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MEASURING RESILIENCE

Community-informed and evidence-based
resilience metrics in New York City

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Regional Plan Association

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Measuring resilience: community-informed and evidence-based resilience metrics in New York City

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Abstract

Environmental Defense Fund and Regional Plan Association worked in collaboration with partners and stakeholders in New York City on a pilot project to characterize consistent resilience priorities articulated by stakeholders and to identify indicators that could be used to measure progress toward those goals across specific geographies. This project aims to lay the groundwork and process for developing specific resilience performance targets in New York City and beyond, that are evidence-based, community-informed, easily updated and can support advocacy and management decision-making over time.

Key words

Climate resilience, vulnerability, goal, target, indicators, progress, community-based

Definitions

Several terms are regularly used throughout this report and are described below. **Climate resilience** is defined as the capacity of socio-ecological systems to equitably support human and natural well-being as climate change and other stressors interact unpredictably over time. A resilient system can:

- Withstand or quickly bounce back from acute shocks (e.g., fires, floods, storms)
- Adapt to long-term changes
- Transform into new configurations that provide mutual benefit to nature and people, especially those most vulnerable to climate impacts.

Climate resilience is determined in large part by the relationship between the **vulnerability** or the tendency of people, individuals or systems to be adversely affected by chronic stresses and acute shocks experienced due to climate change and exposure to climate hazards. Climate resilience is the capacity of individuals and systems to withstand or adapt to those shocks and stressors. For this report, **climate hazards** are focused on the coastal northeast- rising temperatures, an increased frequency of extreme events (e.g. heavy downpours, extended heat waves, hurricanes and storm surge) and rising sea levels. These hazards intersect with the built environment, social vulnerabilities and other factors, resulting in impacts of varying severity.

Executive summary

Overview

In New York City and across the world, we are already experiencing detrimental and worsening impacts of climate change, with low-wealth communities and communities of color being hit hardest. And while there are many accepted measures or indicators of those impacts (e.g. sea level rise, increased frequency of extreme events, amount of high heat days) and targets for greenhouse gas reductions to limit the severity of climate change, there are few established measures of resilience to those climate impacts. Without measurable goals and targets that signify how well our communities, ecosystems, and infrastructure protect themselves, bounce back from and adapt to climate impacts, government officials, advocates and community members alike are unable to effectively assess, track and implement solutions.

Environmental Defense Fund and Regional Plan Association worked in collaboration with partners and stakeholders in New York City on a pilot project to characterize consistent resilience priorities articulated by stakeholders and to identify indicators that could be used to measure progress toward those goals at the scale of a city or state. This project aims to lay the groundwork and process for developing specific resilience performance targets in New York and beyond¹ that are evidence-based, community-informed, easily updated, and used to support advocacy and management decision-making over time.

Our process

¹ The phrase “and beyond” refers to other geographic areas, jurisdictions, or localities outside of the five boroughs of New York City.

We undertook several core activities to complete this project in collaboration with many community-based and environmental organizations, including:

- Conducting an iterative literature review on the key resilience attributes identified by academic sectors and examples of any identified indicators or methods for measuring those attributes.
- Conducting four workshops with community-based and climate-resilience-focused organizations to gather feedback on project processes, direction and outcomes.
- Analyzing community-based plans (Figure 1) in New York City to 1) understand common goals for resilience articulated by communities; and 2) analyze the similarities and differences between how communities, governments and scientists define resilience goals.
- Identifying resilience indicators that could be used to measure progress towards goals (see Table 1).

FIGURE 1

Map of community-based plans reviewed to inform indicator development.

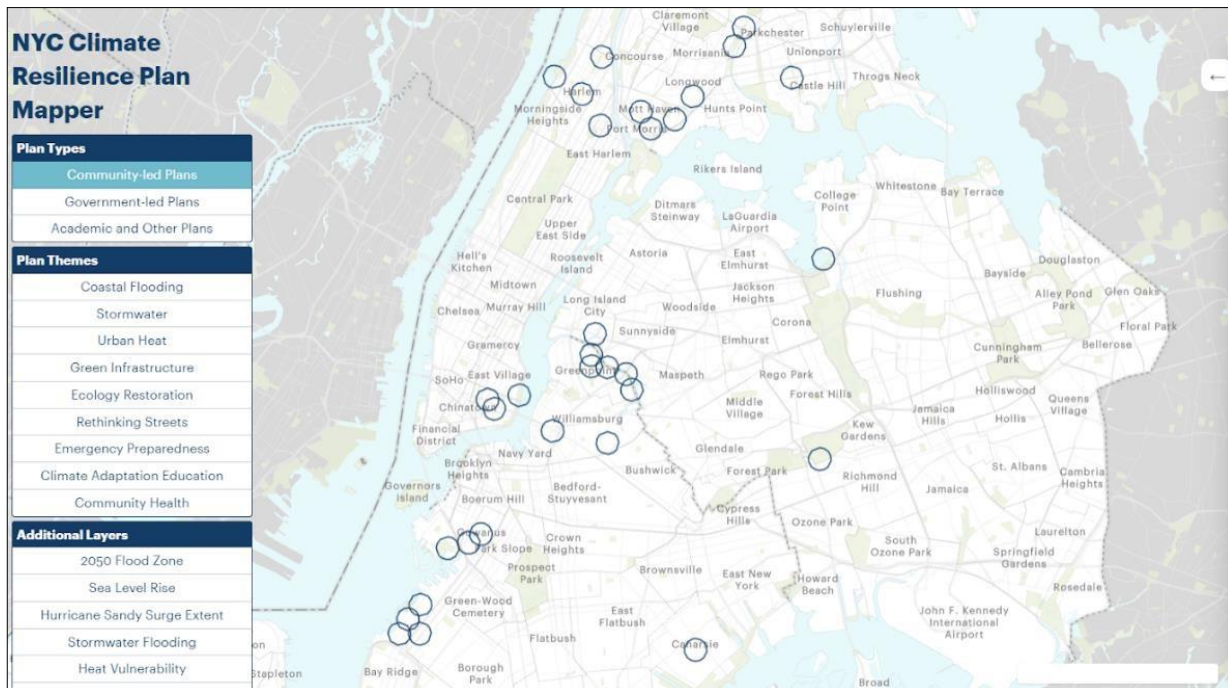


TABLE 1

Definitions for terms related to measuring resilience

Column 1	Theme	Goal	Indicator	Metric	Target
Definition	A category reflecting commonalities or patterns in the language of multiple goals.	Visions or objectives developed by communities for the core attributes of resilience that support function despite the acute shocks and chronic stressors associated with climate change.	A variable that reflects the degree to which a goal is being addressed.	A specific quantitative or qualitative data stream used to measure the indicator.	A measurable, long-term commitment towards a goal, referencing a specific desired performance level.
Example	Green and Natural Infrastructure	Urban tree canopy is maximized, monitored, and healthy	Condition of urban tree canopy	Number of street trees per acre	Every neighborhood should have a healthy and well monitored tree canopy coverage of over XX%

Limitations and challenges

While there is information about climate hazards and vulnerability, there are not sufficient agreed-upon indicators and methods for measuring the resilience of particular geographies. This is in part due to the multiple dimensions of resilience and difficulty in building consensus on indicators that can be used at multiple scales. It is also acknowledged that for some of the themes explored in this report like “governance or education and empowerment,” it is more difficult to measure the performance of the systems or interacting group of components that make up the core attributes of resilience. us to rely on qualitative indicators or those related to the processes or [OBJ] even if they [OBJ]²[OBJ]. For others, such as “healthy communities,” it was easier to identify clear and literal end-of-pipe measurements of the capacity of the systems in place to handle climate impacts (e.g., “combined sewer overflow frequency,” gallons of stormwater captured). These discrepancies in measurement types and availability may have implications for how indicators are combined to tell a fuller story of resilience in a particular geography or system.

² Our goal in this report was to adopt “systems indicators” as much as possible, based on different types of resilience indicators identified by OECD. See also the [Guidelines for Resilience Systems Analysis](#) report by OECD (2014)

There are also many data gaps that would need to be closed to address several areas, highlighted in the indicators section of this report. There is no “one-size-fits-all” approach to measuring resilience. This project drew from a close evaluation of community-based plans developed in New York City, and while there are likely commonalities, there may also be differing priorities and goals specific to other regions, necessitating adaptation of the proposed indicators as they are considered for use in other regions.

Relation to other vulnerability indices and prioritization tools

There are many indicators and mapping tools in use at local, state and federal levels to identify measures of social vulnerability, hazard exposure and/or to prioritize resources or efforts through an environmental justice lens. However, there are few comprehensive indices for measures of the key attributes of resilience.

Amongst measures of vulnerability, there are several social vulnerability indices and tools available across the nation and locally. At the national level, these are based on demographic information and include the Social Vulnerability Index (SoVI), a product of the Hazards and Vulnerability Research Institute at the University of South Carolina (Cutter *et al.*, 2003), and the Social Vulnerability Index (SVI), a product of the U.S. Centers for Disease Control (CDC) (Flanagan *et al.*, 2011).

Resilience indicators can be combined with these maps of social vulnerability and hazard exposure to create a full picture of how functional or present different attributes of resilience are in areas of varying risk. This level of information is helpful to better target and triage specific funding, strategies, and assistance where they are most needed in a form that meets the local context. *See: Applications and next steps*

Resilience Metrics
e.g. Number of hazardous waste sites,
Air quality concentration of PM 2.5

Hazard
ex. Flood zone

Vulnerability
ex. Social Vulnerability Index

Among tools that combine physical risk and social vulnerability, the federal [Climate Mapping for Resilience and Adaptation mapping tool](#) and Federal Emergency Management Agency’s

(FEMA's) new [Community Disaster Resilience Zones \(CDRZ\) platform](#) combine climate hazards and the [Climate and Environmental Justice Screening tool \(CEJST\)](#) are available nationwide. Environmental Defense Fund has also developed a nationally available [Climate Vulnerability Index](#), which draws from 184 data sets of vulnerability and exposure metrics to rank community vulnerability to climate impacts across the nation. New York State's disadvantaged communities map includes measures of environmental burdens and location relative to climate hazards and demographic and health data. The CDRZ, CEJST and disadvantaged communities' maps are used to help prioritize government investments. And finally, the City of New York is developing a flood vulnerability index that will combine social vulnerability and hazard exposure. This approach was pursued in Austin, Texas, by the University of Texas School of Public Affairs, for its [Austin Area Sustainability Indicators](#), which include 18 variables of social vulnerability. It was organized under 6 demographic categories and includes environmental hazards to create a composite multi-climate risk index map of the most vulnerable areas in Austin.

Through this project, we aim to better understand resilience by identifying system-level indicators that can be paired with measures of social vulnerability and hazard exposure. This information is helpful to better measure the spatial distribution of risk and pinpoint policy solutions to address gaps between social and biophysical vulnerabilities and resilience³, target funding, strategies and assistance where most needed in a form that meets the local context, as well as track changes over time. *See also: Applications and next steps.*

Resilience indicators in use

It should be noted that while a comprehensive set of indicators is lacking, there are some resilience indicators in use in New York City and beyond. New York City's PlaNYC/OneNYC report in 2015 as well as the most recent 2023 PlaNYC report, Getting Sustainability Done laid out several indicators and targets relevant to certain aspects of climate resilience including several of the goals identified in this report. Similarly, the New York City Mayor's Office of Management and Budget (OMB) is undergoing an effort to use indicators to evaluate progress toward climate goals through its first-ever Climate Budgeting initiative. Climate Budgeting is a process being pioneered in cities across the world to incorporate science-based climate and sustainability considerations into budget decision-making by evaluating how actions and

³ Tyler, S., & Moench, M. (2012). A framework for urban climate resilience. *Climate and development*, 4(4), 311-326. doi: 10.1080/17565529.2012.745389

spending today contribute to meeting longer-term climate targets. OMB's Environmental Sustainability and Resiliency Task Force will publish the City's first Climate Budget report in April 2024, evaluating the projected impacts of ongoing investments and actions. In the state of Maryland, a report card released in 2022 combined qualitative and quantitative sets of indicators to assess the state's coastal adaptation status. The indicators identified in this report provide a potential way to expand or complement these kinds of efforts and track progress.

To adapt the indicators in this report for use in a "resilience report card," building consensus upon a target (e.g. 100% of homes are resilient to climate threats by 2050) would be an important next step.

The intention for this project is to identify the measurable qualities or traits of social-ecological systems that suggest their overall resilience to climate hazards over specific geography. We aimed to find quantitative, objective indicators and metrics that can be mapped wherever feasible to serve as measures of community-identified resilience attributes (goals), rather than progress toward a specific strategy or action⁴. However, defining strategies and targets for action is an equally important next step. Indicators and metrics can be useful in informing an optimal/target level of resilience. For example, identifying tree canopy percentage in the context of social and heat data can help determine the optimal level of tree canopy percentage in certain areas needed to mitigate the negative impacts of heat.

