flooding: pluvial, fluvial, coastal, and groundwater, which can occur individually or in combination. In the absence of adaptation projects supporting comprehensive Flood Risk Management (FRM), the risks associated with all four of these types of flooding will increase due to sea level rise and the intensification of precipitation expected with climate change. Incremental flood adaptation measures scaled to singular conceptualizations of future conditions can lead to maladaptation. Comprehensive FRM must include neighborhood-specific combinations of structural (e.g., grey) and non-structural (e.g., green) approaches for living with water. These approaches must be implemented across multiple systems and scales, selected through collaborative processes, and be synergistic with the needs and goals of communities. To contribute to a comprehensive flood strategy, natural and nature-based solutions (NNBS) would need to be integrated extensively, and in novel new ways, to an urban ecosystem that has been modified profoundly over centuries of development. Progress is being made, but more information is needed regarding the extent and magnitude of flood hazards, exposure, and vulnerability, accompanied by greater cross sector, cross scale collaboration and decision-making.

2.2.1 Recommendations for Future Research

- Additional research is necessary to develop hazard maps that represent a broader range of flooding hazards and their increase in magnitude in response to anthropogenic climate change. This includes the continued development and integration of high-resolution models that can be used to simulate coastal hydrodynamics, sewer, surface, and groundwater flows in the same modeling platform.

- A denser network of gauges that record subhourly rainfall, water level, and flow in local streams, creeks, and sewers, and groundwater monitoring wells instrumented with water level loggers and salinity/conductivity probes are needed to calibrate and validate numerical models and in order to understand how climate is changing the city's hydrology at the spatial scales relevant for flood resilience.

- Collect and share -- with relevant agencies, researchers, and communities -- additional data on flood-prone buildings, including location and the vertical distribution of people and utilities to prioritize adaptation investments.

- Qualitative and quantitative social science research is needed to comprehensively assess the costs of flooding when it occurs in NYC to respond to climate events and to allocate resources equitably to mitigate harm.

- Research into how NNBS are impacted by flood/storm surge events, hydroperiod[2] changes, rising water tables and salinization, complimented by applied research into if and how NNBS can be enhanced, restored, or created at the spatial scales that would be needed to mitigate the impacts of various flood hazards.

2.2.2 Recommendations for Climate Resiliency

- While traditional floodplain management can be an effective strategy for reducing exposure to fluvial floods, pluvial flood hazards affect a much larger percentage of the city. A landscape-scale approach is needed that integrates strategic and safe stormwater conveyance, retention, and storage appropriately into the built environment. This approach would include design redundancies that are needed to plan for the uncertainty associated with future conditions.

- To advance equity, community stakeholders must have agency in decisions regarding FRM, and especially those strategies that seek to advance the long term social and ecological transformations needed to promote resilience.

2.3 Equity

Since the release of NPCC3 (2019), the City's climate-related equity work has become more explicitly focused on redressing environmental injustice and racial disparities. This includes the adoption of various laws and policies, internal institutional reforms, the formation of an Environmental Justice Advisory Board, and the incorporation of equity into risk assessments and resilience planning. There is, however, limited understanding of climate change impacts and adaptation needs at the community or neighborhood level and limited systematic data exists on city-sponsored adaptation projects and resilience investments. Going forward, the City's climate-related equity work would benefit from more comprehensive data on disaggregated climate risks at the local level and tracking of city-sponsored

[2] A hydroperiod can be defined as the number of days per year that an area of land is wet or the length of time that there is standing water at a location.

climate adaptation projects and resilience investments in different communities. Climate adaptation and resilience planning should also consider the ways that climate change challenges that NYC faces are inextricably linked to the bioregion's early history and how climate risks for the most socially vulnerable populations are connected to both past and present land use decisions and their underlying inequities (See Foster et al., Section 3 (Foster et al., 2024)). Understanding the impacts of this history is vital for formulating effective policies and strategies to mitigate and adapt to climate change. Without the creation and implementation of climate policies and practices that promote racially equitable procedures and outcomes, the City will risk perpetuating these inequities in new forms.

