TECHNICAL REPORT

DRAFT Climate Change Adaptation Indicators Framework for the City of Boston, MA

Prepared by SeaPlan for
The Boston Harbor Association
January 12, 2015

ABSTRACT

Despite global efforts to mitigate climate change, climate change impacts are occurring, and will likely increase in severity in the coming decades. The City of Boston has stated its commitment to mitigating climate change and preparing the city for its impacts through the establishment of the [Climate Action Plan](#) (2010). Through their report, the Climate Action Leadership Committee and the Community Advisory Committee of the City of Boston established the need for an indicators framework to track the progress of the City of Boston in preparing for climate change. "A Draft Climate Adaptation Indicators Framework for the City of Boston, MA" provides a pragmatic approach to establishing indicator metrics to better understand the City of Boston's vulnerabilities and to evaluate and track its progress in implementing preparedness and resilience measures. This report describes the four-step methodology to develop a climate change adaptation (CCA) indicators framework, the resulting draft CCA indicators framework, and recommendations for next steps in implementing and honing this framework.

Cover Images: "High Tide During a 100-Year Storm in the Year 2050 with 2 Feet of Projected Sea Level Rise" by Sasaki Associates; photographs of Downtown Boston courtesy of Andy Lipsky.

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JANUARY 2015

RECOMMENDED CITATION:

Lipsky, A. and Starbuck, K. SeaPlan. Climate Change Indicators Framework for the City of Boston, MA. January 2015. Boston: Doc#220.14.02

SUPPORT FOR THIS PROJECT PROVIDED BY

THE BARR FOUNDATION

This report (doc# 220.14.02) was prepared by SeaPlan and may be downloaded at www.SeaPlan.org.

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Executive Summary

Despite global efforts to mitigate climate change, climate change impacts are occurring, and will likely increase in severity in the coming decades. Current models predict Boston will experience up to two feet of sea-level rise by 2050 and up to six feet by 2100. Because of this, it is imperative for decision makers and the public to determine how to adapt to and prepare for the changing climate, as well as understand the effectiveness of their adaptation-related management actions through monitoring and evaluation to inform future decisions.

The City of Boston has committed to mitigating climate change and preparing the city for its impacts through the establishment of the [Climate Action Plan](#) (2010) and the recently released [2014 Climate Action Plan Update](#). Through these efforts, the City of Boston established the need for an indicators framework to track the progress of the City of Boston in preparing for climate change. The 2014 CAP calls for the establishment of preparedness indicators (Action 2.32 in the 2014 CAP). [SeaPlan](#), [the Boston Harbor Association \(TBHA\)](#), and [EcoAdapt](#) have collaborated with the City of Boston to develop this draft climate adaptation indicators framework to help fill this need. This document has been informed by the CAP Update process and reflects the formative work the City has already accomplished in identifying and beginning to address its climate preparedness and resilience priorities. In addition, this draft framework builds on the ongoing and previous work conducted by the City and its climate action partners and builds on the best available science and policy from national and international climate change adaptation (CCA) indicator programs.

The following draft report describes the team's methodology, the resultant Draft CCA framework, and recommendations for the next steps to further develop an indicators framework. The team's four-step approach to devising the Draft CCA indicators framework included a literature review of the best available science and policy from national and international climate adaptation indicators programs, the identification of sectors in Boston involved with and/or impacted by climate change, the development of CCA indicators and metrics informed by the literature, and the development of a refined list of indicators specific to the needs and priorities of the City of Boston. The results are six high-level indicators and associated metrics which can be applied to measure the City of Boston's preparedness for climate change.

Terms of Reference

Adaptation: Adjustment in natural or human systems in response to actual or expected climactic stimuli or their effects, which moderates harm or exploits beneficial opportunities (IPCC 2007)

Adaptive capacity: The ability of human systems to adapt to and cope with climate change depends on such factors as wealth, technology, education, information, skills, infrastructure, access to resources, and management capabilities (IPCC 2007)

Adaptation indicators: Indicators that focus on both a) planned adaptation to climate change and b) the actual state of adaptation achieved (see definitions of indicator, process and outcome below) (Sniffer 2012, VI)

Baseline: A baseline is the situation before a marine spatial management plan begins; it is the starting point for performance monitoring and evaluation of each performance indicator (Ehler 2014, IX)

Climate change: Any significant change in the measures of climate lasting for an extended period of time, i.e. major changes in temperature, precipitation, or wind patterns that occur over several decades or longer (US EPA 2014)

Climate change adaptation: Adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities. Various types of adaptation can be distinguished, including anticipatory, autonomous and planned adaptation (IPCC, 2007)

Climate change mitigation: An anthropogenic intervention to reduce the sources or enhance the sinks of greenhouse gases (IPCC 2007)

Climate impacts: The effects of climate change on natural and human systems. Depending on the consideration of adaptation, one can distinguish between potential impacts and residual impacts (IPCC 2007)

Climate preparedness: The effort to reduce the risks related to climate change and to prepare for responding to new conditions (Spector and Bamberger 2013)

Evaluation (of adaptation measure): A process for systematically and objectively determining the effectiveness of an adaptation measure in the light of its objectives (UNFCCC 2010, 4)

Indicators: An indicator is a measure of something that we want to know the condition of or that we want to track (e.g., environmental condition). Indicators help us understand where we are, where we are going, and how far we are from the goal (US EPA Region 3 2014)

Outcome indicators: Indicators that measure the effectiveness of adaptation policies and activities (Harley et al. 2008, iii)

Process indicators: Indicators that monitor the progress in implementing adaptation measures (Harley et al. 2008, iii)

Resilience: (1) The ability to recover from or adjust easily to misfortune or change (Merriam-Webster, 2015); (2) The ability to prepare and plan for, absorb, recover from, or more successfully adapt to actual or potential adverse effects (National Research Council 2012, 12); (3) The capacity to adapt to changing conditions and to maintain or regain functionality and vitality in the face of stress or disturbance (Wilson 2013; Newman et al. 2013, 5)

Risk: The potential for an unwanted outcome resulting from an incident, event or occurrence, as determined by its likelihood and the associated consequences (DHS 2008, Newman et al. 2013, 17)

Vulnerability (related to climate change): Vulnerability is the degree to which a system is susceptible to, and unable to cope with, adverse effects of *climate change*, including *climate variability* and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its *sensitivity*, and its adaptive capacity (IPCC 2007)

Acronyms

ADAPT – Adaptive Learning, Dynamic Monitoring, Active, Participatory, Thorough

AdaptME – Adaptation Monitoring and Evaluation

CAP – Climate Action Plan

CCA – Climate Change Adaptation

CCVI – Climate Change Vulnerability Index

CVM – Climate Vulnerability Monitor

EPI – Environmental Performance Index

FEMA – Federal Emergency Management Agency

IIED – International Institute for Environment and Development

MA Plan – Massachusetts Ocean Management Plan

MA CZM – Massachusetts Coastal Zone Management

ND-GAIN – University of Notre Dame Global Adaptation Index

STAR Communities – Sustainable Tools for Assessing and Rating Communities

SMART – Specific, Measurable, Attainable/Achievable, Relevant, Time bound

TACCIMO – Template for Assessing Climate Change Impacts & Management Options

TAMD – Tracking Adaptation Measuring Development

TBHA – The Boston Harbor Association

UKCIP – United Kingdom Climate Impacts Program

UNISDR – United Nations Office for Disaster Risk Reduction

USDA – United States Department of Agriculture

WWF – World Wildlife Fund

I. Introduction

Despite the various mitigation efforts occurring throughout the world, the impacts of climate change will likely still be large (Harley, 2008). As one example, current models predict Boston will experience up to two feet of sea level rise by 2050 and up to six feet by 2100. Because of this, it is imperative for decision makers and the public to determine how to adapt to and prepare for the changing climate, as well as understand the effectiveness of their adaptation-related management actions through monitoring and evaluation to inform future decisions.

The City of Boston (the City) committed to leading a public process to identify and implement actions to expand climate change preparedness beyond municipal agencies. The results of this process formed the basis of a revised Climate Action Plan (CAP) completed in 2014. As part of the CAP, the City previously developed indicators to track climate change mitigation, but has yet to develop indicators to track the City's progress with climate change adaptation. The 2014 CAP calls for the establishment of preparedness indicators (Action 2.32 in the 2014 CAP, p. 64); and this draft framework should assist in the City's efforts to carry out these efforts.

To help fill this gap, [SeaPlan](#), [the Boston Harbor Association \(TBHA\)](#), and [EcoAdapt](#) (the team) worked with the City to develop a climate change adaptation indicators framework for potential use by the City. The draft framework contains key high level indicators, as well as potential metrics that provide more specific information about the high level indicators and could be used by the City when measuring the indicators. These metrics were primarily adapted from the data completed through the literature review found in Appendix 1 and represent *initial* thinking on how these indicators could be measured. The proposed indicators and metrics should be further reviewed by the City of Boston and the Climate Change Preparedness Strategic Committee, and revised as needed.

The following document contains a methodology section which provides an overview of how the team developed the CCA indicators framework, starting with a literature review to identify best practices and the use of screening criteria to narrow down a comprehensive list of potential indicators. The results section of this document contains the proposed CCA framework for Boston, and the conclusion section contains recommended next steps for continuing to refine this framework and developing an climate adaptation indicators system for the City.

II. Methodology

To develop the CCA indicators framework, the team devised a four- step methodology which included:

- Step 1: Conduct Literature Review
- Step 2: Identify Sectors in Boston Likely Impacted by Climate Change
- Step 3: Develop Comprehensive List of Potential Climate Change Adaptation Indicators
- Step 4: Develop Climate Change Adaptation Indicators Framework for Boston

More details on each step can be found below.