Results and applications

Through this project, eight core goal themes, 20 goals and 29 indicators were identified from a review of 41 community-based plans encompassing more than 500 goals. Strong alignment across government and non-government led resilience plans was demonstrated, with a greater overall focus on infrastructure in government-led plans than community organization-led plans. Through our research and engagement with stakeholders, four central applications for indicators were identified:

- Tracking progress toward goals and identifying areas of inequity
- Prioritization of resources to where they are most needed
- Informing planning and advocacy efforts

⁴ Though we aim to measure systems resilience in this report, we use some process indicators as well which tend to track process rather than the system's resilience itself. See also the Guidelines for Resilience Systems Analysis report by OECD (2014)

- Informing resilience policy and management practices

As more funding for resilience planning and implementation is available, it is a particularly opportune time for the production and use of resilience indicators.

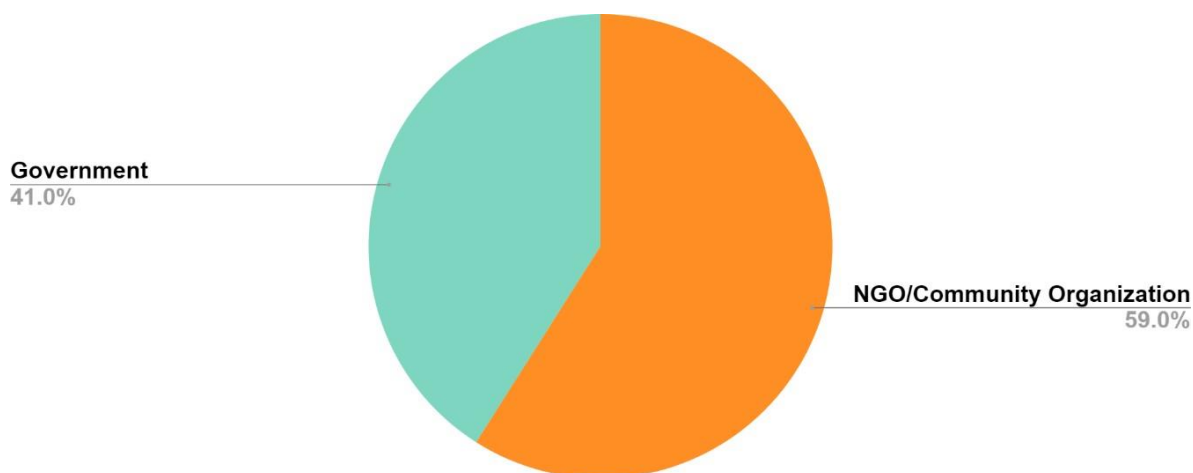
Identifying common themes among community-based plans

To identify indicators, we had to first identify which goals we were aiming to measure against. In the immediate aftermath of Hurricane Sandy, and over the decade since, many communities throughout New York City carried out local resilience planning efforts to ensure that they can be better prepared for disasters and the worsening impacts of climate change. Forty-one of these plans represent the best summation of community-centered resilience goals in New York City neighborhoods and were catalogued by Rebuild by Design and Regional Plan Association with support from Environmental Defense Fund. For this project, we identified all goals within the plans and then iteratively synthesized them into a common set of goals that reflect the breadth of those proposed at the community level via the process described below.

Methods for the original plan collection included an online web search and emailed survey sent through our organizational networks. Plans spanned a variety of scales, including neighborhood, borough, city and state levels and were published by a range of different sources, from neighborhood non-governmental organizations (NGOs), business improvement districts and government agencies. All resilience plans reviewed for this project can be viewed on the [Resilience Mapper](#) tool.

FIGURE 3

Percentage of resilience plans led by government and non-government organizations⁵



All resilience plans were reviewed and identified goals were put into a single data set of more than 500 goals. Goals were then categorized into five primary types and several subtypes to facilitate synthesis across plans (Figures 3-5). Types and subtypes were not assigned on a one-to-one basis to each goal, meaning that goals could have multiple types or subtypes assigned to them. For example, the goal “climate safe emergency shelters are accessible to all and serve as multipurpose community centers” is relevant to both infrastructure and social goal types.

Overall, infrastructure and governance were the most common goal types, with economic and ecological types falling significantly below those types (Figure 4), perhaps because almost all plans reviewed were developed following and shaped by the experience of Hurricane Sandy, a storm which exposed vulnerabilities in infrastructure and government preparedness. There also tended to be more focus on preparing and building infrastructure to prevent flooding in these plans, which might indirectly influence themes like the economy, social and ecological systems, which were less of a focus.

For the goal subtypes, we found that goals with public health themes were overall the most frequent (Figure 5). Emergency preparedness was most frequently referenced underneath the

⁵ It should be noted that one plan included in our review, the Hunts Point Lifelines project, was the result of a collaborative public, private, and government partnership, but was categorized as an NGO/Community-led plan as the project was primarily led by now non-profit/non-governmental organization Rebuild by Design.

governance goal type, and parks and recreation were referenced most frequently under the infrastructure goal type (Table 2). Most plans mentioned infrastructure-related goal subtypes, with a frequent reference to flood protection strategies that integrate green and gray infrastructure and public space. For example, the Wetlands Management Framework for New York City plan calls for increased “city and state investment in stormwater green infrastructure, construction and maintenance” as well as including “natural shoreline protection and land acquisition for wetland migration in city planning efforts” with a focus on policies that preserve open space.

There were two primary reasons for goal synthesis: 1) there was much overlapping language between goals across plans; and 2) the number of goals was far too large to develop a concise set of indicators.

The consolidation process consisted of bringing overwhelmingly similar goals together into a smaller subset and then sharing this subset with community and environmental organizations involved in resilience planning to refine language during the second and third stakeholder workshops. As a final step, the team reviewed the consolidated goal set a third time, cross-referencing with the original set of goals to ensure that all original components of the original set were captured and retained

FIGURE 4

Frequency of goal types across all plans

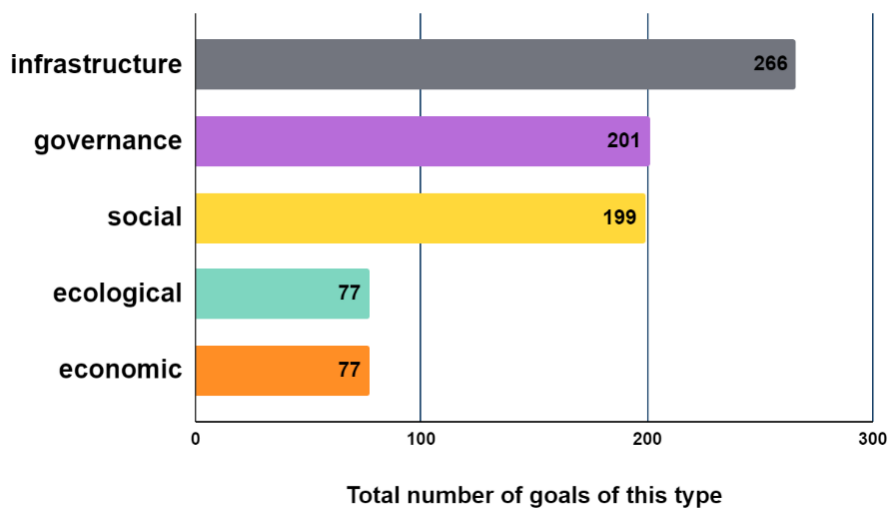


FIGURE 5

Frequency of goal subtypes across all plans

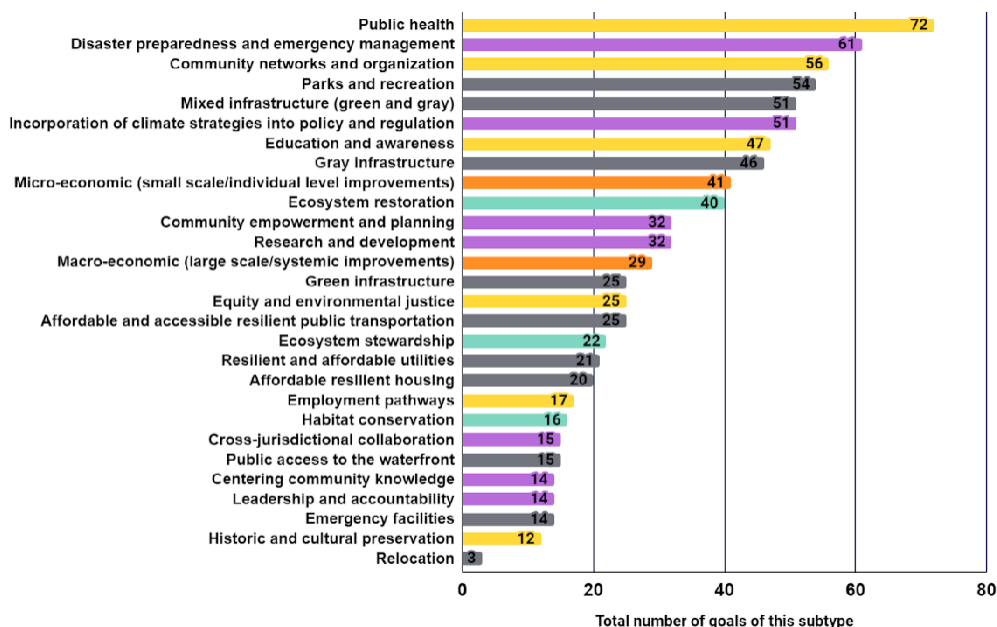


TABLE 2

Most common goal subtypes within each goal type

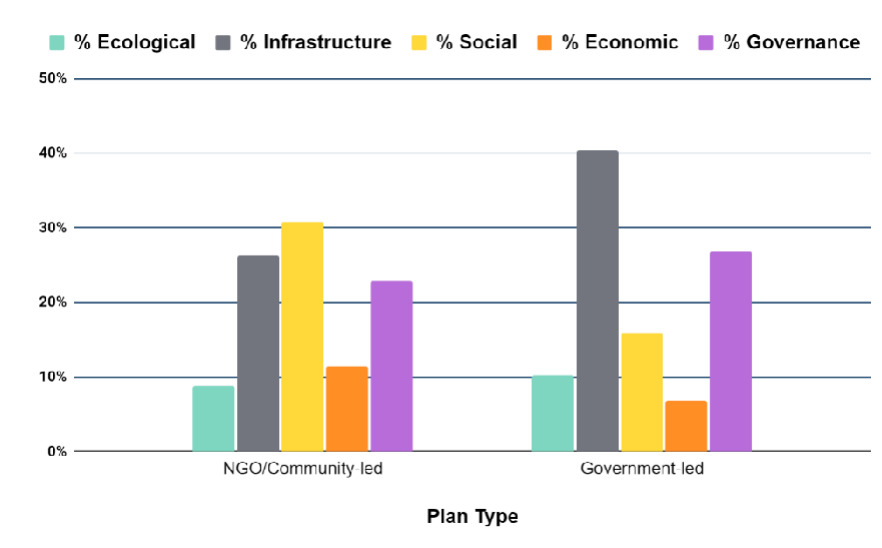
Goal Type	Goal Subtype	Frequency
Ecological	Ecosystem restoration	40
Economic	Micro-economic (small scale/individual level improvements)	41
Infrastructure	Parks and recreation	54
Social	Public health	72
Governance	Disaster preparedness and emergency management	61

To better understand whether there may be differences between the foci of government-led and community-led plans, each plan was categorized into two separate groups—“Government” and “NGO/Community”—and compared to discern the frequency of certain goal types within each group. Observed differences included that government-led plans were more focused on

infrastructure, whereas plans led by non-governmental organizations had a larger focus on social issues (Figure 6).

FIGURE 6

Comparison of the percentage of goals of each type between government and community-led plans



Comparing resilience goals from community plans with academic literature

Community organizations, the interested public and resilience practitioners draw upon knowledge from both science and on-the-ground experience to develop plans. But perspectives of those developing plans and those conducting research can differ. Science helps us to experimentally understand and evaluate the underlying mechanisms of systems that result in more resilient outcomes for communities and ecosystems, and practice helps tangibly apply that knowledge as well as that learned through lived experience and implementation. Ultimately, to become more resilient, the full range of knowledge sources needs to be integrated.

The goals in the plans represent a window into community and practitioner perceptions of what resilience is and what actions they believe are necessary to become more resilient. In general, these goals were expressed as outcomes – i.e., conditions that need to be in place for the community to be resilient. Similarly, resilience science seeks to understand what attributes (i.e., characteristics of systems that influence outcomes) of a socio-ecological system help communities to become resilient.

To better understand alignment, we conducted an initial comparison of attributes of resilience from scientific literature with the synthesized community goals from the plans we reviewed for this project (Table 3). Alignment between these perspectives may have implications for policy, planning, and implementation. For example, if community goals are well aligned with science, this might imply that all are on the same page as to what types of resilience policy and actions might be most desirable, and that strategies aimed at improving these aspects of resilience are more likely to succeed. On the other hand, if science and practice are misaligned, then it might imply that more work is needed to develop more consensus around the types of policies and actions or how to prioritize resources that would work best for communities and result in long-term resilience.