For example, climate displacement is an important dimension of social vulnerability to climate change and should be measured by the City. The City's ability to measure the risks of climate displacement at an appropriate scale, such as at the neighborhood level, could help determine whether and how new climate-resilient infrastructure or infrastructure investments might risk displacement. Without anti-displacement strategies in place, resilience-promoting investments can have inequitable outcomes. These strategies most often require prioritizing community-driven climate resilience approaches that mitigate the risk of displacement.

2.3.1 Recommendations for Future Research

- Collect and analyze more disaggregated climate risk data and systematic tracking of city-sponsored climate investments at the neighborhood level.
- Examine the relationship between the region's history and development patterns, including the legacy of land dispossession, rezoning, discriminatory policies such as redlining, and climate risks for socially vulnerable communities.
- Further develop combined climate displacement and social vulnerability (CDSV) metrics that integrate socio-economic, climate risk, and evictions and housing data to improve information and planning concerning the risks of climate displacement at a fine scale (such as the census tract).

2.3.2 Recommendations for Climate Resiliency

- Promote anti-displacement adaptation and resilience approaches that incorporate an understanding of neighborhood history, take a holistic approach to reducing racialized vulnerability to climate shocks, include inseparable issues like housing and transit access, and recognize that the cost burdens of climate adaptation (e.g., higher energy costs, insurance premiums, relocation) disproportionately result in increased displacement risk to the most socially marginalized communities.
- Understand and seek to scale up the work of community-based organizations that have implemented climate adaptation initiatives attentive to the intersecting nature of climate risks, social vulnerability, and displacement. These initiatives provide multiple benefits including equitable access to renewable energy, affordable and efficient housing, and economic development strategies that promote equitable green, adaptation economies.
- Investigate and incorporate best practices from around the country and that promote integrated, affirmatively anti-racist, equitable, and just approaches to tackling climate (and related) risks. These include those that advance just transitions, community-led planning processes, and collaborative relationships between communities, civic organizations, and state and local government offices and programs.

2.4 Health

Climate change-related health risks are a threat to all New Yorkers, but especially those most vulnerable because of age, poor health, racial and social inequities, and social isolation. Inequities in household and neighborhood physical environments also mediate vulnerability to health impacts of climate change. Most important among climate health risks are those from hot weather and flooding. A changing climate could also increase exposures to air pollution, pollen and mold, mosquito and tick vectors of human illness, and water contaminants. Addressing key environmental and social drivers of vulnerability is an essential adaptation strategy. Many current City policies and strategies, (e.g., improving access to residential air conditioning, tree planting), aim to accomplish this. These efforts can be informed and evaluated using data on climate-health vulnerabilities, such as components of the Heat Vulnerability Index (HVI) and the Flood Vulnerability Index (FVI).

2.4.1 Recommendations for Future Research

- While it is known that housing condition, construction, and location influence vulnerability to climate risks, key knowledge gaps should be addressed in future research. These include indoor temperatures and health risks

in different types of structures and the spatial distribution of social and housing vulnerability to flooding, including the location of basement dwellings.

- While temperature and humidity both influence heat stress and health risks, to better design climate adapted buildings and outdoor environments, a better understanding is needed of the relationships between heat and humidity under a changing climate.

- Social isolation has been clearly established as a strong, independent risk factor for poor health and has a plausible influence on vulnerability to a variety of climate hazards. However, evidence of the role of social isolation in climate vulnerability is inconsistent, in part because it is difficult to measure, and standardized measures are not collected through census or other health surveys. Future research should assess how different dimensions of social isolation are best measured, study how these influence climate vulnerability, and develop and evaluate effective interventions.

2.4.2 Recommendations for Climate Resiliency

Because the built and natural environment shapes vulnerability to health impacts from climate change, creating more climate-adapted and resilient environments for vulnerable people and communities must be a priority. Climate actions and investments and policies in sectors that shape climate vulnerability must reduce longstanding racial, social, and economic inequities, especially in key sectors such as housing, energy, and transportation.