Step 1: Conduct Literature Review

As a first step to developing a CCA indicators framework for Boston, the team conducted a comprehensive literature review to ensure this effort is based on current best practices in the climate change adaptation field. More specifically, the team used the following screening criteria when selecting literature to review:

- Years: 2005 – 2014
- Geography: Local, national (U.S.), and international sources
- Type:
 - CCA guidebooks
 - CCA academic papers
 - CCA programs, indices and rating systems (city, national and international)
 - Climate change-related documents published by the City of Boston

Through reviewing this literature, SeaPlan collected information on:

- The process of designing a CCA indicators framework, including the need for and purpose for evaluating climate change adaptation actions, as well as the challenges associated with adaptation indicator selection
- Articulated recommendations for CCA indicator selection, including:
 - Characteristics of the indicators (e.g., process or outcome indicator)
 - Data availability
 - General best practices
 - Linking indicators to policy initiatives
- Sectors within cities/communities that will likely be impacted by climate change or involved with climate change adaptation (e.g., transportation, electricity/fuel, residential neighborhoods)
- Climate change-related policy goals articulated by Boston which will be useful when selecting indicators that are aligned with Boston's adaptation priorities
- The goals, indicators selected (when applicable), and lessons learned from other

CCA programs from around the world, specifically focusing on each program's applicability to Boston

For a full overview of the literature reviewed and its applicability to Boston, see Appendix 1.

Step 2: Identify Sectors in Boston Impacted by/Addressed through Climate Change Adaptation Efforts

1. Governance & Government
2. Business & Institutions
3. Social & Natural Capital
4. Residential Neighborhoods
5. Public Health & Safety
6. Transportation Infrastructure
7. Food, Water, Sewer, & Protective Infrastructure
8. Telecommunications
9. Electricity & Fuel
10. Community Outreach & Public Engagement

Step 3: Develop Comprehensive List of Potential Indicators

Based on the literature review and previous work conducted by the City of Boston, the team compiled a comprehensive list of potential climate change adaptation indicators and organized the indicators by sectors ([Appendix 2](#)). Following Ayers (2012), the team looked for indicators that answered the following questions:

How would we know that change has happened in this outcome?
How will we know success when we see it?
What would be the evidence of this change?

In addition, the team identified indicators that were related to Boston's top priorities regarding climate change adaptation, as well as the draft strategies identified for the 2014 Climate Action Plan by the Boston's Climate Preparedness Strategic Committee.

Step 4: Develop Climate Change Adaptation Indicators Framework for Boston

Based on best practices in CCA indicator selection, the team narrowed down the long list of potential indicators using the following criteria:

- Indicators that are linked to Boston's articulated climate change adaptation priorities (either in the 2014 Draft CAP or previous policy documents) (e.g., reducing vulnerability, coordination between government agencies, emergency response, establishing policy definitions)
- Indicators that are focused on changing conditions and the Plan being adaptive and flexible

- Top level or overarching indicators that capture a number of important climate change adaptation topics that are most relevant to Boston and Northeastern United States communities
- Indicators that aim to complement the mitigation goals outlined in the Boston CAP to decrease the rate and extent of climate change (e.g., decrease greenhouse gases, urban forestry)
- Indicators that aim to avoid maladaptation
- Indicators that form a broad suite that include both process and outcome indicators

In addition, the team selected potential metrics that provide more specific information about the high level indicators and could be used by the City to measure the broad level indicators.

III. Results

The framework consists of six high-level indicators, including:

- 1) Institutional Planning, Capacity and Coordination;
- 2) Climate Science and Information;
- 3) Public/Stakeholder Engagement and Awareness;
- 3) Public Health and Safety;
- 5) Natural Resources and Coastal Infrastructure; and
- 6) Public/Private Buildings and Utilities.

Each high-level indicator contains potential metrics that provide more specifics about the indicator and could be used by the City when measuring the indicator. These metrics were primarily adapted from data and information compiled in Appendix 1, and represent *initial* thinking on how these indicators could be measured. The draft framework appears on the following pages of this document.

INSTITUTIONAL PLANNING, CAPACITY AND COORDINATION

Indicator: The degree to which planning, capacity and coordination to effectively prepare for and respond to climate change and extreme weather events is in place. Climate change is mainstreamed into city plans and programs. Finances and resources are available to adequately address climate change and related events. Government is able to continue operating and providing critical services during climate-related events.

Includes:

- General government capacity and planning for climate change;
- Government continuity, planning and capacity specific to emergency response;
- Operational coordination, inter and intra-city coordination, regional planning, and coordination of resources/infrastructure not under city jurisdiction; and
- Support for mainstreaming climate change into planning, incentivizing resilience (e.g., businesses are prepared to continue operating during climate change related events).

Indicator type: Enhance preparedness/readiness.

Metrics:

General government planning and capacity –

- Governing structure has established policy definitions for 1) required planning horizons (e.g., end of the century), 2) expected future conditions, and 3) “acceptable risk” from coastal flooding, extreme precipitation and heat.
- Plans are adaptive and flexible; preparedness plans and associated regulations and incentives are indexed to monitored environmental conditions (e.g., sea level, storm intensity), with updates linked to actual monitored/observed conditions.
- Availability of skills and experience for personnel in climate change and disaster resilience (e.g., risk identification, mitigation, planning, response and post-event response).
- Climate preparedness is considered a priority in City planning.
- Integrate climate preparedness into zoning, all project and permit review and licensing and into the regulations and guidelines that govern these processes. Review and improve waterfront development zoning.

Emergency-related planning –

- Emergency plans are in place (e.g., emergency plan, food security plan, post-event recovery plan, evacuation plan), including coordination for extreme weather event activities within and outside of city, clarity of roles, responsibilities.
- City has adequate capacity and supplies for emergencies (e.g., personnel, supplies, equipment, emergency shelters, and vehicle fleet).
- Percentage of people reached by early warning systems for hazards and other

climate-influenced emergency events.

- Assurance of continuity of all critical government administration functions (e.g., computer systems, data - utilize backup generators) during climate change related events.
- System/plan in place to ensure critical city workers can reach offices/destinations during emergency situations.
- Programs are established to assist businesses with developing business continuity plans; Percentage of vulnerable businesses with continuity of business plan [prepared and implemented plans.

Coordination -

- Government structure is in place to coordinate inter- and intra-governmental climate preparedness activities across Metro Boston area and outside of Boston.
- Convene a regional summit to accelerate regional preparedness planning.

Finances -

- Financial support for climate change mainstreaming and related initiatives is in place.
- Financial assistance is provided to vulnerable populations.

CLIMATE SCIENCE AND INFORMATION

Indicator: The degree to which information and data are available and used to adequately address climate change and related events.

Includes:

- Integration of climate science and data into decision-making;
- Availability of data to decision makers to address climate change and related events; and
- Identification of data gaps related to climate change preparedness.

Indicator type: Enhance preparedness/readiness; address vulnerability.

Metrics:

- Knowledge of hazards that the city faces and their likelihoods (e.g., hazards for sectors identified in #5 and #6 to floods, storms, and other hazards).
- Knowledge of vulnerability and exposure (e.g., vulnerability of sectors to climate change and related events, scenarios to assess sea level rise/flooding are completed).
- Data gaps related to needed climate change adaptation information are identified.
- Extent to which climate information is used to inform responses to climate change (e.g., data readily accessible, available, and data are used to inform adaptation interventions).
- Partnerships established with research universities to analyze, test and implement new climate-preparedness strategies.

PUBLIC AND STAKEHOLDER ENGAGEMENT AND AWARENESS

Indicator: The degree to which the public and specific stakeholders are aware of and provide input into preparing for climate change and related events.

Includes:

- Stakeholder/public engagement in planning and preparing for climate change and related events;
- Use of stakeholder/public input in policymaking; and
- Stakeholder/public access to information (e.g., meetings, education materials, networks, schools).

Indicator type: Enhance preparedness/readiness.

Metrics:

- Education and awareness materials/messaging available to public (e.g., website, number of meetings/trainings held, school curriculum; access to storm/hurricane preparedness kits).
- Awareness of public, property owners and tenants to their individual vulnerabilities related to climate change (e.g., percent of at risk households holding flood insurance policies, number of people at meetings); participation of stakeholders/public in pre-event and event response activities.
- Communities exhibit social connectedness and neighborhood cohesion.
- Quality of stakeholder engagement in decision-making to address climate change (e.g., public/stakeholder input and uptake by decision-makers).
- Create neighborhood-based programs that increase climate preparedness while supporting job training and job creation.

PUBLIC HEALTH AND SAFETY

Indicator: The degree to which Boston residents are vulnerable to climate-related health risks and have access to needed services and amenities.

Includes:

- Climate-related deaths (heat)/illnesses/disease; and
- Access to critical services (e.g., health centers) [critical service infrastructure is addressed in *Public/Private Building and Utilities* Indicator].

Indicator type: Enhance preparedness/readiness; address vulnerability.

Metrics:

- Actions are taken by City to help people (especially vulnerable populations) better cope with climate change.
 - Access to critical services (e.g., hospitals, fire departments), cooling centers, and shelters reliable during extreme events, especially for vulnerable populations.
 - Financial and technical assistance for improving people's ability to cope with climate change.
- Number of disease outbreaks and climate-related illnesses, and prevention measures included in ongoing health programs.

NATURAL RESOURCES AND COASTAL INFRASTRUCTURE

Indicator: The degree to which natural ecosystems in Greater Boston are able to withstand impacts of climate change and related events. Green/gray infrastructure is expanded to address climate vulnerabilities. Protective infrastructure (e.g., ecosystem components and coastal infrastructure - dikes, levees and sea walls) exist and are adequate to protect against climate-related events and risks.

Includes:

- Resource management measures – Green/gray infrastructure;
- Ecosystem components, parks, trees, shorelines and coastal habitats; and
- Man-made coastal infrastructure (e.g., dikes, levees and seawalls).

Indicator type: Enhance preparedness/readiness; address vulnerability.

Metrics:

- Effective resource management measures are implemented, including:
 - Green/gray infrastructure and other measures are used as valuable tools in climate preparedness to help reduce the effects of urban heat island, sea level rise, and storm frequency.
 - Legislative and regulatory means of enhancing requirements for green/gray infrastructure are strengthened and expanded.
- Ecosystem components are specifically identified and managed as critical assets to disaster resilience.
 - Awareness of role of ecosystem components in the city's disaster resilience.
 - Extent and condition of ecosystem components (e.g., coastal habitats, shorelines, adjacent shore areas, tree canopy, parks, open space).
 - Parks, trees and ecosystem components are used as valuable tools in climate preparedness to help reduce the effects of urban heat island, sea level rise, and storm frequency.
 - Identified conservation measures for climate change resiliency of natural resources and ecosystems are being implemented (e.g., land and water protection – amount and type of land cover preserved as open space, regulation changes, targeted public funding, enhanced monitoring, tree planting, invasive species removal).
- Adequacy of both man-made and natural coastal infrastructure in protecting against climate change and related events (e.g., dikes, ecosystem components providing protection, levees, flood barriers, sea walls).