Our initial findings suggest that some consistency exists between the synthesized goal statements and resilience literature (Table 3). For example, “communities are connected with information and the best available science about their geographical areas in a format that is accessible and shareable through local networks” is a goal that suggests a characteristic of education and empowerment systems that can enable communities to become more resilient. This alignment seems to occur when the goals are oriented toward processes of systems (e.g., information flows and planning documents) that can help achieve resilience rather than the outcome of becoming resilient. Alignment between community goals and science might indicate a general consensus on the viable pathways toward resilience. This should be considered in efforts to develop specific targets, strategies and actions to address the current state.

Some goals were more oriented toward outcomes of resilience rather than attributes of resilience either because of the way that the goals were consolidated or because communities defined resilience differently.

TABLE 3

Community-based resilience goals associated with applicable science-based characteristics of resilient systems

Goal Category	Community-based Resilience Goal	Applicable characteristics of resilient systems from academic literature
Education and Empowerment	1: Communities are connected by information and the best available science about their geographical areas in a format that is accessible and shareable through local networks.	Access to knowledge, learning capacity, problem solving networks.

Economically and socially restorative	<p>1: Climate resilience investments are prioritized and flow to communities most vulnerable to the impacts of climate change</p> <p>2: Individuals are aware of and have access to insurance policies and financial support that provide the ability to bounce back quickly following damage or an extreme event</p> <p>3: Local residents, especially people of color and low-wealth residents, have fair access to and are well-equipped to get well-paid jobs and take part in or lead aspects of the climate transition</p>	<p>Wealth and reserves but with an equity component, high degree of equity, leadership and initiative, resourcefulness.</p>
Green and natural infrastructure	<p>1: Everyone has access to well-maintained, connected and quality parks and open space that will last in the long term</p> <p>2: Wetlands are preserved, restored, and supported by ongoing stewardship</p> <p>3: Natural resources and habitats are healthy and maximized, combat urban heat, flooding and other climate impacts and benefit health</p> <p>4: People feel deeply connected to their natural environment and its stewardship</p> <p>5: Parks and open space programming and design is rooted in a way that preserves the local cultural and environmental history</p>	<p>Ecological health and connectivity, biodiversity, place attachment, cultural/ecological memory as part of diversity of knowledge sources.</p>
Healthy communities	<p>1: Stormwater is captured or managed to the maximum extent feasible on public and private lands in a way that maximizes environmental and public health and wellbeing and minimizes the risks associated with flooding</p> <p>2: Our homes, recreational spaces and places of work are free of exposure to harmful pollution, contaminants, and extreme heat</p> <p>3: Food systems are resilient to climate threats</p>	<p>A variety of resilience concepts and theories that inform how to achieve these goals.</p>
Governance	<p>1: Community-driven climate resilience plans are in place that ensure that all residents can withstand acute shocks and long-term climate change</p> <p>2: Agency roles and responsibilities for the different aspects of climate resilience are clear, well communicated, adaptable and coordinated across different levels of government</p> <p>3: Resilience planning, capital budgeting and infrastructure development incorporates climate resilience, reflects community values and engages residents, especially of those most impacted by climate change</p> <p>4: Messaging about climate risk is consistent across jurisdictions</p>	<p>Planning and preparedness; governance integrated across sectors and scales; efficient and effective governance; simplicity and understandability of knowledge for decision making; responsive and participatory governance; community involvement and inclusion of local knowledge.</p>
Built infrastructure resilient	<p>1: All buildings and critical infrastructure are resilient to the acute shocks of extreme events and chronic stressors associated with climate change so that all communities can thrive</p> <p>2: Climate safe emergency shelters are accessible to all and serve as multipurpose community centers</p>	<p>1: Safety; flexibility; redundancy and modularity. 2 -3: stability; wealth and reserves policy; levels of capital assets.</p>

	3: Property owners have access to funding and/or financial instruments that support affordable solutions to retrofit or relocate	
Shelter	1: Shelter is available, affordable, and able to withstand acute and long-term climate threats	Capital reserves
Emergency preparedness and response	1: Emergency preparedness plans are in place and evidence-based and community-informed, fostering community awareness and safety, especially of vulnerable populations 2: Communities have capacity to prepare for and respond to emergencies and partner with relevant government agencies 3: Communities and government entities focused on emergency response have strong relationships and communication networks, and trust one another	Preparedness and planning; leadership and initiative; social capital; connectivity; strengthening local institutions; building cross-scale linkages; social networks; trust; readiness.

We also note that there are characteristics of resilience that are prevalent in scientific literature but less present and formulated differently in community-based goals (Table 4).

TABLE 4

Characteristics of resilience identified in academic literature that are not explicitly mentioned in community goals

Resilience Concept	Source
Diversity, redundancy, openness and modularity	Walker and Salt 2006 ⁶ ; Biggs, et al. 2012 ⁷
Tightness of feedback (the time it takes between detection of a signal and being able to respond) and managing and monitoring “slow variables” that help identify when system thresholds are crossed (e.g., temperature or precipitation)	Walker and Salt 2006
Balance (the degree to which a system is skewed toward one strength at the expense of others)	Kerner and Thomas 2014 ⁸
Adaptive Management	Biggs et al., 2012
Social and political diversity	Berkes 2007 ⁹
Learning, diversity and integration of knowledge, and experimentation	Tyler and Moench 2012 ¹⁰ ; Mason et al. 2021 ¹¹ ; Berkes 2007
Resilience thinking (capability, training, and perspective to examine problems holistically, embrace complexity, and see the interconnectedness between things)	Bahadur et al. 2013 ¹² ; Biggs et al. 2012
Acceptance of uncertainty and change	Bahadur et al. 2013; Kerner and Thomas 2014
Transformation versus adaptation	Folke 2006 ¹³
Single points of failure (singular features or aspects of the system, the absence or failure of which will cause the entire system to fail)	Kerner and Thomas 2014

⁶ Walker, B., & Salt, D. (2012). Resilience practice: building capacity to absorb disturbance and maintain function. Island press.

⁷ Biggs, R., Schlüter, M., Biggs, D., Bohensky, E. L., BurnSilver, S., Cundill, G., ... & West, P. C. (2012). Toward principles for enhancing the resilience of ecosystem services. *Annual review of environment and resources*, 37, 421-448. doi.org/10.1146/annurev-environ-051211-123836

⁸ Kerner, D. A., & Thomas, J. S. (2014). Resilience attributes of social-ecological systems: Framing metrics for management. *Resources*, 3(4), 672-702. doi:10.3390/resources3040672

⁹ Berkes, F. (2007). Understanding uncertainty and reducing vulnerability: lessons from resilience thinking. *Natural hazards*, 41, 283-295. Doi: 10.1007/s11069-006-9036-7

¹⁰ Tyler, S., & Moench, M. (2012). A framework for urban climate resilience. *Climate and development*, 4(4), 311-326. doi: 10.1080/17565529.2012.745389

¹¹ Mason, J. G., J. G. Eurich, J. D. Lau, W. Battista, C. M. Free, K. E. Mills, K. Tokunga, L. Z. Zhao, M. Dickey-Collas, M. Valle, G. T. Peci, J. E. Cinner, T. R. McClanahan, E. H. Allison, W. R. Friedman, C. Silva, E. Yanez, M. A. Barbieri, and K. M. Kleisner. Attributes of climate resilience in fisheries: From theory to practice. doi: 10.1111/faf.12630

¹² Bahadur, A. V., M Ibrahim, and T. Tanner. Characterizing resilience: unpacking the concept for tackling climate change and development. *Climate and Development* 5:1, 55-65. Doi: 10.1080/17565529.2012.762334.

¹³ Folke, C. Resilience: The emergence of a perspective for social-ecological systems analyses. *Global Environmental Change* 16 (2006) 253–267. doi:10.1016/j.gloenvcha.2006.04.002

While the focus of this project was not to identify specific actions or strategies to build resilience, comparing how communities and academia define resilience can help to ensure that both the end-goals or outcomes of what communities want to achieve and improvements to the core attributes of systems that cause them to be resilient are improved. Bringing multiple stakeholders is critical to informing both ways to improve or ameliorate existing conditions (e.g., provide grants for retrofitting homes) and to help ensure that pathways for lasting and transformative systems change are identified (e.g., reforming land use policies).

Identifying potential resilience indicators and metrics

Following goal analysis and synthesis, the research team conducted a review of existing academic literature, gray literature and resilience plans to identify indicators, metrics and potential data sources. Indicators and metrics were identified with the aim of finding those that are both best suited to the intent of the goals and have data sets readily available, though in some cases, no clear data sources were identifiable. These were still included, to reflect data gaps and research opportunities for these areas.

Through the review of the literature and the projects, we found the United Nations Sustainable Development Goals Renewable Energy Sustainability Index useful, which applies its 2030 Global Sustainable Development goals and metrics through an online data commons, including data visualizations aimed at assessing current conditions of different components within a particular goal. Our framework most closely mimics this framework in organization and definition. FEMA's Community Lifelines Toolkit includes a set of critical services and conditions that impact a community's daily functions and needs: safety and security; food, hydration, shelter; health and medical; water systems; energy; communications; transportation; hazardous materials. These themes are quite similar to those identified through our process and are organized into components (indicators) and subcomponents (metrics) into a tree diagram, enabling analysis of the resilience of each lifeline through a set of questions applied to each component. We referenced this toolkit in identifying metrics for several goals. And, drawing from each of these examples, we developed a framework to organize community plan themes, goals, indicators, and metrics (Table 5).

TABLE 5

Organization framework for community plan themes, goals, indicators and metrics

Term	Theme	Goal	Indicator	Metric
Example	Green and natural infrastructure	Everyone has access to well-maintained, connected, and quality parks and open space that will last in the long term	Our waterfronts are accessible to all and are resilient to sea level rise	% of waterfront edge that is publicly accessible (excepting natural areas)

For three goals identified through the analysis and consolidation process, we did not develop indicators and metrics. This does not suggest that the goals are not important. Instead, we interpreted these goals to be less directly related to climate resilience than others or to require deeper dives beyond the expertise and immediate focus of the team and project. These included:

- People feel deeply connected to their natural environment and its stewardship
- Economies are based on circular, sustainable and regenerative businesses and infrastructure development
- Parks, open space programming and design are rooted in a way that preserves the local cultural and environmental history

The original inclusion of these goals may have been the result of the fact that several of the resilience plans reviewed were not exclusively resilience plans, but also focused on other aspects of community and public space improvement.

Below, we detail the indicators and metrics and the reasoning for their inclusion

1. Education and empowerment

This goal theme focuses on ensuring that communities are informed about climate hazards and the locally-grounded social and environmental history of risk, as well as ensuring communities are equipped and empowered to take actions that benefit their futures.

Throughout many resilience plans and conversations with stakeholders, the accessibility of actionable risk information and education was raised as a large need. Feedback also highlighted the need for community driven data and information and emphasized the importance for robust social networks that reach local residents through word of mouth and long-term connections. A focus on funding and staff support (required for effective communication and education efforts)

was identified as a potential metric to serve as a proxy for effective programs that engage residents such as in person community meetings, social media platforms, online and print materials. These diverse forms of outreach can help to ensure that information can be reached by all residents.

Information accessibility on climate impacts is essential in supporting residents to take action individually and as a group. Additionally, the relevance of this information is tied to how often supporting data is updated, reflected in the proposed metric for risk information.¹⁴

TABLE 6

Education and empowerment

Goal	Indicator	Metric
1.1 Communities are connected with information and the best available science about their geographical areas in a format that is accessible and shareable through local communication networks	NGOs and community-based organizations effectively reach local residents, implement climate resilience communication, education and advocacy activities	Amount and distribution of budgetary and staff resources and technical expertise for organizations that implement climate resilience education and communication activities within and across geographies <i>See also: Emergency Preparedness and Response Goal 8.2</i>
	Climate and extreme weather event risk information is accessible to the public	Flood and heat risk maps are available and updated every five years and are accessible and able to be downloaded for further analysis. Emergency notification systems are in place and reaching broad populations, directing them to cooling and emergency shelters and resources, as measured by subscribers and social media followers (e.g. NotifyNYC) <i>See also: Governance Goal 5.4 and Emergency Preparedness and Response Goal 8.3</i>

2. Economically and socially restorative

This goal theme focused on ensuring the collective transition to our climate future is economically and socially regenerative, redressing historic injustices to people of color and enabling diverse local cultures to thrive despite climate threats. Access to strong economic and financial resources as well as economic equality across different groups (reflected in Goal 2.1) has been shown to foster resilience and was a recurrent theme in plans and stakeholder

¹⁴ Harnessing risk-informed data for disaster and climate resilience. (2022). Progress in Disaster Science, 16, 100254. <https://doi.org/10.1016/j.pdisas.2022.100254>

discussions.¹⁵ Several efforts such as the federal Justice40 Initiative and New York State’s disadvantaged communities map are intended to support equitable prioritization of resources.^{16,17} The indicator and metric for this goal recognized that tracking and mapping the actual flow of resources can be an effective way to establish accountability and ensure that target communities actually receive benefits. Efforts like New York City’s Climate Budgeting initiative could also be a source for this kind of data in the future.