- Sectoral policies and investments that can advance climate resilience in vulnerable communities include expanded residential cooling access, flood-protected residential building mechanical systems, improved energy affordability, reliability, and backup systems, mandating window screens, and expanding the supply of affordable, healthy, safe housing to provide alternatives to flood-prone basement dwellings.

- Social factors also mediate vulnerability to climate health risks. Thus, investments and programs that strengthen community cohesion and social infrastructure are also needed.

- Vulnerable and marginalized communities should also be the focus of efforts to improve and evaluate communication strategies intended to promote awareness, preparedness, and timely response to warnings.

2.5 Energy & Energy Insecurity

The urgent need to reduce energy use and GHG emissions in NYC, in alignment with NY State's ambitious climate goals, brings to light significant challenges and opportunities. Key among these challenges is the management of energy insecurity (EI), which poses direct and indirect threats to public health and well-being, especially among vulnerable populations such as low-income groups, communities affected by systemic racism, individuals with health conditions and renters. The transition to renewable energy and the electrification of infrastructure, while offering prospects for local economic investment and improved air quality, must be navigated carefully to ensure energy affordability and reliability, particularly during extreme weather events. This transition exacerbates existing vulnerabilities and introduces new risks, particularly for those already facing EI.

2.5.1 Recommendations for Future Research

- Investigate the long-term health impacts of energy transitions on vulnerable populations, including those experiencing EI.

- Explore the effectiveness of existing policies and interventions aimed at reducing EI and their impacts on health outcomes.

- Examine the relationship between renewable energy adoption, energy infrastructure resilience, and community health, with a focus on environmental justice communities.

- Assess the health and safety implications of new energy technologies, such as battery storage, especially in dense urban environments like NYC.

- Expand available data on household energy use and outage data to assess with an equity lens.

2.5.2 Recommendations for Climate Resiliency

- Develop and implement policies to ensure that the benefits of energy transitions, such as improved air quality and reduced GHG emissions, are equitable and accessible to all communities, especially those historically affected by environmental injustice.

- Enhance the resilience of the energy infrastructure to withstand extreme weather events, prioritizing investments in areas with high vulnerability to power outages and EI.

- Foster community-led renewable energy initiatives and expand access to renewable energy sources and energy efficiency programs in low-income and minority communities, reducing both energy costs and health risks.

- Strengthen regulations and safety standards for new energy technologies, such as e-mobility devices, to mitigate risks and ensure public safety.

2.6 Futures and Transitions

NYC is dynamic, and the scale and complexity of the city requires managing interacting socio-economic, ecological-biophysical, and technological-infrastructure components of the urban system. Managing and planning the future NYC to be more adapted and resilient to diverse climate, economic, and social pressures will require understanding diverse futures that also interact in real-time. As climate change unfolds, 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. Long traditions of in- and out-migration, which shaped the city historically, are expected to continue to be an important part of its future, anchoring it in the region and the nation 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 City's built environment will largely remain in place, yet changes in land use and land cover, including conversions in impervious and natural areas, are expected. While NYC planning has often focused on immediate, short-term land use decisions and includes some community participation, planning for the future requires the use of tools for addressing the complexities and uncertainties inherent in climate change and need to include medium- to long-term time-horizons and attention to local variation in physical and socioeconomic characteristics. Incorporating approaches that acknowledge sectoral interdependencies in future planning can prevent a siloed understanding of trade-offs and uncertainties.

Natural and nature-based solutions (NNBS) are critical for addressing climate adaptation needs in the city and can simultaneously provide co-benefits for public health, climate mitigation, flood risk management, and habitat for biodiversity. Yet, planning, implementation, and management of NNBS to achieve equitable distribution and holistic resilience in a complex city system is still a developing practice. Recognizing that the benefits of nature are not evenly distributed across the city, investment in NNBS to address this inequity 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, installing green roofs and bioswales.