PUBLIC AND PRIVATE BUILDINGS AND UTILITIES

Indicator: The degree to which public/private buildings and utilities are adequately prepared to withstand climate change and climate-related events.

Includes extent, condition, and reliability of the following sectors:

- Buildings and infrastructure including:
 - a. Commercial
 - b. Residential
 - c. Government
 - d. Critical facilities (e.g., EMS, fire, police, hospitals)
 - e. Education
 - f. Historical sites and districts
- Utilities including:
 - a. Transportation - Roads, tunnels, airports, rail, MBTA, bridges, ports
 - b. Water
 - c. Stormwater and sewer
 - d. Telecommunications
 - e. Electricity and energy

Indicator type: Enhance preparedness/readiness; address vulnerability.

Metrics:

- Vulnerable buildings/infrastructure and utilities have been identified and prioritized (see Indicator for *Climate Science and Information*).
- For each sector, adaptation measures and capacity are in place to systematically reduce current and future risks to acceptable levels for existing buildings and utility infrastructure. For example:
 - Buildings:*
 - Percent of buildings identified as vulnerable (e.g., in 2013 Climate Ready Boston) implementing adaptation strategies (e.g., high-risk flood zone buildings are elevated).
 - Structural safety and disaster resilience of buildings are adequate (e.g., prepared for climate change).
 - Small-scale resiliency interventions and pilots are established in particularly vulnerable areas.
 - Utilities:*
 - Adaptation measures are being implemented to reduce vulnerability of identified "at-risk" utility structures (e.g., elevation of Deer Island). Some specific examples could include [*note, these examples are not comprehensive*]:
 - a. Transportation - Elevation of high-risk flood zone public transportation stops.
 - b. Water_ Water utilities have back-up generators to avoid power loss.

- c. Stormwater and sewer_- Water absorption plans for neighborhoods are created and implemented.
 - d. Telecommunications_- Existence and maintenance of back-up and stand-by communications systems.
 - e. Electricity and energy - Existence and maintenance of back-up and stand-by power systems.
- Percentage of new development/utility infrastructure designed to withstand climate change.
 - Percentage of new buildings and utility infrastructure incorporating climate preparedness measures into building design.
 - Modifications to building codes are identified in accordance with best practices in building resiliency (work with commonwealth, insurance and finance sectors, and property owners); and application of building codes.
 - Percentage of new buildings and utility infrastructure constructed in high-risk flood zones.

IV. Conclusion & Next Steps

The draft indicators framework presented in this report should serve as a good starting point for the City as it begins implementing the 2014 CAP Update, and specifically as CAP Action 2.32 is addressed by the City and the City's climate action partners. Unfortunately, there does not yet exist in the United States any standardized approach for communities to follow in developing a holistic CCA indicator program. Given Boston's considerable leadership to address mitigation and adaptation to climate change, the City is well positioned to help advance the development of such approaches.

There are numerous local, state, Federal, and international efforts currently underway that address the development of indices or indicators of community resilience and preparedness-- some of which are described in Appendix 1. As the City and its Climate Action partners move forward with developing an indicator system for the City of Boston, a number of initiatives occurring through President Obama's Climate Action Plan should also be consulted to inform these efforts moving forward. These programs include the [U.S. Climate Resilience Toolkit](#), the [Climate Data Initiative](#), [Climate Ready Water Utilities](#), and the [Council and Task Force on Climate Preparedness and Resilience](#). In addition, there is a wealth of community level preparedness and resilience indicator tools being developed for disaster and/or climate change that can help further inform these efforts. For example, The United Nations Office for Disaster Risk Reduction's *Disaster Resilience Scorecard for Cities*, described in Appendix 1, is an excellent model that could be very helpful to Boston's CCA Indicator development.

In spring 2015, SeaPlan and ERG, Inc. will be completing a project for NOAA's Coastal Services Center to develop a comprehensive evaluation of community resilience indicators in the U.S. and develop tools that will be useful to communities that are developing resilience indicators and evaluation frameworks. The products of this work should be very helpful to Boston as it begins to implement Action # 2.32 of the CAP.

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Appendix 1: Literature Review

This section summarizes the literature we reviewed and key points to inform this project. The team divided the literature into the following subsections:

- I. Guidebooks, Toolkits, and Reference Materials for Developing a CCA Indicators Framework
- II. CCA Programs, Rating Systems, and Indices
- III. Climate Change Documents Specific to Boston

See more details on the specific documents we reviewed below, as well as a summary of key points.

I. Guidebooks, Toolkits, and Reference Materials for Developing a CCA Indicators Framework

As noted by Bours and McGinn, et al. (2014) “there has recently been a proliferation of CCAR M&E initiatives, guidelines, and frameworks.”¹ Below is a brief summary of guidebooks, toolkits and reference materials for developing a CCA Indicators Framework that we found most useful for Boston, organized by the agency that developed the material(s). Additional details are also provided on each material, including an overview of the material’s purpose and its potential applicability to Boston.

1. *SEA Change and United Kingdom Climate Impacts Programme (UKCIP)*

SEA Change is a free, online Community of Practice on monitoring and evaluation of climate change in Asia and other locations.² Their goal is to develop a culture of high quality and rigorous M&E frameworks, approaches and methodologies. UKCIP, based at the Environmental Change Institute at the University of Oxford, helps organizations, sectors and governments adapt to climate change by providing, advice, support and practice-based research. Their work emphasizes scientific research, policy making and adaptation practices. UKCIP and SEA Change developed a number of guidebooks and reference materials for developing a CCA indicators framework, including:

- [“Monitoring & evaluation for climate change adaptation and resilience: A synthesis of tools, frameworks and approaches”](#) (2014)

This document provides a comprehensive review of existing monitoring and evaluation toolkits, frameworks and approaches. SEA Change developed this document for policy-makers, researchers, and communities such as Boston to compare various approaches and identify which materials would be most useful to them.³ The SeaPlan team reviewed the approaches described in this document and summarized a number of them below.

¹Bours, D., C. McGinn, and P. Pringle, 2014, *Monitoring & Evaluation for Climate Change Adaptation and Resilience: A Synthesis of Tools, Frameworks and Approaches*: 12, SEA Change and UKCIP, available from: <http://www.seachangecop.org/node/2588>

² Ibid, 2.

³ Ibid.

- [Guidance Note 1](#): “Twelve reasons why climate change adaptation M&E is challenging” (2014)
This guidebook outlines the challenges and complexities that are unique to implementing climate change adaptation M&E programs. It also provides strategies for dealing with these challenges and can serve as a guide for Boston as it develops its own CCA indicator framework.
- [Guidance Note 2](#): “Selecting Indicators for climate change adaptation programming” (2014)
This guidebook provides various approaches for selecting CCA indicators and outlines important indicator criteria. It also discusses the advantages and disadvantages of using process versus outcome based indicators.
- [Guidance Note 3](#): “Theory of Change approach to climate change adaptation programming” (2014)

This guidebook outlines Theory of Change, a critical thinking approach to program design, monitoring, and evaluation that has been influential in international development.⁴ It can be applied to a wide variety of development issues including conflict resolution, gender inequality and climate change. Theory of Change provides a process that engages stakeholders in identifying and achieving long-term climate adaptation goals, making it a possible approach for Boston.

2. Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ)

GIZ assists the German Government in achieving its objectives in the field of international cooperation for sustainable development.⁵ GIZ develops solutions for a variety of development issues including climate change mitigation and adaptation, and has developed the following guides for the German government and other audiences:

- [Making adaptation count \(step-by-step guide\)](#) (2011)
This guide provides a framework for developing M&E systems that tracks the progress of adaptation initiatives. It includes a step by step process for selecting adaptation indicators. It also discusses lessons learned from other adaptation efforts that could prove useful as Boston develops its own indicator program.⁶
- [Adaptation made to measure](#) (2012)
This guide explains a five-step approach to designing an adaptation project, results framework, and monitoring system. It includes examples where this approach has been applied in India, which may be applicable to Boston.⁷

⁴ Bours, D., C. McGinn, and P. Pringle, 2014, Guidance note 3: Theory of Change approach to climate change adaptation programming, SEA Change and UKCIP, February, available from: <http://www.seachangeop.org/node/2933>.

⁵ Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, 2014, Profile: Broad-based expertise for sustainable development, available from: <https://www.giz.de/en/aboutgiz/profile.html>.

⁶ Spearman, M. and H. McGray, 2011, Making Adaptation Count: Concepts and Options for Monitoring and Evaluation of Climate Change Adaptation, GIZ, August.

⁷ Olivier, J., T. Leiter and J. Linke, 2012, *Adaptation Made to Measure: A Guidebook to the Design and Results-based Monitoring of Climate Change Adaptation Projects*, GIZ, July.

3. European Topic Centre on Air and Climate Change (ETC/ACM)

The ETC/ACM is a consortium of 14 European organizations led by Netherlands Institute for Public Health and the Environment (RIVM). These organizations provide support to the European Environment Agency (EEA) through reporting on European environmental policy progress. Areas of focus include air quality and climate change⁸, and they developed the following documents related to climate change adaptation:

- [Climate Change Vulnerability and Adaptation Indicators](#) (2008)
This technical paper discusses fundamental concepts surrounding the development of adaptation indicators. The framework focuses on developing process-based and outcome-based indicators, which could be applicable to Boston.⁹
- [Development of Adaptation Indicators](#) (2009)
This technical report provides a framework for developing adaptation indicators, and focuses specifically on applying the framework to the vulnerability of biodiversity to climate change.¹⁰

4. Learning to ADAPT

The [Learning to ADAPT report](#) (2012) provides a potential approach for establishing an M&E program for climate adaptation. It includes principles of successful adaptation indicator and discusses existing approaches and challenges. The report also poses questions to consider when setting up M&E adaptation programs that could be applicable to Boston, including¹¹:

- To what extent are climate change adaptation, disaster risk management and development integrated across sectors and scales?
- What processes are in place to support governments, communities and other stakeholders to effectively manage the uncertainties related to climate change?
- How are findings from scenario planning exercises and climate-sensitive vulnerability assessments being integrated into existing strategies?