The indicator for Goal 2.2 focuses on flood insurance. Recovering from the financial shocks of immediate repairs and other costs is one of the biggest challenges households face after a disaster, and the large racial wealth gap in the city means that low- and moderate-income households, typically people of color and immigrants, experience these shocks at disproportionately high rates, which can further affect health and cause housing insecurity.¹⁸ Home insurance policy uptake is also an indicator used by New York City to track progress on its flood preparedness efforts. Insurance can prove key to helping these households recover from disaster shocks or falling into poverty, but rates can prove unaffordable, and so tracking affordability and access to insurance policies is critical.^{19,20}

¹⁵ Rifat, S. A. A., & Liu, W. (2020). Measuring community disaster resilience in the conterminous coastal United States. *ISPRS International Journal of Geo-Information*, 9(8), 469. <https://doi.org/10.3390/ijgi9080469>

¹⁶ The White House. (2022). Justice40. <https://www.whitehouse.gov/environmentaljustice/justice40/>

¹⁷ Samantha Moldonado. (2023, March 29). Final Map of ‘Climate Disadvantaged’ Communities Now Includes Blocks Previously Excluded—But Other Vulnerable Areas Left Out. *The City*. <https://www.thecity.nyc/2023/03/29/final-map-climate-disadvantaged-communities/>

¹⁸ Bufe, S., Roll, S., Kondratjeva, O., Skees, S., & Grinstein-Weiss, M. (2022). Financial shocks and financial well-being: What builds resiliency in lower-income households? *Social Indicators Research*, 161(1), 379–407. <https://doi.org/10.1007/s11205-021-02828-y>

¹⁹ Dixon, L., Clancy, N., Miller, B. M., Hoegberg, S., Lewis, M. M., Bender, B., Ebinger, S., Hodges, M., Syck, G. M., Nagy, C., & Choquette, S. R. (2017). The cost and affordability of flood insurance in new york city: Economic impacts of rising premiums and policy options for one- to four-family homes. RAND Corporation. https://www.rand.org/pubs/research_reports/RR1776.html

²⁰ Carolyn Kousky, & French, K. (2022). Inclusive Insurance for Climate-Related Disasters: A Roadmap for the United States. *Ceres*. <https://blogs.edf.org/markets/wp-content/blogs.dir/32/files/2023/01/Inclusive-Insurance-Report.pdf>

Lastly, as Goal 2.3 focuses on advancing economic equity, the suite of indicators under this goal reflect avenues through which fair access to high-quality green jobs can be improved, especially for women, people of color and low-wealth residents. In addition to the community-identified need, the Brookings Institute has noted that the clean energy economy workforce is currently older and male-dominated, lacking racial diversity as compared to the national average.²¹ Fair access can be improved through publicly funded pre apprenticeship programs and job application support, training and education and better hiring procedures.²²

TABLE 7

Economically and socially restorative

Goal	Indicator	Metric
2.1: Climate resilience investments are prioritized and flow to communities most vulnerable to the impacts of climate change	Government funding for climate resilience flows equitably	% of climate resilience funding (resilient infrastructure, retrofits and buyouts) annually flowing to designated disadvantaged communities
Goal 2.2: Individuals are aware of and have access to insurance policies and financial support that provide the ability to bounce back quickly following damage or any extreme events	All individuals at risk of flooding have access to insurance ²³	% of units across a given jurisdiction eligible for flood insurance that are subscribed Affordability of insurance, as measured through ratio of insurance premiums to total housing costs/housing burden
Goal 2.3: Local residents, especially people of color and low-wealth residents, have fair access to and are well-equipped to get well-paid jobs and take part in or lead aspects of the climate transition	High quality clean energy and green-collar job opportunities are created and made accessible to most impacted communities	Amount of funding dedicated to direct entry pre-apprenticeship programs Number of people from frontline communities graduating from pre apprenticeship programs Number of workers hired through project labor agreements

²¹ Mark Muro, Ranjitha Shivaram, Adie Tomer, & Joseph Kane. (2019). Advancing inclusion through clean energy jobs. The Brookings Institute. <https://www.brookings.edu/articles/advancing-inclusion-through-clean-energy-jobs/>

²² Mark Muro, Ranjitha Shivaram, Adie Tomer, & Joseph Kane. (2019). Advancing inclusion through clean energy jobs. The Brookings Institute. https://www.brookings.edu/wp-content/uploads/2019/04/2019.04_metro_Clean-Energy-Jobs_Report_Muro-Tomer-Shivaram-Kane_updated.pdf

²³ The goal here is to subsidize flood insurance for everyone. It should be noted that while that has real benefits (such as preventing people from losing their homes), it can also lead to observed risks (such as encouraging new building and re-building in at-risk areas, and ultimately, unsustainable subsidy of flood insurance).

3. Green and natural infrastructure

Goal theme three focuses on making sure that natural areas and green infrastructure approaches are an integral part of the fabric of our communities and supportive of the health and well-being of people and nature. Many resilience plans and stakeholder feedback emphasized the need for green and nature-based infrastructure solutions to mitigate flooding impacts and improve the health and well-being of impacted communities as well as the natural environment.

Access to healthy green spaces and waterfront areas was emphasized throughout both plans and stakeholder discussions. With the present threat of climate change impacts and extreme weather events, the condition and quality of open spaces is critical to the healthy functioning of neighborhoods and can provide benefits like cooling, reduced air pollution and habitat conservation.²⁴ Indicators for Goal 3.1 focus on the longevity and accessibility of public green spaces over time in light of climate impacts. Well-maintained parks in proximity to residents provide escapes on hot days and provide long term benefits to communities.

Wetlands were specifically identified in plans and stakeholder discussions as essential for climate resilience, due to their function as part of the natural ecosystem and in mitigating flood impacts.²⁵ Given their critical role in helping coastal areas alleviate the impacts of climate change, the indicators for Goal 3.2 center on both the prevalence of wetlands and their health.²⁶

Lastly, solutions that center or mimic natural systems and processes provide multiple benefits including serving as protective mechanisms against heavy rainfall, extreme heat and other climate impacts. The indicators for Goal 3.3 focus on maximization of biodiversity and prevalence of natural infrastructure that can help combat urban heat and manage flooding. This is likely why the 2023 PlaNYC report, Getting Sustainability Done, included tree canopy as a climate resilience indicator.²⁷

TABLE 8

²⁴ Mehdi Rakhshandehroo, Mohd Johari Mohd Yusof, Roozbeh Arabi, Mohammad Parva, & Ashkan Nochian. (2017). The environmental benefits of urban open green spaces https://frsb.upm.edu.my/upload/dokumen/20171108145406paper_2_.pdf

²⁵ Erin Conlisk, Liz Chamberlin, Marian Vernon, & Kristen E. Dybala. (2022). Evidence for the Multiple Benefits of Wetland Conservation in North America: Carbon, Biodiversity, and Beyond. Point Blue Conservation Science. <https://www.nrdc.org/sites/default/files/evidence-multiple-benefits-wetlands-conservation-report-202301.pdf>

²⁶ Natural Areas Conservancy's Map of New York City. Natural Areas Conservancy. <https://naturalareasnyc.org/map>

²⁷ Toward a Rainproof New York City: Turning the concrete jungle into a sponge. (2022). Rebuild by Design. <https://rebuildbydesign.org/wp-content/uploads/2022/09/Toward-a-Rainproof-NYC-Compressed.pdf>

Green and natural infrastructure

Goal	Indicator	Metric
Goal 3.1: Everyone has access to well-maintained, connected and quality parks and open space that will last in the long term	Waterfronts are accessible to all and are resilient to sea level rise	% of parks that are not going to be permanently inundated due to sea level rise by 2100 % of waterfront edge that is publicly accessible (excepting natural areas)
	Green spaces are within a 10-minute walk for all residents	% of areas within or outside of a 10-minute walk from a park or open space
	Local parks and open space are in good condition	Park conditions are rated in good or acceptable condition based on local metrics (e.g., NYC Parks Grade)
Goal 3.2: Wetlands, are preserved, restored and supported by ongoing stewardship	Presence of wetlands are higher than or comparable to a historic baseline	Acres of wetlands lost or gained since a relevant local baseline (e.g., 1974 survey in New York)
	Wetlands are healthy and able to migrate along with sea level rise	% of wetlands graded as “healthy” by relevant local metrics (e.g., Natural Areas Conservancy’s rapid assessment in NYC) % of wetlands with open migration pathways
Goal 3.3: Natural resources and habitats are healthy and maximized, combat urban heat, flooding and other climate impacts, and benefit health	Stormwater is absorbed by natural/green infrastructure	% of local green infrastructure target met Gallons of stormwater captured annually by green infrastructure <i>See also Healthy Communities goal 4.1</i>
		% of trees rated as healthy % of coverage of tree canopy Pounds of air pollutants removed annually
	Biodiversity is maximized	Biodiversity is maximized comparable to a historic baseline

4. Healthy communities

This theme focuses on ensuring our environment is safe for people and nature and promotes public health and well-being, centering on the intersections between climate risk and public

health, an area that received robust stakeholder input throughout our process due especially to the exacerbating impacts of climate change on poor air and water quality.

For example, increased stormwater poses secondary risks in areas like New York City where stormwater and sewer systems are combined, resulting in untreated sewage directly discharging into rivers during rainstorms, elevating bacteria and nutrient levels and degrading water quality. The indicators for Goal 4.1 focus on water quality and quantity. When stormwater management is effective, water bodies are cleaner; flood risk is reduced, and quality of life improves.

The indicators for 4.2 focus on the intersection between climate and air quality, extreme heat and chemical exposure. Poor air quality and extreme heat can impact everyone, but disproportionately impact those with risk factors such as pulmonary diseases and age, and especially those without access to air conditioning or cool and clean air environments. High heat days, increasing due to climate change, are now one of the biggest causes for cardiovascular incidents and disease in the country.²⁸ Similarly, flood risks exacerbate existing pollution hazards. Facilities that store potentially harmful pollutants (such as oil, bulk chemicals, and toxic release inventory) can result in exposure when located in flood hazard areas.

Lastly, access to food (Goal 4.3) is one of the most essential human needs and is identified as such in FEMA’s Community Lifelines. Indicators for this section focus on flood risks that pose a threat to food access. For example, out of the six major food distribution centers in New York City that serve bodegas and supermarkets—the largest, Hunts Point Food Center, is vulnerable to both storm surge and seal level rise. This means one extreme event can create widespread disruption across a food supply chain that is already vulnerable to rising prices and inaccessibility of healthy options.²⁹

TABLE 9

Healthy communities

Goal	Indicator	Metric
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²⁸ Centers for Disease Control and Prevention. Extreme Heat. <https://www.cdc.gov/disasters/extremeheat/index.html>

²⁹ City of New York Food Policy. (2021). Food Forward NYC: A Policy and Action Plan to Reshape NYC’s Food System. <https://www.nyc.gov/assets/foodpolicy/downloads/pdf/Food-Forward-NYC.pdf>

Goal 4.1: Stormwater is captured or managed to the maximum extent feasible on public and private lands in a way that maximizes environmental and public health and wellbeing and minimizes the risks associated with flooding	Water quality meets EPA recreational water quality criteria	Status on relevant Waterbody Inventory/Priority Waterbodies List - use assessments indicating that waterways are not impaired for primary contact recreation
	Stormwater is effectively captured	Combined sewer overflow frequency and volume
		Stormwater discharge as compared to annual rainfall % of stormwater managed (i.e. retained, infiltrated, evapotranspired, reused, or detained and not run off), annually <i>See also: Green and Natural Infrastructure Goal 3.3</i>
Goal 4.2: Our homes, recreational spaces and places of work are free of exposure to harmful pollution, contaminants and extreme heat	Air quality is healthy and safe for all	Concentration of PM 2.5 Concentration of PM 1 Concentration of PM 10
	All communities are able to cope with higher temperatures and heat waves	Heat stress death rate % of households with air conditioning. <i>Note for all indicators, comparing differences across demographics and income levels is important. In this case, comparing % of households with access to air conditioning across differing income levels or another way to measure affordability and access is especially critical.</i> <i>See also: Shelter Goal 7.1.</i>
	All communities are safe from exposure to potentially harmful chemicals	# of hazardous and chemical bulk storage sites in the floodplain and not designed to withstand a flood
Goal 4.3: Food systems are resilient to climate threats	Major food storage or grocery stores are safe from flood exposure	% of grocery stores and storage facilities in a given geography in the FEMA 500-year floodplain and/or meeting climate resilient design guidelines.