2.6.1 Recommendations for Future Research

This first NPCC Futures and Transitions Working Group 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. Such frameworks – those that acknowledge inherent complexities in New York City -- 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. These new frameworks offer longer-term scenarios to guide the decision-making today and, with continued use, in the future. Developing and making meaningful use of such frameworks at the scale of NYC will require new research:

- Much work remains to be done to assess alternative visions and scenarios, and their inherent uncertainties, but so doing will build the necessary tools for a climate adapted, sustainable, and equitable future NYC.

- Future research needs to examine housing futures, nature futures, and the intersectionality of the built, social, and ecological futures and ways to minimized trade-offs that may emerge through short-term decisions underlining the need for long-term visions and plans.

- Prior NPCCs have noted the need for regular and meaningful indicators of climate impacts in perpetuity and the equity and flood chapters advance these in this assessment, but the role of indicators within the context of planning tools for the future is a gap that requires future research and assessment.

2.6.2 Recommendations for Climate Resiliency

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. Participatory processes are critical in co-developing shared visions that bring together diverse perspectives and forms of knowledge, and a sustained engagement process is also critically needed to identify the City's climate research priorities and co-produce a future public climate research agenda for the city. Without such shared positive visions for the future, it is unlikely that plans made now will achieve the equity, justice, sustainability, and resilience goals of a future NYC and its communities.

- 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 as well to resiliency in a multi-hazard world.

- Climate resiliency will need to adapt to future unknowns. Long-term planning that incorporates flexible adaptation pathways and uncertainty across many spatial scales, as determined by sectoral or community need, is imperative.

3 Looking forward to NPCC 5

NPCC4 confirms, with a high degree of certainty, that NYC's future will be warmer -- including more extreme heat events that may lead to increased morbidity and mortality in summers, and wetter -- with specific risk from intense rainfall and inland flooding. Compound and cascading events are also very likely to expose the city to increased climate risk. Addressing the risks presented by climate change will require multiple levels of investment, innovation, and transformation across sectors including (but not limited to) housing, transportation, land use, ecosystems, and critical infrastructure. All of these efforts will require innovative urban climate action, planning, and investments. For NYC to achieve a more resilient, equitable, and adaptable future, intersectoral and multisectoral climate-forward planning will be necessary. These efforts need ongoing and urgent consideration now, as well as a continued commitment throughout the coming years. In this section, we offer suggestions and recommendations to help support the city and the next NPCC panel in these efforts.

3.1 Harness holistic, multi-disciplinary approaches that blend climate and related socio-demographic risks in the planning process

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 (or many other socioeconomic characteristics) – depends on policy and a broader commitment to a just transition. These possible futures 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. There is also a need to evaluate, assess, and monitor the progress of these planning initiatives including attention to capacities and collaboration with community-based organizations and government entities to implement the plans.

Future NPCC panels will, therefore, benefit from an interdisciplinary composition. While the exact composition of any panel will need to be determined by future priorities, the experience of NPCC4 is that those panels will need expertise from Earth, social, and health sciences as well as researchers from other allied academic fields including, but not limited to planning, architecture, law, business, humanities, and the arts.

3.2 Center equity in adaptation planning and decision making

Equity and social justice should continue to 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. Centering equity in climate adaptation and mitigation actions provides an opportunity to decrease impacts on the most vulnerable. The potential for maladaptive and inequitable effects of climate adaptation strategies and other sectoral actions influencing climate risks should be considered to ensure that near-term actions are not maladaptive in the long term.

In addition to centering equity in the content of future assessments, it is important to also strive for representational equity in the composition of future panels and their working groups. One way of accomplishing this is to include early

career scholars and researchers that draw from a wide range of public and private New York area educational institutions and are diversified by rank, age, and experience, as well as by race, ethnicity, and economic status.