5. Global Environment Facility Climate-Evaluation Community of Practice

Climate-Evaluation (Climate-Eval) is an online community of practice hosted by the Global Environment Facility Independent Evaluation Office (GEF IEO) in Washington, D.C. The community of practice's goal is to establish evaluation standards, support capacity development, and share good practices in evaluations of climate change and development¹². It has published the following guides:

- [Tracking progress for effective action: A framework for monitoring and evaluation adaptation to climate change](#) (2011)

⁸ European Topic Centre for Air Pollution and Climate Change Mitigation (ETC/ACC), 2014, European Environment Agency.

⁹ Harley, M., L. Horrocks, and N. Hodgson et al., 2008, *Climate Change Vulnerability and Adaptation Indicators*, ETC/ACC Technical Paper 2008/9, ETC/ACC, December, 10-11.

¹⁰ Harley, M.L. and J. van Minnen, 2009, *Development of Adaptation Indicators*, ETC/ACC Technical Paper, December.

¹¹ Villanueva, P.S., 2010, Learning to ADAPT: Monitoring and Evaluation Approaches in Climate Change Adaptation and Disaster Risk Reduction - Challenges, Gaps and Ways Forward, SCR Discussion Paper 9, UK Institute of Development Studies, Plan International and Christian Aid, September, 2.

¹² Climate-Eval, 2014, About Climate-Eval, available from: <https://www.climate-eval.org/about>

This report outlines a framework for creating a monitoring and evaluation program for climate change adaptation. It provides a six step guide to establishing an adaptation program, discusses key adaptation challenges and provides a list of sample indicators that could be applicable to Boston¹³. See Appendix 7.

- [Climate change adaptation monitoring and assessment tool](#) (AMAT) (2014)
The Adaptation Monitoring and Assessment Tool (AMAT) was released with the goal of increasing developing countries' resilience to climate change by integrating adaptation practices into development policies and programs. This tool contains a [spreadsheet](#) with a list of indicators to measure a country's progress towards reducing climate change vulnerability. While the tool is geared towards developing countries, aspects may be useful for Boston¹⁴.

6. *Cooperative for Assistance and Relief Everywhere (CARE) and International Institute for Environment and Development (IIED)*

CARE is a humanitarian organization that focuses on a variety of international issues including climate change. International Institute for Environment and Development (IIED) is an international development and environmental policy research organization based in the UK that have contributed to multiple international policy processes and frameworks, including the Intergovernmental Panel on Climate Change (IPCC). IIED also created the Tracking Adaptation Measuring Development framework summarized in the body of this report. Care and IIED developed the following manual:

- [Participatory monitoring, evaluation, reflection and learning \(PMERL\) project for community-based adaptation](#) (2012)
This manual was created to support adaptive decision-making in vulnerable communities. It is intended to be an open-source methodology for vulnerable communities to inform climate adaptation planning and implementation. It describes key concepts for community-based adaptation, outlines a strategy for implementing PMERL strategies, and provides tools and methods for PMERL development.¹⁵

7. *Adaptation Fund*

The Adaptation Fund was established to finance concrete adaptation projects and programs in vulnerable developing countries that are parties to the Kyoto Protocol.¹⁶ The fund has dedicated more than \$265 million to increase climate resilience in 44 countries around the world¹⁷, and developed the following report:

- [Results framework and baseline guidance: Project-level](#) (2011)
This report provides guidance for developing a results framework for adaptation projects. It describes the phases of project design and performance assessment,

¹³ Sanahuja, H.E., 2011, *A Framework for Monitoring and Evaluating Adaptation to Climate Change*, Climate-Eval, August.

¹⁴ Global Environment Facility, 2014, LDCF/SSCF Adaptation Monitoring and Assessment Tool (AMAT).

¹⁵ Ayers, J., S. Anderson, S. Pradhan, and T. Rossing, 2012, *Participatory Monitoring, Evaluation, Reflection and Learning for Community-based Adaptation*, CARE and IIED, June.

¹⁶ The Kyoto Protocol is an international agreement which sets internationally binding greenhouse gas emission reduction targets for participating countries

¹⁷ The Adaptation Fund, 2014, About the Adaptation Fund, available from: <https://www.adaptation-fund.org/about>.

and provides advice on selecting indicators, setting targets, and collecting data. Although it is designed specifically for the countries associated with the Adaptation Fund, its overall framework may be applicable to Boston¹⁸.

8. *Climate Investment Funds (CIF)*

CIF provides climate change mitigation resources to developing and middle income countries. Their funding supports projects related to clean technology and energy, forests, and climate change resilience¹⁹, and they developed the following toolkit:

- [PPCR \(Pilot Program for Climate Resilience\) Monitoring and Reporting Toolkit](#) (2014)

This toolkit provides an overview of the 5 PPCR indicators. The five indicators, which may be applicable to Boston, include²⁰:

- 1) Degree of integration of climate change into planning
- 2) Evidence of strengthened government capacity and coordination mechanism to mainstream climate resilience
- 3) Quality and extent to which climate responsive instruments/investment models are developed and tested
- 4) Extent to which vulnerable households, communities, businesses and public sector services use improved PPCR supported tools, instruments, strategies and activities to respond to climate variability or climate change
- 5) Number of people supported by the PPCR to cope with the effects of climate change

II. CCA Programs, Rating Systems and Indices

We also conducted a literature review of CCA programs, rating systems and indices from around the world. In total, we researched 12 different programs (Appendix 2), including programs with adaptation plans for individual cities such as New York City and San Francisco, as well as national adaptation plans for Australia, Germany and other countries. We also looked into international programs that evaluate and rank countries, such as the ND-Gain index, DARA's Climate Vulnerability Index and others. Reviewing the methodology of these programs can provide insight into developing a set of indicators for Boston. While many of programs cannot be directly applied to Boston, they offer guidelines for selecting indicators.

In general, the programs that seemed to be the most successful began by establishing concrete goals and selected easily measurable indicators that were relevant to these goals. Some programs are well established, while others are still in the process of establishing adaptation goals and developing indicators.

Below is a summary of five different indicator programs which were selected from the literature review based on their strong methodology and the applicability of their indicators to Boston. For a complete list of programs, rating systems and indices reviewed, see Appendix 1.

¹⁸ The Adaptation Fund, 2011, *Results Framework and Baseline Guidance, Project-level*.

¹⁹ Climate Investment Funds, 2015, About the Climate Investment Funds, available from: www.climateinvestmentfunds.org/cif/aboutus.

²⁰ Climate Investment Funds, 2013-4, *PPCR Results Framework and Monitoring and Reporting Toolkit*, 2..

1. STAR Community Rating System

Overview

The overall goal of this project is to create a sustainability framework that could be implemented in communities across the country. The STAR framework can be used voluntarily by any community to track their progress towards sustainability goals, such as reducing greenhouse gas emissions or improving water and energy efficiency. The STAR Community Rating System is flexible in that it gives local leaders the choice of selecting different targets based on their own community's needs.

To create the framework, researchers selected community objectives under the categories: Built Environment, Climate and Energy, Economy and jobs, Education, Arts and Community, Equity and Empowerment, Health and Safety, and Natural Systems. They identified between 5 and 7 objectives for each category and selected two types of indicators for each objective. These indicators include:

- Community level outcomes- measurable indicators that demonstrate a community's sustainability progress
- Local actions- the steps taken toward the community level outcomes such as concrete plans or funds.²¹

Communities receive a rating based on how many outcomes and actions they achieve.

Applicability to Boston

The STAR framework is currently the only indicator program geared towards cities such as Boston. Under STAR's Climate and Energy objectives, there are specific local actions related to climate change adaptation that may be applicable to Boston²²:

1. Adopt a climate change adaptation plan
2. Require that internal decisions by local government departments use the most current climate science and that staff monitor climate change impacts
3. Develop a committee that includes climate scientists, adjacent jurisdictions, regional coalitions, state and federal agencies, and/or non-governmental organizations for the purpose of understanding and addressing shared vulnerabilities
4. Create an education and outreach campaign to engage citizens and businesses in climate change vulnerability reduction efforts
5. Adopt zoning code, building code, or other legally binding regulations that address future climate change threats
6. Create or enhance programs and services that specifically help address climate change threats
7. Enforce regulations or offer incentives to encourage residents and businesses to shift behaviors to prepare for future climate change impacts

Table 1 below displays SeaPlan's analysis of Boston's progress towards each of these objectives

Table 1. Progress of the City of Boston towards STAR Climate and Energy Objectives

STAR Actions	Boston's Progress
	<ul style="list-style-type: none">• One goal of the 2014 CAP update is to create

²¹ STAR Framework, 2014, 9.

²² Ibid., 35-6.

1. Adopt a climate change adaptation plan	a comprehensive climate change preparedness plan.
2. Require that internal decisions by local government departments use the most current climate science and that staff monitor climate change impacts	<ul style="list-style-type: none"> Under MA State law, state agencies are required to take climate change threats into account for all projects.
3. Develop a committee that includes climate scientists, adjacent jurisdictions, regional coalitions, state and federal agencies, and/or non-governmental organizations for the purpose of understanding and addressing shared vulnerabilities	<ul style="list-style-type: none"> In 2013, The Boston Green Ribbon Commission was created and tasked with providing advice on climate action plan updates. The commission includes a Climate Preparedness working group that is considering climate vulnerabilities.
4. Create an education and outreach campaign to engage citizens and businesses in climate change vulnerability reduction efforts	<ul style="list-style-type: none"> Boston has launched a communications campaign to engage citizens in the 2014 CAP update process Though more mitigation focused, communications program Greenovate Boston also exists to engage citizens and change public behavior
5. Adopt zoning code, building code, or other legally binding regulations that address future climate change threats	<ul style="list-style-type: none"> Under article 80 of the Boston Zoning Code, the Boston Redevelopment Authority (BRA) requires project developers to analyze potential effects of climate change such as flooding In addition, The Boston Conservation Commission has proposed a Local Wetlands Ordinance for Boston
6. Create or enhance programs and services that specifically help address climate change threats	<ul style="list-style-type: none"> Boston created the Complete Streets program, which established guidelines for new streets. Complete Streets has a wide variety of sustainability goals including reducing flooding.
7. Enforce regulations or offer incentives to encourage residents and businesses to shift behaviors to prepare for future climate change impacts	N/A – Unable to find via literature review; consult with City
8. Improve facilities throughout the community to be better prepared for climate change threats	<ul style="list-style-type: none"> The Boston Society of Architects published Building Resilience in Boston, a report that includes best practices and recommendations for improving Boston's buildings.