5. Governance

This goal theme focuses on ensuring that clear leadership is in place with a whole of government approach involving all ministries, public administrations and agencies, in order to manage all the various aspects of climate risk mitigation. Many indicators in this section are more process-oriented, given the challenges inherent to measuring governance.

The prevalence of silos and the need for holistic, collaborative strategies across agencies and government jurisdictions came up throughout plan review and stakeholder discussions. The indicator and metrics for Goal 5.1 focuses on climate resilience planning, as this is one of the few measurable ways to determine if governments have worked together to act or plan for action in the future. Metrics for this indicator focus also on the quality of engagement and empowerment in planning, as people who live in a place know what it needs and what is lacking and therefore can provide critical guidance in developing resilience strategies. It is also especially important that those most vulnerable to climate impacts be prioritized in the planning process.

The indicators for Goal 5.2 focus on the degree to which government agencies are well organized and equipped to build climate resilience. One of the most critical benchmarks for government function is staffing in general and then specifically for the issue of focus. An example of the latter is the creation of a new Bureau of Coastal Resilience within New York City's Department of Environmental Protection. Additionally, a shared (and publicly accessible) vision and resilience strategy can unite different agencies across multiple scales and require coordination at the city, state and even federal levels. Consistent tracking and reporting on such strategies and capacity can help build awareness and trust between governments and their constituents.

The indicators for Goal 5.3 focus on government implementation and management of resilience plans and actions. While federal, state and local governments have recently invested billions of dollars in climate funding, it is important that these funds are tracked and tied to the larger, multi-jurisdictional shared goals. New York City Mayor's Office of Management and Budget, for example, has committed to developing a means to track climate investments for the City.

Lastly, as climate impacts can occur at a regional scale and often require a cross-jurisdictional approach, the indicators for Goal 5.4 focus on the reach, accessibility and coordination on communications about climate and risk information. Resilience strategies can require broad regional or watershed-scale approaches, as is the case with the Army Corps' New York-New Jersey Harbor and Tributaries Study that is proposed for the the New York-New Jersey metropolitan region. A shared communication approach can also allow municipalities or states to identify areas where they can aid or benefit one another.³⁰ Finally, collaborative and accessible (i.e. shared in multiple languages) climate risk messaging, notifications and data,

³⁰ Dane, Alex and Hotchkiss, Eliza. (2019). Resilience Roadmap: A Collaborative Approach to Multi-Jurisdictional Resilience Planning. National Renewable Energy Laboratory. <https://www.nrel.gov/docs/fy19osti/73509.pdf>

along with other collaborative governance strategies, allows for residents and leadership alike to form a collective understanding of how to prepare for emergencies and build a resilient future.

TABLE 10

Governance

Goal	Indicator	Metric
Goal 5.1: Community-driven climate resilience plans are in place that ensure that all residents can withstand acute shocks and long-term climate change	All communities have an evidence-based, community-driven climate resilience plan in place that centers residents who are most impacted by climate change	<p>% of municipalities or in the case of NYC, community districts, that have a climate resilience plan in place</p> <p>% of municipalities or community districts that have plans that:</p> <ul style="list-style-type: none"> • Were developed through robust community engagement, especially of socially vulnerable communities.³¹ • Include clear near-term as well as long-term strategies for reducing risk • Preserve culturally-important sites from losses due to sea level rise <p><i>See also: Governance Goal 5.3</i></p>
Goal 5.2: Agency roles and responsibilities for the different aspects of climate resilience are clear, well communicated, adaptable and coordinated across jurisdictions and levels of government	Staffing capacity is adequate within key environmental and resilience-focused offices and departments	<p>Vacancy and staffing rates for environmental and climate resilience agencies, e.g.:</p> <ul style="list-style-type: none"> • Relevant Mayor’s Offices • Departments of Environmental Protection • Offices of Emergency Management • Housing Departments
	Organizational chart of roles and responsibilities is clear for how flood, extreme heat and other climate impacts, and involves relevant agencies at municipal, state, federal and county levels (as applicable)	<p>An organizational chart of governance roles and responsibilities exists with specification on resilience leads for all relevant government agencies.</p> <p>Every relevant government agency has and is tracking progress towards shared goals, with clear indicators and targets for success, and is progressing toward overall improvements</p> <p>A public-friendly version of this organizational chart is available online as</p>

³¹ Robust community engagement means that a strong participatory process, particularly focusing on the needs of communities most vulnerable and exposed to the impacts of climate change, has been implemented and that the plan is based on the needs and priorities of those communities. Strong process means that goals for participation and demographic representation were met, and that a multi-pronged direct and indirect outreach strategy was conducted, and that barriers to participation (language, technical facility, and more) were mitigated.

		part of a resilience website and communications strategy, indicating who is responsible for what in a way that the public can understand (e.g. who to call if you are dealing with flooding in your home/neighborhood)
Goal 5.3: Resilience planning, capital budgeting and infrastructure development incorporates climate resilience, reflects community values and engages residents, especially those most impacted by climate change	Government action on resilience is driven by robust community engagement and centers communities most impacted by climate change	See metrics for Governance Goal 5.1 (robust engagement in planning), also relevant to this goal and indicator. Every relevant government agency in the jurisdiction of measure has and is tracking progress towards shared goals, with measurable targets for success, and is progressing toward overall improvements # of attendees in public meetings surrounding resilience planning
	Capital budgeting incorporates funding for and tracking of climate adaptation and mitigation	% or total amount of government capital and operating budgets dedicated to resilience management and infrastructure
Goal 5.4: Messaging about climate risk is consistent across jurisdictions	Information about climate risk is accessible to all and coordinated	Flood and heat risk maps are consistent across government departments and available online updated every five years
	Updated and timely reporting on climate risks	Emergency notification systems are in place and reaching broad populations in multiple languages, directing them to cooling and emergency shelters and other relevant resources. Systems are in place and functioning that coordinate messaging across levels of government and jurisdictions <i>See also: Education and Empowerment Goal 1.1, and Emergency Preparedness and Response Goal 8.3</i>

6. Built infrastructure

This theme is focused on ensuring that all infrastructure is built or retrofitted to withstand climate threats, especially the critical infrastructure and infrastructure systems essential for communities to function amid the acute and chronic stressors associated with climate change.

Exposure to climate impacts can restrict people's access to food, healthcare, telecommunications, transportation and other basic utilities, and thus their health, livelihood

and well-being.³² The indicators identified for Goal 6.1 therefore focus on the core systems that communities rely to support daily life, informed by both community input and existing understanding of critical infrastructure and function, including FEMA’s “community lifelines” that enable the continuous operation of critical government and business functions and are essential to human health and safety or economic security.³³ Overall, it will be difficult to measure whether structures are meeting resilience design guidelines unless new data sources or requirements are developed. New York City’s energy efficiency grades³⁴ could serve as a potential model to consider for adopting a similar building rating system for resilience.

Emergency shelter availability, safety and proximity (the focus of Goal 6.2) came up several times in community-based planning efforts as important components of resilience for times of extreme heat, storms and other emergencies. Also discussed was the concept of “resilience hubs,” or those that serve as shelter as well as central gathering spaces for planning, coordinating and response.³⁵ Indicators were focused on proximity and distribution of cooling centers due to these data likely being more readily available. Efforts like WE ACT’s 2020 Cooling Center Report highlight ways that citizen science and/or government data could augment indicators proposed through measuring additional detail on the function and availability of these centers (e.g., whether they are regularly open, provide activities and resources to support those temporarily spending time in the center, and whether signs and other efforts to build awareness about the centers are in place).³⁶

This goal theme closely intersects with #7: Shelter, which was separated into its own goal theme due to the complexity and importance of resilience housing emphasized in planning and stakeholder workshops.

³² National Oceanic and Atmospheric Administration (NOAA). U.S. Climate Resilience Toolkit. Available online: <https://toolkit.climate.gov/topics/built-environment/energy>

³³ Federal Emergency Management Agency (FEMA). Community Lifelines. Available online: <https://www.fema.gov/emergency-managers/practitioners/lifelines>

³⁴ The NYC Department of Buildings assigns “energy grades” to qualifying buildings based on level of annual energy and water consumption as compared to the US EPA benchmarks.

For information about qualifying buildings: New York City Department of Buildings. (2016). Local Law No. 133. https://www.nyc.gov/assets/buildings/local_laws/ll133of2016.pdf

For detailed information about NYC’s energy grading system: NYC Department of Buildings. Benchmarking and Energy Efficiency Rating. <https://www.nyc.gov/site/buildings/codes/benchmarking.page>

³⁵ WE ACT for Environmental Justice in New York City has identified cooling centers (from extreme heat) as an important need for residents and has made recommendations for availability and accessibility of these centers given the impact of extreme heat on vulnerable communities.

³⁶ WE ACT for Environmental Justice. (2020). A Call for NYC Cooling Center Improvements: Results from WE ACT for Environmental Justice’s Cooling Center Audit Project. <https://www.weact.org/wp-content/uploads/2020/07/WE-ACT-Cooling-Center-Report-Short032320.pdf>

TABLE 11

Built infrastructure

Goal	Indicator	Metric
Goal 6.1: All buildings and critical infrastructure are resilient to the acute shocks of extreme events and chronic stressors associated with climate change so that all communities can thrive	Buildings, transit systems and other critical infrastructure are resilient to climate threats	<p>Buildings and land use:</p> <ul style="list-style-type: none"> • % of buildings built or retrofitted to meet climate resilient design guidelines • % of buildings within the floodplain at risk of flooding • FEMA National flood insurance program (NFIP) claims from NFIP policyholders³⁷ • Damaged property data in adjusted U.S. dollars³⁸ • Disaster recovery costs (FEMA + CDBG-DR) <p>Transportation:</p> <ul style="list-style-type: none"> • Transit Performance Score • Neighborhood walkability score • Hours and frequency of weather-related service disruptions for public transit • % of evacuation and major transportation routes at risk of or closure frequency due to relevant flood risks (e.g., tidal, rainwater, and storm surge inundation as individual and compound threats) <p>Food supply: % of major food storage and depot operations (e.g., Hunts Point) that are built or retrofitted to withstand flooding and power outages.</p> <p>Fuel supply: % of major fuel storage and transportation systems that are built or retrofitted to withstand flooding and power outages.</p> <p>Electricity</p> <ul style="list-style-type: none"> • Total # of hours interruption annually per customer, average # of interruptions that a customer would experience • Network Reliability Index • Level and duration of interruptions due to extreme events (heat, flood, cold) <p>Water supply and wastewater treatment: # hours interruption annually of sewage and drinking water treatment facilities</p> <p>Healthcare: % of healthcare facilities/hospitals built or retrofitted to withstand extreme flood and heat.</p>

³⁷ This metric is likely to be highly variable depending on changes in the NFIP market, however it is one of the few regularly available data sets for damages, and so was included.

³⁸ This data set includes a combination of property damage data (pulled from NWS Storm Events Database) and crop/agriculture loss data (pulled from USDA crop insurance data) and is updated annually.

		Internet: # of hours interruption annually of internet access per customer
		Emergency facilities: all emergency shelters, fire stations, police departments and other emergency preparedness and response facilities are built or retrofitted to withstand climate threats according to climate resiliency design guidelines
		<i>See also: Green Infrastructure Goal 3.1</i>
	Programs and resources for retrofitting or relocating critical infrastructure are available to meet the demand	Total applications for revolving loan fund programs and federal grants vs. actual amount funded
		Total assessed need gap for retrofits or replacement of housing and critical infrastructure
Goal 6.2: Climate safe emergency shelters are accessible to all and serve as multipurpose community centers	All residents are within a 15-minute walk or transit trip of a shelter that provides safety from flood and heat exposure	Analysis demonstrates that shelters that provide cooling and flood risks (e.g., elevated out of the floodplain and with unobstructed access to safe egress/transit routes) cover all neighborhoods across the region.
		Locations of shelters and distributional equity across the region
		<i>See also: Emergency Preparedness Goal 8.2</i>

7. Shelter

This theme focuses on ensuring that everyone has access to local safe and reliable shelter despite climate shocks and stressors. Shelter is a necessary facet of a healthy human life and can protect people from the variability and harshness of the elements, among other hazards or threats.

The ability of housing to meet those basic needs is dependent on its safety, reliability and longevity in a changing climate. Resilient and affordable housing also helps communities thrive in the long term and gain efficiencies and reduced costs in the form of avoided losses/damages to government and private property. While improvements to design guidelines and regulations can help to ensure that new development is designed for resilience, the vast majority of our infrastructure stock that is in flood-prone areas now would either need to be retrofitted or relocated to accommodate permanent and frequent flooding and ideally also for energy efficiency (buffering housing from extremes and reducing greenhouse gas emissions).

Indicators for Goal 7.1 therefore focus on adaptation, relocation and availability of shelter for all populations. In terms of adaptation, retrofits can be costly and challenging for owners to take

on, and programs to support their adaptation or relocation will be necessary to help scale these efforts, which is why indicators for this goal focus on support programs. Overall, it will be difficult to measure actual retrofits or relocations unless new data sources or requirements to meet a resilient design standard are established that could also double as data sources over time. New York City’s energy efficiency grades could serve as a potential model to consider in the future for a rating and review program within the region and beyond for resilience that could also serve as such a data source.