3.3 Evaluate and assess adaptation projects and initiatives

Adaptation efforts require their own assessments, and that will start with stewardship from the City and its communities to undergo periodic self-evaluation. In order to meaningfully assess the value, efficacy and success of adaptation planning efforts in New York, the City's adaptation actions must be monitored and evaluated over time (Blake et al., 2019; C40 Cities et al., 2019; Olazabal & Ruiz De Gopegui, 2021). It is especially important for New York City decisionmakers and stakeholders to understand which approaches to adaptation, including short-, medium- and long-term investments, are most effective in terms of reducing climate risk and enhancing resilience to the effects of climate change locally (Dinshaw et al., 2014) (New York City Panel on Climate Change, 2019). It will also be critical for the City to design adaption measures and strategies with evaluation and monitoring in mind (e.g. in situ measurements; indicators of climate exposure, vulnerability, risk or resilience; context-specific indicators of adaptation interventions) from the ideation stage (Boulanger, 2023).

Monitoring and measuring the efficacy of adaptation measures has received only limited research attention and remains an important area for ongoing research. For example, the evaluation of the effectiveness of ecosystem-based adaptation and nature-based solutions (NBS) is still mainly based on modelling, and data from monitoring and in situ measurements remain fragmentary (Donatti et al., 2020; Sauvé et al., 2023). If properly designed and used, adaptation metrics, indicators and monitoring can enhance local understanding of which types of adaptation measure are effective and why, as suggested by previous NPCC assessment reports (Blake et al., 2019; Leiter et al., 2019).

3.4 Improve the efficacy of climate risk communications

To meet the myriad challenges posed by climate change, New York City will benefit from a concerted risk communication strategy that clearly outlines goals, objectives, and tactics for the many sectors of the City and customizes messages for the many different audiences. Climate risk communication in the context of municipal policy and planning decision-making operates at many levels, which makes such coordination challenging. Because climate change is deeply intersectional with impacts that are often unevenly distributed across race and economic status, no single report or communication strategy will suffice. Risk communication is also not a one-way, one-time process but instead is multi-directional and ongoing. Effective risk communication requires understanding different audiences' needs and tailoring risk message content to meet those needs.

Local Law 42 charges NPCC with the assessment of the most recent science and data regarding climate risk in New York City and providing advice on its communication to City residents. The wide range of this ambition suggests that the cycle of NPCC reports generates information that is valuable to share with groups as diverse as biophysical and social scientists, policy makers, planners, architects, engineers, community groups, and individuals at every level of educational attainment. Meeting these diverse needs can be challenging, especially given the practical constraints on the NPCC and the importance of ensuring the reliability and clarity of the information. Further, simply making this information available does not mean that audiences will seek it out or find it useful. NPCC4 has sought to balance these demands by delivering peer reviewed, subject specific assessments, a new web-based archive, and a series of summaries intended for a wide range of audiences. Future NPCC panels and New York City offices and agencies will benefit from continuing to innovate and evaluate the effectiveness and efficacy of their climate risk communications. Engaging with community organizations and other stakeholders to provide input and feedback on proposed messages is one way to increase the value of risk communication and decrease the potential for unintended negative consequences. The more diverse audiences have access to this information the more inclusive and equitable the process of climate adaptation and mitigation will be. The science is clear that the City and its residents will need to change to meet the challenges of a climate altered present and future. Effective climate risk communication will be critical to ensuring that people understand why such change is necessary and how they can engage in meeting those challenges.

3.5 Learn from processes that make other Assessments run efficiently

NPCC is designed by local law to ensure that those involved do not have conflicts of interest, and as such has been undertaken by researchers and academics who volunteer their time to the multi-year commitment required to conduct each assessment. This follows the model for service on the National Climate Assessment (NCA) and the Intergovernmental Panel on Climate Change (IPCC) but not the recent New York State Climate Impacts Assessment (NYSCIA), which provided small stipends for contributors. Importantly, all three of these other Assessment bodies have strong, financed support systems.

Ensuring that NPCC is effective and inclusive of researchers from a variety of academic and research venues may require revisiting the Local Law 42 of 2012 requirement that NPCC panel members serve in a voluntary capacity.