2. New York City (NYC) and San Francisco

Overview

NYC - NYC has developed PlaNYC, which is an effort to address NYC's long-term challenges, including changes in populations, economic conditions, infrastructure, and climate. The Plan sets forth a broad range of goals across the following areas: Housing, Parks and Public Space, Brownfields, Waterways, Water Supply, Transportation, Energy, Air Quality and Climate Change.

San Francisco - San Francisco created a working group, AdaptSF, to address the city's main climate change threats, which include sea level rise, flooding, and extreme heat events. The group has not selected climate adaptation indicators, but it has completed several different adaptation initiatives including a study on sea level rise

impacts on the Port of San Francisco and an assessment of public health impacts from extreme heat. Currently, the group is working on the following initiatives²³:

- integrating sea level rise and energy assurance planning into San Francisco's Capital Planning and Hazard and Mitigation plans
- communicating public health impacts to San Franciscans
- communicating flood risk and opportunities for home owners to invest in flood insurance
- evaluating San Francisco's sea wall and impacts of sea level rise on the Embarcadero and Financial District
- evaluating potential sea level rise climate change impacts on San Francisco International Airport
- developing a plan for transit impacts

Applicability to Boston

While San Francisco has not developed a set of climate change adaptation indicators, they have developed a key set of climate change priorities that could be applicable to Boston, including sea level rise and flooding, extreme heat events, and natural environment preservation.²⁴

PlaNYC may be more directly applicable to Boston, as they have developed recommended metrics related to coastal resilience and adaptation. See metrics in Table 2. below:

Table 2. plaNYC resiliency and adaptation metrics.²⁵

Category	Metric
Coastal Protection	Federal dollars secured for coastal protection projects
	Number of buildings with reduced coastal risk due to coastal protection projects
	Number of cubic yards of beach sand nourishment
Buildings	Number of buildings implementing Core Flood Resiliency Measures
	Number of square feet of residential and non-residential buildings implementing Core Flood resiliency measures
Insurance	Percent of residences in 100-year floodplain purchasing flood insurance
	Average premium paid for National Flood Insurance Program (NFIP) policies
Utilities	Percent of residences in 100-year floodplain purchasing flood insurance
	Average premium paid for National Flood Insurance Program (NFIP) policies
Liquid Fuels	Percent of gas stations with quick-connects for generators
	Percent of regional fuel terminal capacity in the 100—year floodplain hardened against a 100-year flood
	Percent of regional refining capacity in the 100-year floodplain hardened against a 100-year flood

²³ San Francisco Department of the Environment, 2013, San Francisco Climate Action Strategy.

²⁴ SF Environment, 2014, Adaptation, <http://sfenvironment.org/article/climate-change/adaptation>.

²⁵ The City of New York, 2014, *plaNYC Progress Report 2014*, 89, available from: <http://www.nyc.gov/html/planyc/html/publications/publications.shtml>.

Healthcare	Percent of hospital beds in 500-year floodplain meeting resiliency standards
	Percent of beds in nursing homes and adult care facilities in 100-year floodplain meeting resiliency requirements
Telecommunications	Number of critical telecommunications facilities implementing Core Flood Resiliency Measures
Transportation	Number of lane-miles reconstructed or resurfaced
	Percent of New York City transportation assets adapted for climate change resiliency
Parks	Percent of DPR facilities in Sandy inundation zone upgraded for greater resiliency
	Number of trees inspected and pruned
Waste and Wastewater	Number of wastewater facilities or assets protected or raised above the 100-year floodplain
	Number of right-of-way bioswales constructed
	Number of sewer miles built in areas with no or partial sewers
	Number of Bluebelt Best Management Practices (BMPs)
	Percent of water quality samples complying with Surface Water Treatment Rule standard for turbidity
Solid waste	Number of DSNY facilities protected or raised above the 100-year floodplain
Food supply	Number of grocery stores with generators or quick connects for generators
	Percent of DCAS food procurement backstopped with more resilient distributors

PlaNYC also identified ten sustainability indicators to track conditions and monitor goals (related to topics such as solid waste, air quality and climate change).²⁶ While PlaNYC notes the importance of climate change adaptation and “increasing the resiliency of our communities, natural systems, and infrastructure to climate risks”, the one sustainability indicator related to climate change is more focused on mitigation than adaptation (a metric to measure “greenhouse gas emissions”). For a complete list of sustainability indicators, see Appendix 6.

3. Australia’s Proposed National Adaptation Framework

Overview

In 2013, the Australian Government published a climate adaptation outlook report that summarized Australia’s preparedness for climate change and proposed a national adaptation framework which has yet to be adopted.²⁷ This proposed adaptation framework focuses on three areas²⁸:

²⁶ The City of New York, 2014, 32-33.

²⁷ Commonwealth of Australia, 2013, *The Climate Adaptation Outlook: A Proposed National Adaptation Assessment Framework*. Department of Industry, Innovation, Climate Change, Science, Research, and Tertiary Education, June, available from: <http://www.environment.gov.au/climate-change/adaptation>.

²⁸ Ibid., 2.

- 1) Drivers- factors such as resource allocation, climate risks, and market pressures that influence behavior.
- 2) Activities- actions taken by the government, industry and communities as a result of drivers.
- 3) Outcomes for climate risk management, ideally supporting sustainable management of climate change risks in Australia.

Applicability to Boston

While indicators for Australia have not been put in place, a list has been proposed (See Appendix 7). This list includes indicators specifically for managing climate risks in the coastal zone²⁹ that may be applicable to Boston, including:

- Capacity of planning frameworks to support effective management of climate risks in the coastal zone
- Number of local governments considering climate change risks in land use planning

4. Tracking Adaptation Measuring Development (TAMD)

Overview

In addition to adaptation programs specific to individual cities and countries, indices have also been established for comparing different countries' climate change vulnerability and preparedness. These programs vary in their goals, but they have well-established methodologies, aspects of which may be applicable to Boston. The Tracking Adaptation and Measuring Development (TAMD) program developed by the International Institute for Environment and Development (IIED), stood out because of its unique approach. While other programs focus solely on climate adaption, the TAMD framework also considers the impacts on climate change adaptation on development. The indicators they selected:

- Have broad applicability to different countries
- Measure climate change vulnerability to demonstrate the impact of adaptation measures
- Account for social, economic, political, cultural and environmental factors

For each indicator, the IIED created a rubric for evaluating specific countries. There are a specific set of questions associated with each indicator. A country's overall score can then be calculated based on the 9 indicators.

Applicability to Boston

The TAMD framework was largely created for developing countries and is still in its pilot phase. However, they selected 9 broad indicators that could be applicable to Boston:

1. [Climate Change integration into planning: Assesses the extent to which climate change risks are considered in national and institutional planning.](#)
2. [Institutional Coordination for Integration:](#) Evaluates climate risk management coordination across government agencies and other institutions.
3. [Budgeting and Finance:](#) Captures the extent to which climate change measures are budgeted for and have financial support

²⁹ Ibid., 2013.

4. [Institutional Knowledge and Capacity](#): Assesses institutional knowledge of climate change and how it informs adaptation planning
5. [Climate Information](#): Evaluates how new climate information informs adaptation planning
6. [Uncertainty](#): Assesses the degree to which adaptation planning addresses future climate change uncertainty
7. [Participation](#): Evaluates inclusion of all relevant stakeholders vertically (across different levels of government) and horizontally (across different sectors).
8. [Awareness among stakeholders](#): Measures stakeholder awareness of climate change issues, risks and responses
9. [Vulnerability/Resilience](#): Evaluates the ability of a population to respond and recover from climate change

These indicator categories, as well as the type of information collected on each indicator and framework format (as shown in the hyperlinks above), may be useful as we develop indicators for Boston.

In addition, IIED has encountered several challenges in applying its framework to other countries, which include lack of climate change data and government involvement in its pilot countries.³⁰ These challenges were specific to developing countries, but should still be considered if applying aspects of the TAMD framework to Boston.

5. ND-GAIN Index

Overview

Similar to TAMD, the ND-Gain Index, run by Notre Dame University's Climate Change Initiative, is a free open source index that evaluates countries' climate change readiness and vulnerabilities. The index uses indicators to rank 177 countries. In 2012, the United States is ranked #13. Results are released annually to inform leaders on potential vulnerabilities to climate change.

The indicators selected by the ND-Gain Program include:

- Vulnerability indicators focused on the following sectors: water, food, health, ecosystem services, human habitat and infrastructure.
- Economic indicators selected to measure economic freedom as this is generally related to sustainable practices
- Government indicators that emphasized fair policies
- Social indicators that measured citizen participation and international collaboration

Each country receives a value for each indicator and these values are used to calculate an overall ND-GAIN Score.³¹

³⁰ International Institute for Environment and Development (IIED), 2013, *Tracking Adaptation and Measuring Development (TAMD) in Ghana, Kenya, Mozambique, Nepal, Pakistan: Meta-analysis Findings from Appraisal and Design Phase*, available from: <http://pubs.iied.org/pdfs/G03631.pdf>.

³¹ University of Notre Dame Global Adaptation Index (ND-GAIN), 2013, *Detailed Methodology Report*, available from: <http://www3.nd.edu/~nchawla/methodology.pdf>.