In some cases, a shelter’s existence in the floodplain and susceptibility to future extreme events creates too high of a risk for residents. To protect public health and wellbeing, housing buyout programs can remove vulnerable housing from the flood zone and help to slowly restore floodplains back to their original state by removing structures that cannot withstand repetitive future flood events.

TABLE 12

Shelter

Goal	Indicator	Metric
Goal 7.1: Shelter is available, affordable, and able to withstand acute and long-term climate threats	Information, technical assistance and applications for energy upgrades and retrofits are accessible online for landlords, business owners and homeowners	Federal and state funding program websites provide clear information about availability of government programs for energy and resiliency retrofits.
	Housing is climate resilient and available to all, proportionate to what is needed for all income levels	% of housing units built or retrofitted to meet climate resilient design guidelines or within the floodplain (also a metric for Goal 6.1) and, amongst those: <ul style="list-style-type: none"> • Availability at different price points compared to population at those income levels • % renter occupied % total unhoused population that have access to a shelter (anytime) % of shelters that are resilient to flood and heat threats. <i>See also: Healthy Communities Goal 4.2</i>

Goal 7.2: Property owners have access to funding and/or financial instruments that support affordable solutions to retrofit or relocate	Funding and financing can keep pace with the demand for private retrofits and retreat	Programs for private funding and financing of retrofits for all housing types are available
	Federal and state relocation programs are well funded and adopt equitable practices (ex: relocation assistance)	Government funding and financing for retrofits distributed by community district and among populations/ individuals of different income levels (e.g., % going toward disadvantaged communities and/or low-income residents) % of property acquisition programs that offer relocation assistance # and types of funding sources for property acquisition programs at federal and state levels

8. Emergency preparedness and response

This goal theme focuses on ensuring that communities and governments are prepared for and able to quickly recover from the impacts of acute disasters.

Community members and groups play a key role in these efforts not only because they are on the frontlines of response, but also because they possess the most in-depth knowledge of local needs, especially those of vulnerable populations. The indicators for Goal 8.1 therefore focus on the presence and effectiveness of emergency plans at reaching those that most need support, with an emphasis on the degree to which these efforts reflect strong relationships between community and coordinating agencies.

The indicators and metrics under goal 8.2 focus on the capacity for agencies and community partners to successfully execute emergency plans. Capacity is needed at all stages of preparedness and response— developing procedures, implementing warning systems, providing emergency personnel and supplies, conducting rescue efforts and sheltering evacuees.

In addition to government agencies, local institutions such as libraries, healthcare facilities and community-based organizations also serve as key players in response and recovery efforts. For community groups and government agencies to work together effectively, strong relationships, collaboration and mutual trust are needed. Although identifying quantitative indicators for this goal was a challenge, metrics for Goal 8.3 focus on relevant communication networks and coordinated preparedness efforts. Partnerships and co-development of resources and trainings with community organizations and emergency management agencies can help to improve access to resources for those most vulnerable, build trust, and deepen local and government knowledge

of preparedness options and important context.

TABLE 13

Emergency preparedness and response

Goal	Indicator	Metric
Goal 8.1: Emergency preparedness plans are in place and are evidence-based and community-informed, fostering community awareness and safety, especially of vulnerable populations	Emergency preparedness and response plans are informed by residents and in place in all communities	% plans that included community input during development % of plans that include a coordination chain for communications
	Preparedness plans include specific response measures and procedures for socially vulnerable residents	% of plans that include specific response measures and procedures for vulnerable residents (e.g., elderly, disabilities, low income, etc.)
Goal 8.2: Communities have capacity to prepare for and respond to emergencies and partner with relevant government agencies	Communities have the capacity to carry out their role during emergency response	# of paid staff dedicated to emergency response and preparedness Funding (and distribution by geography) for community organizations that conduct emergency response & preparedness
	Important social infrastructure (organizations, gathering spaces, etc.) are well-resourced	% Local libraries open 7 days a week
		% of population within 1 mile of public hospital/clinic <i>See also: Built Infrastructure Goal 6.1</i>
	Community district or local community affairs budgets Distribution of budgetary and staff resources of organizations that implement climate resilience education and communication activities across geography <i>See also: Education and Empowerment Goal 1.1</i>	
Goal 8.3: Communities and government entities focused on emergency response have strong relationships and communication networks, and trust one another	Communities and agencies practice emergency preparedness and response procedures as a group. <i>See also Governance goal 5.2</i>	# of times emergency procedures are practiced annually with multiple coordinating agencies & community partners # emergency preparedness workshops, trainings, and/or public meetings and events joined by government staff in each community district/borough/County

Climate and extreme weather event risk information is accessible to the public

Emergency notification systems are in place and reaching constituents within the jurisdiction of focus, directing them to cooling and emergency shelters and resources, as measured by subscribers, social media followers, and actual use of shelter during emergency situations.

See also: Education and Empowerment Goal 1.1 and Governance Goal 5.4

Looking forward: Applications and next steps

The impetus for this project was that practitioners lack a framework for measuring progress in achieving levels of resilience, despite rising need and increased investments in resilient infrastructure. If we are to make informed and effective advocacy and policy-making decisions around resilience, we need ways to measure progress. Through the project, three primary user groups for these indicators were identified: 1) government managers; 2) advocates; and 3) community-based organizations. Several applications for use, organized by these users, are laid out below.

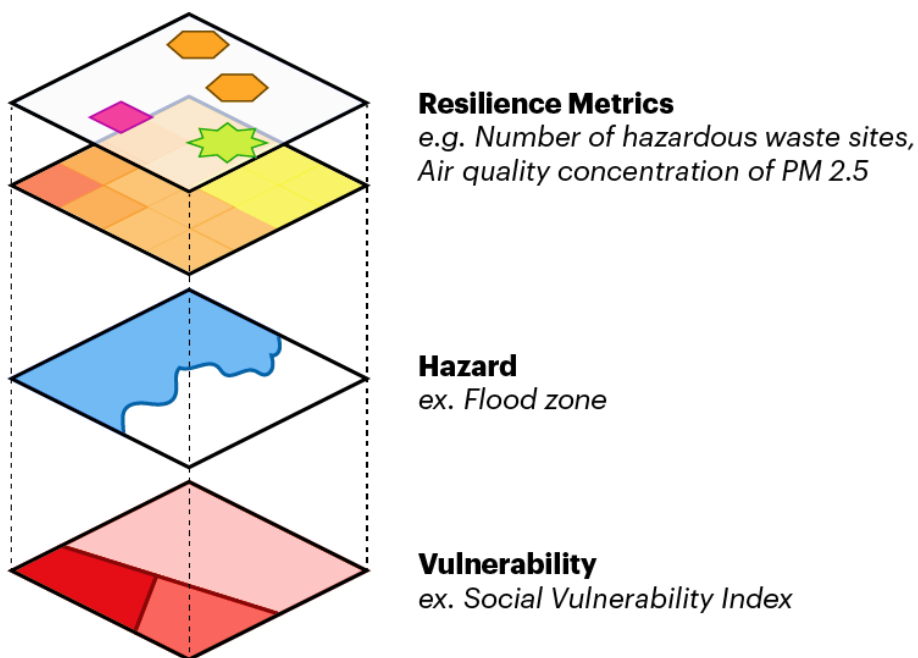
Government managers

Federal, state and city resilience managers such as Chief Resilience Officers are charged with reducing the impacts of climate change. Whether through plans, policies or programs, government managers are accountable to the public to improve resilience in communities. Without indicators, they are faced with the difficult challenge of managing improvement without any clear sense of the impacts of their actions. For these users, having the ability to apply indicators directly to their work - in an overall resilience index, mapped with social vulnerability and hazard data or as individual or thematic combinations (e.g., “built infrastructure,” “governance,” “emergency preparedness and response,” etc.) - can be useful in answering the question of “how resilient are we?” within and across geographies to the public as well as internal teams (Figure 6). Combining indicators and indices of vulnerability and exposure can also help to reveal differences across demographics, which can help to clarify environmental justice needs, as areas with higher percentages of people of color and low-income populations, are also often overburdened by multiple environmental stressors.

FIGURE 7

Layering resilience metrics, hazards and vulnerability together to support decision-making.

Using mapping tools to layer vulnerability metrics, hazard zones or metrics, and resilience metrics can help managers better focus efforts where they are most needed, in more specific ways. For example, retrofitting critical infrastructure for flood risk is most needed in areas with high social vulnerability, high exposure to hazards and low critical infrastructure resilience.



Having a common resilience index could help to build alignment and foster collaboration across agencies in developing strategies within and across agency purviews that support shared goals. For example, New York City OMB is undergoing an effort through its Climate Budgeting process to use key, science-based climate indicators and metrics to evaluate how near-term spending contributes to meeting long-term climate goals across all City agencies. Indices can also help inform grant and resource prioritization. As discussed in the executive summary, mapping tools such as the new Climate & Economic Justice Screening Tool (CEJST) tool are increasingly being used for identifying community burden and vulnerability nationwide; but not many tools measure resilience.

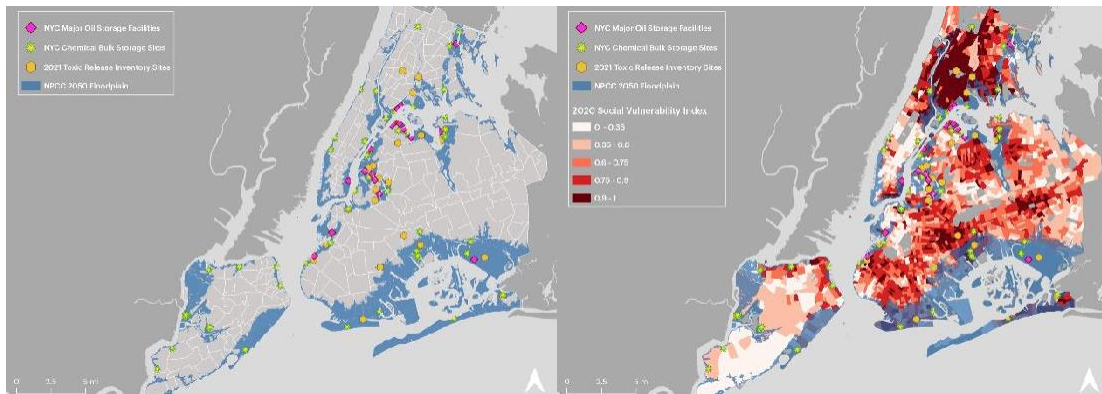
In addition to an overall index, being able to explore individual indicators can help to inform targeted strategies and measure how well governments are doing in achieving specific goals. Focusing on how a specific indicator is performing within or across different jurisdictions can help to inform strategies or progress towards a goal. For example, proximity to toxic chemical storage facilities is one identified indicator of environmental health that intersects with flood risk exposure and social vulnerability. Mapping this indicator along with vulnerability and exposure risk can enable a manager to better target prevention actions. If data such as changes in the number of toxic facilities in the floodplain, or number of facilities retrofitted to withstand floods can be collected over time, it can help managers assess progress, identify how pollution is distributed amongst different neighborhoods, where action to reduce pollution should be focused and enhance environmental and climate justice. Another such example is measuring tree canopy, which can provide multiple benefits such as heat reduction, habitat, carbon storage, stormwater absorption and natural cooling. High tree canopy coverage is especially crucial for neighborhoods that are otherwise overburdened by social and environmental stressors and lack the resources they need to be resilient. For instance, it is more challenging for households in low-income neighborhoods to afford air conditioning on a day of extreme heat. The two variables— lack of tree canopy cover and SVI can be combined to serve as an important guide for planning tree planting and maintenance.