Researchers from the non-profit sector, private sector, and those in grant-funded academic positions can make vital contributions to future NPCC efforts, but typically require some form of compensation in order to devote the substantial time required to serve on the NPCC.

The NPCC also provides an invaluable opportunity for the training of students and new researchers. The NPCC4 student internship program allowed student interns to participate in many of the work groups, but in contrast to the panel members, student members could not participate in a volunteer capacity. Thus, identifying resources to support and sustain a robust student internship/fellowship program is also an important part of the NPCC success as well as training the future workforce of adaptation professionals for the City.

Support for the organization and production of the Assessment is also vital to the success and sustainability of future NPCC efforts. This includes administrative support for the organization of the panel's work and report production, as well as resources for a robust co-production process, which engages city officials, agency representatives, as well as non-city entities such as non-profits and community groups. For example, NPCC4 had the good fortune of working with Climate Adaptation Partners to co-produce these structures for its Assessment for the first time. These structures will benefit from being strengthened for future assessments.

3.6 Key Topics for NPCC5

Each NPCC report covers a limited set of topics that are relevant to the adaptation goals and planning of the city. All reports cover climate factors but the breadth of allied topics cycles through pressing needs and evolving sustained assessment frameworks. Below is a list of thematic areas that NPCC4 recommends receive attention in the next Assessment.

- Ecological Impacts and Natural and Nature-based Solutions: NNBS are critical for addressing climate adaptation needs in the city and can simultaneously provide co-benefits for well-being and public health, climate mitigation, flood risk management, and habitat for biodiversity. Yet, planning, implementation, and management of NNBS to achieve equitable distribution and holistic resilience in a complex city system is still a developing practice. Greater attention to the role and integration of NNBS in the City's climate adaptation and mitigation plans is warranted.

- Housing risk and resiliency: Climate change threatens housing in many ways, both direct and indirect. While many chapters in this report touched on the housing sector, there is a need for more explicit attention to impacts of climate change on the housing sector including attention to the unhoused and precariously housed, housing affordability, housing shortages, and the conditions and resiliencies of the city's housing stocks.

- Spatial and temporal scale dependencies: Climate risk is experienced over a range of spatial scales from the individual person to regional systems (e.g., drought). NYC residents and ecology are impacted at every scale from the street-level to the region, and, therefore, future NPCC assessments will need to work across a range of social and spatial geographies to support climate adaptation and mitigation in the city. This Assessment brought in a wide range of new temporal scales – from hourly flooding to long-term scenario planning – and points to the need to continue to expand on these scales as necessary (such as subhourly flooding, daily climate warnings or communications, end-of-century demographic futures).

- Infrastructure and built environment: While many aspects of climate risks associated with aspects of the city's built environment and infrastructure systems have been addressed by prior NPCCs, there is a continued need for attention to the impacts of climate change on the city's vital infrastructure systems (water, transportation, communication, energy, etc.), There is also a need to consider governance and management of these systems and to identify ways to enhance adaptation, health, and equity, and to align with mitigation efforts. For example, near-, medium-, and long-term changes to how streets, sidewalks, and other public spaces that are part of the public right-of-way are designed, governed, and managed at different spatial scales can begin to reverse maladaptive uses and enable a more sustainable future.

4 Conclusion

Local Law 42 created the NPCC to help "prepare for, [adapt to], and mitigate the expected impact of climate change on New York City's communities, vulnerable populations, public health, natural systems, critical infrastructure, buildings and the economy." This fourth report of the NPCC validates the critical role that science informed policy making plays in the creation of an equitable, resilient, and sustainable future for NYC.