Applicability to Boston

As the ND-GAIN index is designed to evaluate whole countries, not all of the indicators used in their model are applicable to Boston. Appendix 8 contains a list of all the climate vulnerability indicators used in the ND-GAIN index, and below are specific vulnerability indicators which may be applicable to Boston:

- Coastal infrastructure indicators that consider what percent of the population lives at or below 5 meters above sea level³²
- Energy infrastructure indicators that measure energy structures that are at risk of climate-related events, and the population with access to reliable electricity³³
- Transport infrastructure indicators that include frequency of flood per unit area and the percentage of surfaces paved³⁴

6. The United Nations Office for Disaster Risk Reduction (UNISDR), “Disaster Resilience Scorecard for Cities”

Overview

The Disaster Resilience Scorecard provides a series of assessments that helps cities understand their resilience to natural disasters.³⁵ The scorecard is meant to allow cities to understand their current level of disaster resilience, to prioritize investments and funds, and track progress in disaster resilience improvements.³⁶ The scorecard contains 85 disaster resilience criteria, focused on 1) research, 2) organization, 3) infrastructure, 4) response capability, 5) environment, and 6) recovery.³⁷

Applicability to Boston

As the Disaster Resilience Scorecard is meant to be general and relevant to most cities, the disaster resilience criteria are likely applicable to Boston. In addition, the organization of criteria into “ten essentials of disaster” management is also likely useful.

III. Climate Change Documents Specific to Boston

We also conducted a literature review of Boston’s articulated climate change concerns and policy priorities related to climate change adaptation. This information will help the team select indicators that measure adaptation progress against Boston’s top climate change concerns and policy priorities. The literature review consisted of:

- Boston’s Climate Action Plan (2011),
- Climate Ready Boston (2013),
- DRAFT 2014 Climate Action Plan, and
- Other climate change-related materials for Boston.

Note that this document is based solely on a literature review and initial conversations with the City of Boston and TBHA, and may not be comprehensive or completely

³² ND-GAIN, 2013, 31-2.

³³ Ibid., 32-3.

³⁴ Ibid., 33-4.

³⁵ United Nations Office for Disaster Risk Reduction (UNISDR), 2014, *Disaster Resilience Scorecard for Cities, Working Document*, prepared by AECOM and IBM, available from: <http://www.unisdr.org/2014/campaign-cities/Resilience%20Scorecard%20V1.5.pdf>.

³⁶ Ibid.

³⁷ Ibid., 2.

accurate. Furthermore, this list of climate change concerns and policy priorities will likely be modified based on additional conversations with the City and TBHA, working sessions with a technical advisory committee developed for this project, and meetings with a strategic committee developed by the City to assist with updating the Climate Action Plan this year.

A. Top Climate Change Concerns for Boston

Based on conversations with the City of Boston and review of the 2011 Climate Action Plan, below is a list of proposed top climate change concerns for Boston:

- Sea level rise/flooding
- Increased frequency and intensity of storms
- Increased frequency and intensity of heat waves³⁸

B. Top Climate Change Adaptation Policy Priorities for Boston

Boston is undertaking a variety of initiatives to help prepare for and adapt to the climate change concerns listed above. Based on a literature review, below is a proposed list of the City's top policy priorities to help Boston prepare for and adapt to climate change:

1. Vulnerability of buildings, water and sewer infrastructure, public transportation, and seawalls to climate change impacts (flooding, storms, and heat)
 - a. General municipal buildings (facilities identified as vulnerable to sea level rise, flooding, and storm surge including City Hall and others)³⁹
 - b. New buildings and building renovations (considering climate change during planning, zoning and project review; certain facilities must adhere to preparedness and resilience guidelines)⁴⁰
 - c. Schools, community centers, and neighborhood emergency shelters (facilities that act as emergency shelters, but also have high-priority vulnerabilities)⁴¹
 - d. Police, fire and EMS stations (facilities identified as vulnerable to sea level rise, flooding, and storm surge)
 - e. Public housing and other property (facilities identified as high-priority vulnerable properties)⁴²
2. Vulnerability of Boston's transportation and water infrastructure system

³⁸ Climate Action Leadership Committee, 2011, *Climate Action in Boston: Recommendations of the Boston Climate Action Leadership Committee and the Community Advisory Committee on Climate Action*, City of Boston.

³⁹ Spector, C. and L. Bamberger, 2013, *Climate Ready Boston: Municipal Vulnerability to Climate Change*. *Climate Preparedness Task Force*, City of Boston, October, available from: <http://www.cityofboston.gov/climate/adaptation/>.

⁴⁰ Climate Action Leadership Committee, 2011, Mayor Martin J. Walsh, 2014, *Greenovate Boston: 2014 Climate Action Plan Update*, City of Boston, available from: <http://www.cityofboston.gov/climate/bostonsplan/>.

⁴¹ Spector and Bamberger, 2013.

⁴² Ibid.

- a. Transportation (extreme heat and storms can affect roads, sidewalks, railroad tracks, public transportation; sea level rise and storms can result in flooding of transport routes)
 - b. Water and Sewer Infrastructure (effect of sea level rise and increased precipitation on city's storm water and sewer system)⁴³
- 3. Vulnerability of Boston's neighborhoods and environment, which include their buildings and homes, historic character, and natural features
 - a. Historic preservation (historic districts built on fill and susceptible to flooding; historic sites susceptible to flooding, sea level rise and erosion)⁴⁴
 - b. Parks and the urban forest (changes in precipitation and temperature can stress trees and vegetation)⁴⁵
 - c. Open space and wetlands (protecting wetlands to guard against sea level rise)⁴⁶
- 4. Public health, safety and heat
 - a. Excessive heat events affecting vulnerable populations, tourists, etc.⁴⁷
 - b. Excessive heat events affecting the electric grid (air conditioning using up electricity)⁴⁸
 - c. Potential emergencies that could worsen due to climate change, such as cleaning up contaminated floodwater and other debris after floods, directing traffic around flood zones⁴⁹
 - d. Developing municipal emergency plans that include climate change preparedness, and those plans must be reviewed and practiced
 - e. Preparing a sufficient vehicle fleet in Boston to cope with emergencies
 - f. Public safety during emergencies, such as rescuing people trapped in homes, providing access to emergency shelters
 - g. Helping Boston businesses and residents prepare for emergencies
 - h. Continuing care for vulnerable individuals during a major disaster (those with chronic health conditions, etc.)⁵⁰
- 5. Coordination between State and Federal agencies to address climate change concerns [coordination is essential for increasing the climate preparedness of Boston]
 - a. Major infrastructure not under city jurisdiction (several systems and infrastructure, including MBTA, Logan Airport, Deer Island Waste Water Treatment Plant, Charles River Dam, etc.

⁴³ Ibid.

⁴⁴ Ibid.

⁴⁵ Climate Action Leadership Committee, 2011; Spector and Bamberger, 2013.

⁴⁶ Climate Action Leadership Committee, 2011.

⁴⁷ Spector and Bamberger, 2013.

⁴⁸ Mayor Martin J. Walsh, 2014.

⁴⁹ Spector and Bamberger, 2013.

⁵⁰ Spector and Bamberger, 2013.

- b. Need for operational coordination emergency response will require more coordination and regional planning with the Commonwealth, neighboring cities, private and institutional entities⁵¹
- 6. Community outreach and public engagement
 - a. Developing educational materials, outreach strategies, and community/organizational networks on climate change preparedness to engage public and spread awareness⁵²
- 7. Resources/funding to support and research climate change preparedness
 - a. Office of Administration and Finance recognizes that all departments need to address climate change impacts in their capital and operating budget proposals⁵³
 - b. Securing funding to support climate change preparedness capital projects⁵⁴
 - c. Collect and analyze new data, and integrate new data into CAP⁵⁵

⁵¹ Ibid.

⁵² Climate Action Leadership Committee, 2011.

⁵³ Spector and Bamberger, 2013.

⁵⁴ Climate Action Leadership Committee.

⁵⁵ Ibid.

Appendix 2: List of Potential Indicators to Measure Climate Change Preparedness in Boston, MA.

Recommended Sectors	Key Issues Related to Climate Change	Potential Indicators & Metrics
1. Governance & Government		
Information and understanding	Information and data are available to adequately address climate change and related events <ul style="list-style-type: none"> Studies conducted (vulnerability, scenarios to assess sea level rise (SLR), temperature) Data availability & gaps 	Studies: <ul style="list-style-type: none"> Knowledge of hazards that the city faces and their likelihood (priority vulnerabilities are identified)¹ Knowledge of exposure and vulnerability² Understanding of critical assets (e.g., infrastructure) and the relationships between them are identified in the form of potential “failure chains”³ Process ensuring frequent and complete updates of climate change-related scenarios (e.g., buildings, schools, ecosystem services)⁴ Percent geographic area of City surveyed to identify vulnerable areas Percentage of applicable City sectors that have been assessed for vulnerability following standardized procedures Number of climate change adaptation studies conducted Provide climate-preparedness examples and pilot innovative solutions using City-owned facilities and land Vulnerability of sites with toxic/hazardous materials and other sites that may create greater vulnerability to the community are identified (and ways to increase preparedness) Partnership with research universities developed to determine, analyze, test and implement new climate-preparedness strategies Studies conducted to determine new climate resilient technologies (e.g., new pavement materials, green infrastructure) Data availability & gaps: <ul style="list-style-type: none"> Central Preparedness Information System is established containing information on current knowledge and data gaps The Climate Action Plan (CAP) identifies key preparedness planning data and information necessary to meet goals/objectives
Government planning activity	Government is prepared to adequately address climate change and related events <ul style="list-style-type: none"> City planning <ul style="list-style-type: none"> Climate change integrated into all city planning Operates under uncertainty and is flexible 	City planning: <ul style="list-style-type: none"> The degree to which planning, capacity and coordination to effectively prepare for and respond to climate change and extreme weather events is in place Governing structure has established policy definitions for 1) required planning horizons, 2) expected future conditions, and 3) “acceptable risk” from coastal flooding, extreme precipitation and heat Number/percentage of City plans with effective climate change preparedness integrated (e.g., emergency response)