FIGURE 8

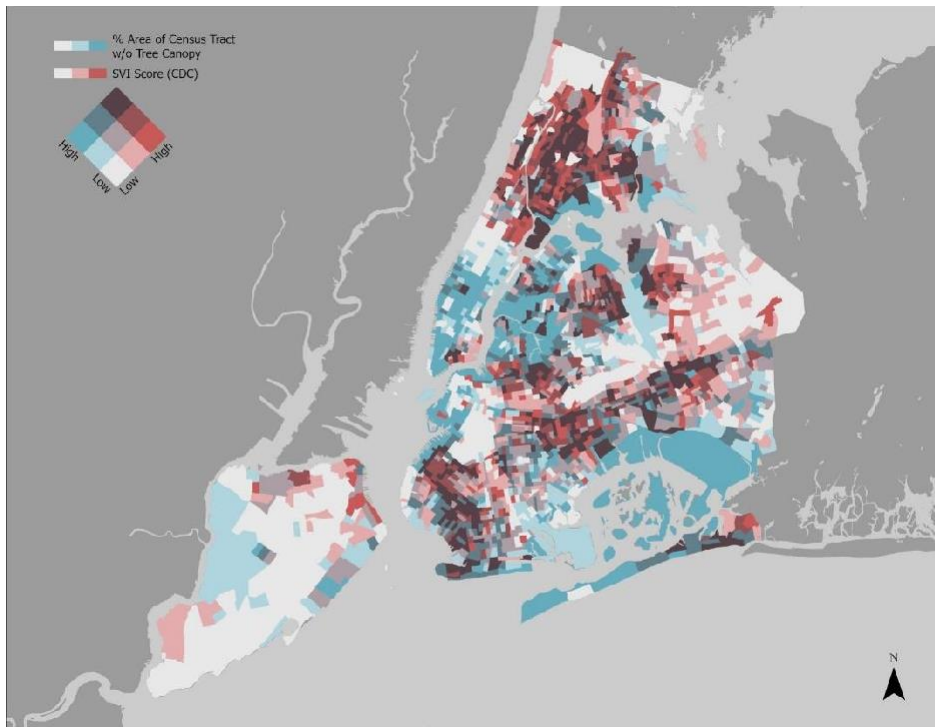
Examples of individual indicators paired with social vulnerability and climate hazards

Examples of how a single indicator, (a) hazardous and chemical bulk storage sites or (b) tree canopy, can be mapped along with social vulnerability and exposure to a relevant climate hazard to support more targeted management action. See also New York City Environmental Justice Alliance's Waterfront Justice Project, which first identified the importance of mapping these sites in the context of the floodplain in the New York City area.

(a)



(b)



Advocates

Advocacy groups play a critical role in advancing progress in a community by educating the public and holding government managers and elected officials accountable. Combining indicators into a simple index or resilience report card can be a useful way to support advocates' efforts. For example, demonstrating that one area is underperforming compared to others can

help to motivate increased public pressure and action by decision-makers. Additionally, indicators can help advocates highlight the potential negative or positive impacts of policy and decision-making, such as revealing the potential impacts of expanding dense development in an area with high hazard exposure, low resilience and high social vulnerability.

Community-based organizations (CBOs)

CBOs possess the most up-to-date knowledge of the issues faced by their community and are key players in advancing local planning efforts. Many also are involved in advocacy around or provide direct services related to resilience - assisting with food, shelter, emergency preparedness, maintenance of parks and infrastructure and other areas. Indicators identified through this project could be used in several ways by CBOs:

- **For evaluation and planning:** mapped indicators in the form of public-friendly report cards can be useful to educate community members. Or, when developed into a checklist or questionnaire, they can provide a platform to evaluate areas in need of resources or management action. These activities can inform local planning and engagement with decision-makers. A community-conducted evaluation of the condition of resilience attributes (resilient shelter, transportation, etc.) could help inform resilience plans through the lens of community members. One example of this type of application is the [Plan Integration for Resilience Scorecard](#), a tool for reviewing plans through the lens of how well a particular plan element may impact local resilience. Community organizations can also use these indicators to track progress over time and target feedback.
- **Justification for resource investments:** indicators can also be used to leverage financial support to a community or district in the form of grants and discretionary funding, as well as guide participatory budgeting processes. These funds and resources can be key in bringing about progress and enhancing community resilience. Data availability in some areas is a challenge, especially at a neighborhood level. Providing ways for communities to close these data gaps through their own analyses of their community can promote citizen science and empower residents to participate in policy- and decision-making.

Improving community resilience through Citizen Science

Citizen science can be used to fill in data and knowledge gaps, supplementing or expanding data sets with which to measure the proposed indicators or local hazard information. One such case is FloodNet, a collaboration between community groups, academic institutions, and the New York City government that provides information on hyperlocal flood events in the city and aims to sharpen local understanding of climate threats. FloodNet incorporates data both from researchers and the Community Flood Watch Project, which allows individual residents to report local rain-based flooding, share experiences, and access resources related to flooding across the City.

Communities can use this shared database of images, reports, and maps to advocate for their neighborhood's needs and visions to city leaders, identify neighborhoods that are vulnerable to high tides, storm surge, and stormwater runoff, and contribute information that can be used by researchers.

Opportunities for application

There are several applications for these indicators to establish ways to better track progress toward resilience goals, prioritize resources, inform policy and to improve management and decision-making.

As a next step, we aim to engage to work with relevant New York City agency staff, legislators and advocates to support the adoption of measurable indicators as an accountability and management best practice. We also aim to pilot the use of these indicators in planning and policy efforts, toward specific performance targets at state and hyperlocal levels, through partnerships with advocacy-focused and community-based organizations and governments to co-develop user-oriented applications. Environmental Defense Fund's Climate Vulnerability Index also provides an opportune data set from which to draw and potentially develop tailored report cards or decision support tools for government managers to manage specific climate hazards relevant to their region.

Lastly, this report highlights several data gaps. Partnerships with government agencies, academia and others may present opportunities to close these gaps, and regularly maintain available, up-to-date data sets for resilience metrics, social vulnerability and hazards, which are critical to informing good management decisions and making information accessible to the broader public. One near-term example of such an opportunity is New York City's proposal to develop a climate budget, which would track spending on climate improvements and the impacts of the City's budget on climate change. This project provides a suite of community-

driven goals and indicators that could be considered as part of a holistic effort to better track localities' efforts and impacts.

Thanks to the robust input of many stakeholders throughout this process, we aim to explore these and other opportunities to advance the use of resilience indicators and metrics.

Appendix A: Potential data sources for indicators and metrics in New York City

The following table includes potential data sources in New York City for each indicator and metric proposed. Wherever possible, nationally available data sources were referenced. In some cases, those marked with an asterisk (*) reflect that either data sources do not yet exist or would require original analysis or additional work to compile. For all data sets, mapping with social vulnerability factors including demographics of race and income, and with climate hazard maps will maximize the utility of these indicators for understanding equity and areas of highest priority for each theme.

Theme	Goal	Indicator	Metric	Potential data sources
Education and Empowerment	1.1 Communities are connected with information and the best available science about their geographical areas in a format that is accessible and shareable through local communication networks	NGOs and community-based organizations effectively reach local residents, implement climate resilience communication, education and advocacy activities	Amount and distribution of budgetary and sta resources for organizations that implement climate resilience education and communicat activities within and across geographies	<ul style="list-style-type: none"> • Stewmap • NGO & community-based organization websites
		Climate and extreme weather event risk information is accessible to the public	<p>Flood and heat risk maps are available and updated every five years and are accessible and able to be downloaded for further analysis.</p> <p>Emergency notification systems are in place and reaching broad populations, directing them to cooling and emergency shelters and resources, as measured by subscribers and social media followers (e.g. NotifyNYC)</p>	<ul style="list-style-type: none"> • State and City flood and heat risk maps • Government social media accounts and ads dedicated to risk awareness
Economically and Socially Restorative	2.1: Climate resilience investments are prioritized and flow to communities most vulnerable to the impacts of climate change	Government funding for climate resilience flows equitably	% of climate resilience funding (resilient infrastructure, retrofits, and buyouts) annually flowing to designated disadvantaged communities	<ul style="list-style-type: none"> • State ad local budgets • Disadvantaged communities maps

	Goal 2.2: Individuals are aware of and have access to insurance policies and financial support that provide the ability to bounce back quickly following damage or any extreme events	All individuals at risk of flooding have access to insurance	% of units across a given jurisdiction eligible for flood insurance that are subscribed Affordability of insurance, as measured through ratio of insurance premiums to total housing costs/housing burden ³⁹	NFIP policy counts Housing value
	Goal 2.3: Local residents, especially people of color and low-wealth residents, have fair access to and are well-equipped to get well-paid jobs and take part in or lead aspects of the climate transition	High quality clean energy and green-collar job opportunities are created and made accessible to most impacted communities	Amount of funding dedicated to direct entry pre-apprenticeship programs Number of people from frontline communities graduating from pre apprenticeship programs ⁴⁰ Number of workers hired through project labor agreements	NYC workforce data portal DOE Energy and Employment Report Interstate Renewable Energy Council's National solar job census NYC Project Labor agreements
Green and Natural Infrastructure	Goal 3.1: Everyone has access to well-maintained, connected, and quality parks and open space that will last in the long term	Waterfronts are accessible to all and are resilient to sea level rise	% of parks that are not going to be permanently inundated due to sea level rise by 2100 % of waterfront edge that is publicly accessible (excepting natural areas)	Flood hazard maps, waterfront parks: NYC waterfront access map *note that no data set yet exists for which parks meet resilient design standards, but this would be a useful future data source
		Green spaces are within a 10-minute walk for all residents	% of areas within or outside of a 10-minute walk from a park or open space	Park data
		Local parks and open space are in good condition	Park conditions are rated in good or acceptable condition based on local metrics	NYC Parks grade

³⁹ Dixon, L., Clancy, N., Miller, B. M., Hoegberg, S., Lewis, M. M., Bender, B., Ebinger, S., Hodges, M., Syck, G. M., Nagy, C., & Choquette, S. R. (2017). The cost and affordability of flood insurance in new york city: Economic impacts of rising premiums and policy options for one- to four-family homes. RAND Corporation. https://www.rand.org/pubs/research_reports/RR1776.html

⁴⁰ Lara Skinner & Anita Raman. (2022). Climate for change: A complete climate jobs roadmap for New York City. ILR School Cornell University. https://www.ilr.cornell.edu/sites/default/files-d8/2022-05/Climate_for_Change_NYC_Full_Report_VD.pdf

Goal 3.2: Wetlands are preserved, restored and supported by ongoing stewardship	Presence of wetlands are higher than or comparable to a historic baseline	Acres of wetlands lost or gained since a relevant local baseline (e.g., 1974 survey in New York)	NYC Wetlands data
	Wetlands are healthy and able to migrate along with sea level rise	% of wetlands graded as “healthy” by relevant local metrics (e.g., Natural Areas Conservancy’s rapid assessment in NYC) % of wetlands with open migration pathways ⁴¹	Regional Plan Association shorelines report Natural Areas conservancy map for NYC
Goal 3.3: Natural resources and habitats are healthy and maximized, combat urban heat, flooding and other climate impacts, and benefit health	Stormwater is absorbed by natural/green infrastructure	% of local green infrastructure target met	NYC DEP Green infrastructure data
		Gallons of stormwater captured annually by green infrastructure <i>See also Healthy Communities goal 4.1</i>	*not all data sets may be readily available. NYC is also looking at “greened acres” as a measure of amount of stormwater managed by green infrastructure annually
	Tree canopy and biomass are healthy, widespread and equitably distributed, providing habitat, carbon storage and cooling	% of trees rated as healthy	New York City Tree Map
% of tree canopy coverage		Forestry tree points in NYC including “forestry work orders,” “forestry inspections” and “forestry planting spaces”	
Pounds of air pollutants removed annually		NYC landcover raster data USFS Tree Canopy Cover Dataset NYC Nature goals https://naturegoals.nyc/goals-targets/	
Biodiversity is maximized	Biodiversity is maximized comparable to a historic baseline	NYS: NYS Environmental conservation map	

⁴¹Calvin, E; R Freudenberg; and S McCoy. 2018. The New Shoreline: Integrating Community and Ecological Resilience around Tidal Wetlands. Chapter 5: Planning for Wetland Pathways. Regional Plan Association. Available online: <https://s3.us-east-1.amazonaws.com/rpa-org/pdfs/RPA-New-Shoreline-Report.pdf>

				*data available, but the baseline would need to be established
Healthy Communities	Goal 4.1: Stormwater is captured or managed to the maximum extent feasible on public and private lands in a way that maximizes environmental and public health and wellbeing and minimizes the risks associated with flooding	Water quality meets swimmable water quality standards	Status on relevant Waterbody Inventory/Priority Waterbodies List ⁴² - use assessments indicating that waterways are not impaired for primary contact recreation	NYS: Water quality monitoring and management data
		Stormwater is effectively captured	Combined sewer overflow frequency and volume	NYC: Stormwater Management Program 2022 Report
			Stormwater discharge as compared to annual rainfall	NYS: CSO map
			% of stormwater managed (i.e., retained, infiltrated, evapotranspired, reused, or detained and not run off), annually	See also: <i>Green and Natural Infrastructure Goal 3.3</i> PurpleAir map portal
	Goal 4.2: Our homes, recreational spaces and places of work are free of exposure to harmful pollution, contaminants and extreme heat	Air quality is healthy and safe for all ⁴³	Concentration of PM 2.5	NASA HAQAST dataset : has resources or various AQ indicators
			Concentration of PM 1	
			Concentration of PM 10	
		All communities are able to cope with higher temperatures and heat waves	Heat stress death rate ⁴⁴	NYC: Environmental and Health data portal
			% of households with air conditioning <i>Note for all indicators, comparing differences across demographics and income levels is important. In this case, comparing %households with access to air conditioning across tracts with differing income levels or another way to measure affordability and access is especially critical.</i>	NYS: Heat vulnerability Index See also: <i>Shelter Goal 7.1.</i>