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Acknowledgements

NPCC Panel Co-chairs

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

Christian Braneon, PhD, (NPCC panel co-chair / Climate Science and Projections Workgroup co-chair) CUNY Institute for Demographic Research, City University of New York, NASA Goddard Institute for Space Studies, Columbia Climate School, New York, New York

Robin Leichenko, (NPCC panel co-chair), Rutgers University, New Brunswick, New Jersey

Richard Moss, PhD, (NPCC panel co-chair) Pacific Northwest National Laboratory Joint Global Change Research Institute, University of Maryland, College Park, Maryland

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

NPCC Panel Members

Ana Baptista, PhD, (NPCC Equity Workgroup co-chair), Associate Professor of Professional Practice, Environmental Policy and Sustainability Management Graduate Program, New School University; and Associate Director, Tishman Environment and Design Center, New School University, New York, New York

Sheila Foster, (NPCC Equity Workgroup co-chair), The Scott K. Ginsburg Professor of Urban Law and Policy; Professor of Public Policy, Georgetown Law, Georgetown University, Washington DC

Radley Horton, PhD, Research Professor, Columbia University Lamont-Doherty Earth Observatory, New York, New York

Kim Knowlton, PhD, Assistant Professor of Environmental Health Sciences, Columbia University Irving Medical Center, Mailman School of Public Health, New York, New York

Nicole Maher, PhD, Senior Coastal Scientist, The Nature Conservancy, New York, New York

Thomas Matte, MD, MPH, (NPCC Health Workgroup co-chair), Senior Lecturer, Environmental Health, Mailman School of Public Health, Columbia University (Co-Chair), New York, New York

Peter Marcotullio, PhD, (NPCC Energy Workgroup co-chair), Professor of Geography and Director of the Institute for Sustainable Cities, Hunter College; Associate of the City University of New York (CUNY) Advanced Science Research Center (ASRC); and Faculty Member, Earth and Environmental Sciences Program, CUNY Graduate Center, New York, New York

Katherine McComas, PhD, Professor, Department of Communication, Cornell University, Ithaca, New York

Timon McPhearson, PhD, (NPCC Futures and Transitions Workgroup co-chair), Professor, Urban Ecology and Director, Urban Systems Lab, The New School, New York, New York, Cary Institute of Ecosystem Studies, Millbrook, New York

Franco Montalto, PhD, (NPCC Flooding Workgroup co-chair), Professor, Civil, Architectural and Environmental Engineering, Drexel University, Philadelphia, Pennsylvania

Philip Orton, PhD, Research Associate Professor, Ocean Engineering, Stevens Institute of Technology, Hoboken, New Jersey

Bernice Rosenzweig, PhD, (NPCC Flooding Workgroup co-chair), OSilas Endowed Professor in Environmental Studies, Sarah Lawrence College, Bronxville, New York

John Kuo Wei Tchen, PhD, Clement A. Price Chair of Public History and Humanities and Director, Clement Price Institute on Ethnicity, Culture and the Modern Experience, Rutgers University, Newark, New Jersey

Gernot Wagner, PhD, Climate Economist, Columbia Business School, New York, New York

Fellows & Interns

Georgia Grzywacz, Columbia University

Amanda O'Lear, Rutgers University

Jennifer Ventrella, The New School

Liv Yoon, PhD, School of Kinesiology, The University of British Columbia, Vancouver, BC

See full list for contributions to all parts of the Assessment at https://climateassessment.nyc.

Interagency Climate Advisory Team (ICAT) Members

See full list of ICAT members at https://climateassessment.nyc.

External Advisors[3]

Cythnia Rosenzweig, PhD, Senior Research Scientist, NASA Goddard Institute for Space Studies (GISS), Adjunct Senior Research Scientist, Center for Climate Systems Research (CCSR) Columbia Climate School

William Solecki, PhD, Professor of Geography, Hunter College; Director of CUNY Institute for Sustainable Cities

Other Contributors

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

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

Daniel Bader, PhD, Program Manager, Columbia University Lamont-Doherty Earth Observatory, New York, New York

Adam Parris, (formerly MOCEJ) Senior Consultant Climate Planning, ICF, New York, New York

Emilie Schnarr, (formerly MOCEJ) Climate Science Lead, Key Bank, New York, New York

Victoria Cerullo, (formerly MOCEJ) Senior Advisor to the First Deputy Mayor, New York, New York

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

Johanna Tysk, MFA, Koko Labs, Malmo, Sweden

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