	<ul style="list-style-type: none"> ○ Plans are adaptive and reflect new data/emerging issues • Data use in decisions • Monitoring progress 	<ul style="list-style-type: none"> • Climate preparedness is a key component of all City planning; integrated into zoning, all project and permit review and licensing/regulations and guidelines that govern these processes • Climate change is mainstreamed into city plans and programs⁵ • Establish guidelines on climate-preparedness planning horizons • City plans consider the uncertainty associated with climate change (e.g., plans are adaptive and flexible)⁶ • Coordination of all relevant pre-event planning and preparation activities exists for the city's area, with clarity of roles and accountability across all relevant organizations⁷ • Extent to which any proposals in government is also evaluated for climate change resilience benefits or impairments⁸) • City adaptation and preparedness plans are linked to climate data (e.g., SLR, heat, and storm frequency/intensity projections) & vulnerability assessment surveys • Climate preparedness analysis is part of every capital decision (Office of Administration and Finance can modify its process to institutionalize this) • Plans are adaptive and flexible; preparedness plans and associated regulations and incentives are indexed to monitored environmental conditions (e.g., sea level, storm intensity), with updates linked to actual monitored/observed conditions <p>Data use in decisions:</p> <ul style="list-style-type: none"> • Extent to which climate information is i) used to inform responses to climate change and ii) generated at all levels of society⁹The degree to which information and data are available and used to adequately address climate change and related events • Extent to which climate information is used to inform responses to climate change (data readily accessible, data are used to inform adaptation interventions) <p>Monitoring progress:</p> <ul style="list-style-type: none"> • Indicators are established to monitor progress and report annually
Coordination	<p>Boston is coordinating its climate change plans and responses with other partners to its best ability</p> <p>Coordination with state, regional and federal partners (e.g., Logan, Massachusetts Bay Transportation Authority (MBTA), emergency response)</p>	<p>Coordination with state, regional and federal partners</p> <ul style="list-style-type: none"> • Interoperability with neighboring cities/states and other levels of government of critical systems and procedures¹⁰ • Extent and quality of coordination of climate risk management across relevant institutions¹¹ • Government structure is in place to coordinate inter- and intra-governmental climate preparedness activities across Metro Boston area and outside of Boston • Coordination of all relevant event response activities, with clarity of roles and accountability across all relevant organizations; participation and coordination of all relevant organizations in the structure(s) defined¹² • Based on # of state and federal preparedness activities, percentage of relevant City departments that have been active in either informing their operations with state/federal/regional efforts • Plans for non-municipal infrastructure includes relevant sections for City activities and City Plans (and vice versa) • The City's emergency response is coordinated with neighboring cities and private institutions • Mechanism/plan for coordination developed and implemented for regional preparedness planning, development of regulatory requirements, infrastructure investment and other programs/policies (e.g., preparedness of vital infrastructure that City has no jurisdiction)

Government continuity (IT, critical infrastructure, buildings)	Government is able to continue operating and providing critical services during climate related events <ul style="list-style-type: none"> Vulnerability of government buildings and critical services & adaptation measures (e.g., City Hall, first floor, core digital and communications infrastructure on first floor) Government personnel 	Vulnerability of government buildings and critical services & adaptation measures <ul style="list-style-type: none"> High-priority facility specific vulnerabilities reduced (e.g., those identified in 2013 assessment – City Hall; report on progress annually) Percent of government buildings and critical services considered vulnerable to climate-related events New City buildings and repair of existing buildings include climate preparedness measures (e.g., elevating sensitive equipment, flood proofing) Percentage of City’s critical services (IT, communications, and transportation centers) able to function in emergency situations Identified measures for climate-change resiliency of government buildings and critical services are being implemented Protection of critical law and order/responder assets (e.g., emergency vehicles, critical IT system, key buildings)¹³ Disaster resilience of prison system¹⁴ Assurance of continuity of all critical administration functions¹⁵ Assurance of continuity of computer systems and data critical to government continuity and other critical infrastructure¹⁶ Number or percentage municipal buildings with backup generators or alternative energy source The competent committees (e.g., district office, local authorities, private and civic sector) in flood-prone watersheds have a realistic, effective plan of action at their disposal as part of the flood prevention strategy Government personnel <ul style="list-style-type: none"> System/plan in place to ensure city workers can reach offices during emergency situation
Resources/Funding	Finances and resources are available to adequately address climate change and related events <ul style="list-style-type: none"> Finances – existing and potential Funds spent Staff 	Finances – existing and potential <ul style="list-style-type: none"> Finances and resources are available to adequately address climate change and related events Amount of funds available for climate risk assessments and adaptation projects Adequacy of financial planning for all actions necessary for climate change resilience¹⁷ Federal dollars secured for climate-informed coastal restoration projects¹⁸ Dollars secured by the City to support climate change preparedness/adaptation Number of grants submitted to support climate change preparedness measures/# grants won Capital funding for projects to collect data on climate change and resilience measures Operating funding to meet all operating costs of climate change resilience activities Contingency funds for post climate change event/disaster recovery (“Rainy-day funding”; most severe event) Financial support for climate change mainstreaming and related initiatives¹⁹ Required funding for CCA provided Capital and budget proposals incorporate climate change impacts Resources acquired to develop green infrastructure Funding secured for flood protection projects Funds spent <ul style="list-style-type: none"> Amount of money spent by government to repair sites in Boston because of climate-related damage

		Staff <ul style="list-style-type: none"> • Number of disaster experts on staff in city government or number of people who have resilience as part of their job description • Availability of skills and experience in climate change and disaster resilience (e.g., risk identification, mitigation, planning, response and post-event response)²⁰ • Director or other official with climate action responsibility hired • Required staff for CCA provided
2. Business & Institutions		
Commercial buildings	Commercial buildings are adequately prepared to withstand climate change and related events <ul style="list-style-type: none"> • Vulnerability of commercial buildings & adaptation measures 	Vulnerability of commercial buildings & adaptation measures <ul style="list-style-type: none"> • Number of/percent of commercial buildings considered vulnerable to climate-related events • New commercial buildings and repair of existing commercial buildings include climate preparedness measures (e.g., withstand sea level rise, not constructed in high-risk flood zones) • Identified measures for climate-change resiliency of commercial buildings are being implemented • Existence of building codes to address climate-related risks/application of codes²¹ <p>Percent of capital improvement projects which incorporate hazard mitigation and climate change principles</p> <ul style="list-style-type: none"> • Percentage of Boston's buildings/critical infrastructure adapted for climate change resiliency or implementing climate adaptation measures
Business continuity	Businesses are prepared to continue operating during climate change related events <ul style="list-style-type: none"> • Vulnerable business buildings and adaptation measures • Business continuity 	Vulnerable business buildings & adaptation measures <ul style="list-style-type: none"> • Number of/percent of business buildings considered vulnerable to climate-related events • Identified measures for climate-change resiliency of business buildings are being implemented Business continuity <ul style="list-style-type: none"> • % employment at risk • % of business output at risk • Programs are established to assist small businesses in increasing preparedness and developing business continuity plans • Workers are protected in extreme weather • Number of/Percentage of vulnerable businesses with continuity of business plan [prepared and implemented plans]; business plan to recover from emergency • Boston residents are able to get to work during climate-related events • Space available within the City for workers when office space is not accessible • Percentage of lost productivity due to climate-related flooding • Number of lost work days because of climate-related events²²

3. Social & Natural Capital		
Parks, open space and green infrastructure	<p>Parks, trees and open space are prepared to withstand climate change and related events; parks, trees, and green infrastructure are prioritized to help reduce the urban heat island effect</p> <ul style="list-style-type: none"> Vulnerability of parks and open space & adaptation measures Open space preservation Tree canopy <ul style="list-style-type: none"> Acquire funds Trees remain healthy (health monitored) Continue Grow Boston Greener initiative 	<p>Vulnerability of parks and open space & adaptation measures</p> <ul style="list-style-type: none"> Percent of parks and open space areas considered vulnerable to climate change and related events Number of resiliency renovations to park facilities and buildings Identified adaptation measures are implemented in Boston Harbor Islands and other parks/open space <p>Open space preservation</p> <ul style="list-style-type: none"> Amount and type of land cover preserved as open space Square miles of green space or vegetative cover Area or capacity of urban agriculture including community gardens City's new open space plan incorporates climate change <p>Tree canopy</p> <ul style="list-style-type: none"> Plan to significantly increase tree canopy cover is developed and implemented Growth of total tree inventory Health of trees in Boston is monitored and maintained Percentage of Boston that has a tree canopy Amount of funds acquired for tree planting and maintenance Grow Boston Greener's tree initiative is prioritized as an important initiative <p>Green infrastructure</p> <ul style="list-style-type: none"> Percentage or number of building with cool or green roofs Legislative and regulatory means of expanding requirements for green infrastructure and coastal protection are explored
Ecosystem Components	<p>Ecosystem is able to withstand impacts of climate change and related events/ecosystem components can be utilized to decrease vulnerability of a system</p> <ul style="list-style-type: none"> Vulnerability of ecosystem to climate change and related events Ecosystem protects system from impacts of climate change 	<p>Vulnerability of Boston's ecosystem to climate change and related events & adaptation measures</p> <ul style="list-style-type: none"> The degree to which natural ecosystems in Greater Boston are able to withstand impacts of climate change and related events/ecosystem components and can be utilized to decrease vulnerability of a system. Ecosystem components are specifically identified and managed as critical assets to disaster resilience Awareness of the role that ecosystem services may play in the city's climate change resilience (UNISDR) Ecosystem health (change in health of services in last five years)²³ Identified measures for climate-change resiliency of ecosystems are being implemented (e.g., land and water protection – amount and type of land cover preserved as open space, regulation changes, targeted public funding, enhanced monitoring, invasive species removal) Invasive species are removed or controlled Percentage of identified critical natural resources that have been evaluated Biodiversity and landscape diversity is promoted Healthy watersheds and natural corridors are protected <p>Ecosystem protects system from impacts of climate change</p> <ul style="list-style-type: none"> Beach sand nourishment efforts are implemented²⁴ Local wetlands ordinance is implemented that takes sea level rise into account <p>Shore protection techniques and open space preserves allow beaches and coastal wetlands to gradually move inland as sea level rises</p>