⁴² New York State Department of Environmental Conservation. Monitoring Assessment–Water Quality. <https://www.dec.ny.gov/chemical/8459.html>

⁴³ New York City Department of Health and Mental Hygiene. Air Quality Data Explorer. Available online: <https://a816-dohbsp.nyc.gov/IndicatorPublic/beta/data-explorer/air-quality/?id=92#display=summary>

⁴⁴ New York City Department of Health and Mental Hygiene. Climate and Health–Heat Vulnerability Index. Available online: <https://a816-dohbsp.nyc.gov/IndicatorPublic/beta/key-topics/climatehealth/hvi/>

	All communities are safe from exposure to potentially harmful chemicals	# of hazardous and chemical bulk storage sites in the floodplain and not designed to withstand a flood ⁴⁵	<p>NYC Environmental Justice Alliance waterfront justice map</p> <p>NYS: Environmental remediation sites</p> <p>NYC property data</p> <p>EPA Superfund sites *Not likely available: design flood elevation of these sites</p>
	Goal 4.3: Food systems are resilient to climate threats	Major food storage or grocery stores are safe from flood exposure	<p>% of grocery stores and storage facilities in a given geography in the FEMA 500-year floodplain and/or meeting climate resilient design guidelines.</p> <p>NYS: Retail food stores</p> <p>Federal open data on retail food stores</p> <p>NYC Open data</p>
Governance	Goal 5.1: Community-driven climate resilience plans are in place that ensure that all residents can withstand acute shocks and long-term climate change	All communities have an evidence-based, community-driven climate resilience plan in place that centers residents who are most impacted by climate change	<p>% of municipalities or in the case of NYC, Community districts, that have a climate resilience plan in place</p> <p>% of municipalities or community districts that have plans that:</p> <ul style="list-style-type: none"> • Were developed through robust community engagement, especially of socially vulnerable communities. • Include clear near-term as well as long-term strategies for reducing risk • Preserve culturally-important sites from losses due to sea level rise <p>Plans from state websites, including the Climate Smart Communities program, municipalities, Community Boards, local community organizations and NGOs *Original qualitative analysis of climate resilience plans or survey of civic organizations regarding the quality of the resilience plan would likely be needed to measure against this goal <i>See also: Governance Goal 5.3</i></p>
	Goal 5.2: Agency roles and responsibilities for the different aspects of climate resilience are clear, well communicated, adaptable and	Staffing capacity is adequate within key environmental and resilience-focused offices and departments	<p>Vacancy and staffing rates for environmental and climate resilience agencies, e.g.:</p> <ul style="list-style-type: none"> • Relevant Mayor's Offices • Departments of Environmental Protection • Offices of Emergency Management <p>NYC: NYC Comptroller City Agency vacancy data and information</p> <p>City agency job postings</p>

⁴⁵ New York City Environmental Justice Alliance. Waterfront Justice Project Map. Available online: <https://nyc-eja.org/waterfront-map/>

coordinated across jurisdictions and levels of government		<ul style="list-style-type: none"> Housing Departments 	NYS: State department job vacancies *This would likely also require some original analysis or a new data source/reporting to be developed
	Organizational chart of roles and responsibilities is clear for how flood, extreme heat and other climate impacts, and involves relevant agencies at municipal, state, federal and county levels (as applicable)	<p>An organizational chart of governance roles and responsibilities exists with specification on resilience leads for all relevant government agencies.</p> <p>Every relevant government agency has and is tracking progress towards shared goals, with clear indicators and targets for success, and is progressing toward overall improvements</p> <p>A public-friendly version of this organizational chart is available online as part of a resilience website and communications strategy, indicating who is responsible for what in a way that the public can understand.</p>	*This would likely require original analysis or a new data source/reporting to be developed
Goal 5.3: Resilience planning, capital budgeting and infrastructure development incorporates climate resilience, reflects community values and engages residents, especially of those most impacted by climate change	Government action on resilience is driven by robust community engagement and centers communities most impacted by climate change	<p>See metrics for Governance Goal 5.1 (robust engagement in planning), also relevant to this goal and indicator.</p> <p>Every relevant government agency in the jurisdiction of measure has and is tracking progress towards shared goals, with measurable targets for success, and is progressing toward overall improvements</p> <p># of attendees in public meetings surrounding resilience planning</p>	*This would likely require original analysis or a new data source/reporting to be developed
	Capital budgeting incorporates funding for and tracking of climate adaptation and mitigation	% or total amount of government capital and operating budgets dedicated to resilience management and infrastructure	NYC OMB is developing a Climate Budget publication, for sustainability and resiliency, for April 2024 NYC capital budget NYS budget appropriations for State agencies

	Goal 5.4: Messaging about climate risk is consistent across jurisdictions	Information about climate risk is accessible to all and coordinated Updated and timely reporting on climate risks	Flood and heat risk maps are consistent across government departments and available online updated every five years Emergency notification systems are in place and reaching broad populations in multiple languages, directing them to cooling and emergency shelters and other relevant resources. Systems are in place and functioning that coordinate messaging across levels of government and jurisdictions	*This information would need to be gathered, but is readily available and binary – either they exist and are up to date, or not Relevant government websites and social media followers/analytics vs. total population (e.g., NotifyNYC)* <i>See also: Education and Empowerment Goal 1.1, and Emergency Preparedness and Response Goal 8.3</i>
Built infrastructure	Goal 6.1: All buildings and critical infrastructure are resilient to the acute shocks of extreme events and chronic stressors associated with climate change so that all communities can thrive climate change	Buildings, transit systems, and other critical infrastructure are resilient to climate threats	Buildings and land use: <ul style="list-style-type: none"> • % of buildings built or retrofitted to meet climate resilient design guidelines (CRDGs) • % of buildings within the floodplain at risk of flooding • FEMA National flood insurance program (NFIP) claims from NFIP policyholders • Damaged property data in adjusted U.S. dollars • Disaster recovery costs Transportation: <ul style="list-style-type: none"> • Transit Performance Score⁴⁶ • Neighborhood walkability score • Hours and frequency of weather-related service disruptions for public transit • % of evacuation and major transportation routes at risk of or closure frequency due to relevant flood risks (e.g., tidal, rainwater and 	*Data does not yet exist for how many buildings and infrastructure are meeting CRDGs, but this would provide a useful future data set if developed NYC Open data MapPLUTO SHELDUS damage data FEMA and HUD data sets regarding NFIP policies and disaster costs Alltransit performance score RedFin's walk score Municipal and state data on closures and impacts Hazard History and Consequence tool

⁴⁶ Center for Neighborhood Technology. 2023. Alltransit Performance Score. Available online at: <https://alltransit.cnt.org/rankings/>

	<p>storm surge inundation as individual and compound threats)</p> <p>Fuel supply: % of major fuel storage and transportation systems that are built or retrofitted to withstand flooding and power outages.</p> <p>Electricity</p> <ul style="list-style-type: none"> • Total # of hours interruption annually per customer, or average # of interruptions that a customer would experience) • Network Reliability Index • Level and duration of interruptions due to extreme events (heat, flood, cold) <p>Water supply and wastewater treatment: # hours interruption annually of sewage and drinking water treatment facilities</p> <p>Healthcare: % of healthcare facilities/hospitals built or retrofitted to withstand extreme flood and heat.</p> <p>Internet: # of hours interruption annually of internet access per customer</p> <p>Emergency facilities: all emergency shelters, fire stations, police departments and other emergency preparedness and response facilities are built or retrofitted to withstand climate threats according to climate resiliency design guidelines</p>	<p>Data may be available in state and local level hazard mitigation plans</p> <p>System average interruption duration index (SAIDI) or System Average Interruption Frequency Index (SAIFI) (average # of interruptions that a customer would experience)</p> <p>Hazard History and Consequence tool</p> <p>Department of Environmental Protection data</p> <p><i>See also: Green Infrastructure Goal 3.1</i></p>
<p>Programs and resources for retrofitting or relocating critical infrastructure are available to meet the demand</p>	<p>Total applications for revolving loan fund programs and federal grants vs. actual amount funded</p> <p>Total assessed need gap for retrofits or replacement of housing and critical infrastructure</p>	<p>*Data and analysis would need to be collected/conducted</p>

	Goal 6.2: Climate safe emergency shelters are accessible to all and serve as multipurpose community centers	All residents are within a 15-minute walk or transit trip of a shelter that provides safety from flood and heat exposure	Analysis demonstrates that shelters that provide cooling and safety from flood risks (e.g., elevated out of the floodplain and with unobstructed access to safe egress/transit routes) cover all neighborhoods across the region. Locations of shelters and distributional equity across the region	TIGER/Line analysis of NYC cooling center location coverage New York State Department of Health Cooling Center Application NYC hurricane safe evacuation centers NYC Homeless shelter locations <i>See also: Emergency Preparedness Goal 8.2</i>
Shelter	Goal 7.1: Shelter is available, affordable, and able to withstand acute and long-term climate threats	Information and applications for energy upgrades and retrofits are accessible online for landlords, business owners, and homeowners	Federal and state funding program websites provide clear information about availability of government programs for energy and resiliency retrofits.	*Qualitative analysis would need to be conducted/data not readily available NYSERDA RetrofitNY Program Department of Housing and Urban Development Green and Resilient Retrofit Program FEMA Housing Assistance
		Housing is climate resilient and available to all, proportionate to what is needed for all income levels	% of housing units built or retrofitted to meet climate resilient design guidelines or within the floodplain (also a metric for Goal 6.1) and, amongst those: <ul style="list-style-type: none"> • Availability at different price points compared to population at those income levels • % of renters occupied % of total unhoused population that have access to a shelter (anytime) % of shelters that are resilient to flood and heat threats.	*Data does not yet exist for how many buildings and infrastructure are meeting Climate Resilience Design Guidelines, but this would provide a useful future data set if developed <i>See also: Healthy Communities Goal 4.2</i>
	Goal 7.2: Property owners have access to funding and/or financial instruments that support	Funding and financing are able to keep pace with the demand for private retrofits and retreat	Programs for private funding and financing of retrofits for all housing types are available <u>Government funding and financing for retrofits distributed by community district and</u>	*Requires review of funding sources/data not yet available

	affordable solutions to retrofit or relocate		among populations/ individuals of different income levels (e.g., % going toward disadvantaged communities and/or low-income residents)	
		Federal and state relocation programs are well funded and adopt equitable practices (ex: relocation assistance)	% of property acquisition programs that offer relocation assistance	*Requires review of funding sources/data not yet available
			# and types of funding sources for property acquisition programs at federal and state levels	
Emergency Preparedness	Goal 8.1: Emergency preparedness plans are in place and are evidence-based and community-informed, fostering community awareness and safety, especially of vulnerable populations	Emergency preparedness and response plans are informed by residents and in place in all communities	% of plans that included community input during development	NYC Office of Emergency Management Strategic Plan
			% of plans that include a coordination chain for communications	Ready New York
	Preparedness plans include specific response measures and procedures for socially vulnerable residents	% of plans that include specific response measures and procedures for vulnerable residents (e.g., elderly, disabilities, low income, etc.)	*Qualitative review of emergency plans developed by offices of emergency management:	
	Goal 8.2: Communities have capacity to prepare for and respond to emergencies and partner with relevant government agencies	Communities have the capacity to carry out their role during emergency response	# of paid staff dedicated to emergency response and preparedness	*Data would need to be developed
			Funding (and distribution by geography) for community organizations that conduct emergency response and preparedness	
	Important social infrastructure (organizations, gathering spaces, etc.) are well-resourced	% of local libraries open seven days a week	NYC Department of Planning Capital Planning Explorer	
		% of population within one mile of public hospital/clinic <i>See also: Built Infrastructure Goal 6.1</i>	National Historic GIS Data Finder	
		Community district or local community affairs budgets	*Qualitative analysis of government budgets	
		Distribution of budgetary and staff resources of organizations that implement climate resilience education and communication activities across geography	<i>See also: Education and Empowerment Goal 1.1</i>	

<p>Goal 8.3: Communities and government entities focused on emergency response have strong relationships and communication networks, and trust one another</p>	<p>Communities and agencies practice emergency preparedness and response procedures as a group. See also <i>Governance goal 5.2</i></p>	<p># of times emergency procedures are practiced annually with multiple coordinating agencies & community partners</p> <p># emergency preparedness workshops, trainings, and/or public meetings and events joined by government staff in each community district/borough/County</p>	<p>*Data would need to be developed</p>
	<p>Climate and extreme weather event risk information is accessible to the public</p>	<p>Emergency notification systems are in place and reaching constituents within the jurisdiction of focus, directing them to cooling and emergency shelters and resources, as measured by subscribers, social media followers, and actual use of shelter during emergency situations.</p>	<p>*Data would need to be compiled, analysis of government social media accounts and ads dedicated to risk awareness (e.g., NotifyNYC)</p> <p><i>See also: Education and Empowerment Goal 1.1 and Governance Goal 5.4</i></p>

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