Cultural Resources (heritage, preservation)	Historical sites and districts are prepared to withstand climate change and related events <ul style="list-style-type: none"> Vulnerability of historical sites/districts & adaptation measures (e.g., Back Bay Architectural District, Bay Village Historic District) 	Vulnerability of historical sites/districts & adaptation measures <ul style="list-style-type: none"> Percentage of/Number of historical buildings/sites susceptible to sea level rise/flooding/erosion Number of historical buildings/sites updated with climate resilience measures Identified measures for climate-change resiliency of historical buildings/sites are being implemented
4. Residential Neighborhoods		
Residences/buildings	Residences and buildings are prepared to withstand climate change and related events <ul style="list-style-type: none"> Vulnerability of residential buildings/areas & adaptation measures 	Vulnerability of residential buildings/areas & adaptation measures <ul style="list-style-type: none"> The degree to which commercial and residential buildings and infrastructure are adequately prepared to withstand climate change and related events Number of/percent of residential buildings considered vulnerable to climate-related events New residential buildings and repair of existing residential buildings include climate preparedness measures (e.g., withstand sea level rise, not constructed in high-risk flood zones) Identified measures for climate-change resiliency of residential buildings/areas are being implemented Small-scale resiliency interventions and pilots are established in particularly vulnerable areas Up to date climate change projections and scenarios are developed to support neighborhood-level planning and design Building preparedness priorities, best practices, guidelines for implementation and cost/benefit information are established in coordination with property owners, neighborhood groups, and other stakeholders Modifications to building codes are identified in accordance with best practices in building resiliency (work with commonwealth, insurance and finance sectors, and property owners) Consideration of climate change in current and updated zoning, floodplain, and construction code documents Percent of capital improvement projects which incorporate hazard mitigation and climate change principles Percent of at risk households holding flood insurance policies²⁵ Number of occupied repetitive loss properties Percent population at risk of displacement (housing was destroyed) Modifications to building codes are identified in accordance with best practices in building resiliency (work with commonwealth, insurance and finance sectors, and property owners); and application of building codes An evacuation plan is developed by BRA for extreme weather events for coastal buildings Number, square footage, or percentage of buildings with decreased risk of damage due to resilience measures by private owners Number of buildings implementing Core Flood Resilience measures²⁶ Number of buildings constructed in high-risk flood zones

		<ul style="list-style-type: none"> Capital construction plans for public housing address impacts of climate change and current vulnerable housing units are upgraded/replaced
5. Public Health & Safety		
Public health & cooling	<p>Boston residents are not vulnerable to climate-related health risks & have access to needed amenities</p> <ul style="list-style-type: none"> Climate-related deaths (heat)/illnesses/disease <ul style="list-style-type: none"> Cooling center system improved Air conditioning in houses Vulnerable populations stay cool Worker safety (staff fatigue) Events (drinking water, fans) Vulnerable populations <ul style="list-style-type: none"> Public housing facilities Access to critical services (health centers) 	<p>Climate-related deaths, illnesses, disease</p> <ul style="list-style-type: none"> The degree to which Boston residents are vulnerable to climate-related health risks and have access to needed services and amenities Number of climate-prepared cooling centers per square mile Miles or percent of pavement using cool pavement technology Ratio of # of Bostonians/capacity of climate-prepared cooling centers Number of days with good Air Quality Index scores Number of climate-related disease outbreaks and illnesses, and prevention measures included in ongoing health programs Number of climate-related deaths (due to heat, flooding)/number of days with climate-related hazards Number of people that are better able to cope with climate change²⁷ Identification of potential disease outbreaks and prevention measures into ongoing health programs Number of climate-related toxic spills that occur every [x] years Intensity of UHI effect (there are new models and methods being proposed to measure this) Percentage of homes with air conditioning Ratio of # of Bostonians with air conditioning in homes/number of homes Extreme heat event plan updated every [x] years and implemented <p>Vulnerable populations</p> <ul style="list-style-type: none"> Number of vulnerable public housing facilities Actions are taken by City to help people (including vulnerable populations) better cope with climate change (access to cooling centers, financial and technical assistance) Engagement of vulnerable segments of the population Public health programs aimed at vulnerable populations and low-income households integrate climate preparedness elements Financial and technical assistance is provided to vulnerable populations and low-income households in reducing vulnerability Access of vulnerable populations to major health treatment locations Percent of population considered “vulnerable” (e.g., obese, smokes, diabetic, disabled, over 65) Operational procedures are updated to ensure worker safety during extreme heat events Based on vulnerability analysis, the percentage of population at risk with access to emergency response shelter Links between emergency resources and vulnerable populations

<p>Emergency response</p>	<p>Boston's emergency response is prepared for climate-related risks</p> <ul style="list-style-type: none"> • Vulnerability of critical service facilities <ul style="list-style-type: none"> ○ Emergency shelters ○ Police, fire, EMS ○ Emergency plans ○ Refine Department's Continuity of Operations Plan (CoOPs) to incorporate climate change ○ Refine emergency operations plan (EOP) • Capacity for emergencies <ul style="list-style-type: none"> ○ Personnel ○ Supplies/equipment ○ Access to emergency shelters ○ Emergency vehicle fleet ○ Focus on vulnerable populations • Access to critical services (police, fire) 	<p>Vulnerability of critical service facilities</p> <ul style="list-style-type: none"> • Number of/percent of emergency shelters considered vulnerable to climate-related events • Number of/percent of police, fire, and EMS stations considered vulnerable to climate change and related events • Identified measures for climate-change resiliency of critical service facilities are being implemented • Number of climate-resilient emergency shelters per square mile/Capacity of climate-resilient emergency shelters • Percentage of climate-resilient emergency shelters in vulnerable areas of the city • New design and construction work completed to increase preparedness of vulnerable emergency shelters • Likely ability to meet needs for shelter/safe places • Ability to meet likely needs for staple goods (e.g., sanitation, bedding) • Access to critical services reliable during extreme events <p>Emergency plans</p> <ul style="list-style-type: none"> • Emergency Communication (early warning) system in place/ Percentage of people reached by early warning systems for hazards and other climate-influenced events/Access to information (public, communication between personnel)²⁸ • Coordination for all post-event activities in the city's area, with clarity of roles and accountability across all relevant organizations [presence of org chart]²⁹ • Existence of emergency response plans • "Surge" capacity of police also to support first responder duties (e.g., backup) • Definition of other first responder and staffing needs, availability (e.g., fire, ambulance) • Definition of equipment and supply needs, and availability of equipment • Drills (practice and rehearsal involving public and professionals/effectiveness) • Planning for post event recovery (comprehensive post event recovery plans)³⁰ • All CoOPs should be updated to take into the account the impacts of climate change • Municipal emergency plans are reviewed and modified every [x] years; coordinated with private, state and federal emergency plans • Existence of thorough evacuation plan identifying who has the right to order evacuations, and who will be in charge of transporting residents • Number of actions completed to improve emergency preparedness • Number of non-profits or community organizations engaged in emergency management planning • Website developed and updated (as needed) containing information on how to handle emergencies for a variety of stakeholders; # of visits to website <p>Capacity for emergencies</p> <ul style="list-style-type: none"> • Number of emergency workers undergoing City coordinated hazards training taking into account changing weather risks or climate-influenced emergency/hazards • Number of climate-resilient emergency supplies and equipment available • Existence of emergency operations centers (with standard operating procedures) • Availability of emergency healthcare including facilities and urgent medical supplies for acute needs • Number of transitional housing units available if needed
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		<ul style="list-style-type: none"> • Number of police and fire stations • Number of emergency shelters • Number of emergency vehicles in City <p>Capacity for cleaning up hazardous spills, contaminated floodwater and debris</p>
Health institutions (e.g., hospitals)	Health institutions are prepared for climate change and related risks Vulnerability of health institutions & adaptation measures	Vulnerability of health institutions & adaptation measures <ul style="list-style-type: none"> • Number of/percent of health institutions considered vulnerable to climate-related events • Identified measures for climate-change resiliency of health institutions are being implemented • Structural safety and disaster resilience of health care and emergency facilities • Percentage of hospital and healthcare facilities implementing climate preparedness into building design including back-up power • Percent of hospitals in 500-year floodplain meeting resilience standards³¹ • Percentage of hospitals with shelter in place and evacuation plans that meet required standards • Percent of nursing homes and adult care facilities in 100-year floodplain meeting resiliency requirements³²
Education facilities	Education facilities are prepared for climate change and related risks <ul style="list-style-type: none"> • Vulnerability of education facilities & adaptation measures 	Vulnerability of education facilities & adaptation measures <ul style="list-style-type: none"> • Structural safety of education facilities (education facilities at risk of damage)³³ • Loss of teaching time (e.g., number of teaching days lost)³⁴
6. Transportation Infrastructure		
Public transportation (roads, tunnels, airports, rail – MBTA, highways, ports)	Public transportation is prepared for climate change and related risks <ul style="list-style-type: none"> • Vulnerability of public transportation (Roads, tunnels, airports, rail, MBTA, bridges, ports) • Public transportation plans 	Vulnerability of public transportation <ul style="list-style-type: none"> • Road – service from road system at risk of loss (e.g., miles become impassable)³⁵ • The degree to which public buildings and infrastructure are adequately prepared to withstand climate change and related events. • Road – survival of critical access and evacuation routes (e.g., emergency routes that become impassable)³⁶ • Rail/metro – service from rail system at risk of loss (e.g., carrying capacity of affected rail lines)³⁷ • Airport loss factor (e.g., number of flights out per day after disaster)³⁸ • River/seaport loss factor (e.g., estimated number of dockings per day possible after disaster)³⁹ • Percentage of projects within flood-prone areas using climate-informed storm water management technologies • Access/transportation to critical infrastructure and services reliable during extreme events • Number of/percent of public transportation infrastructure considered vulnerable to climate change and related events • Adaptation measures are being implemented to reduce vulnerability of identified “at-risk” transportation structures (e.g., new pavement that can withstand extreme weather, elevating high-risk flood zone public transportation stops) • Identified measures for climate-change resiliency of public transportation are being implemented • Number of transportation disruptions due to flooding or infrastructure damage • Number of or percentage of transportation assets adapted for climate change resilience (e.g., using new pavement technologies, green infrastructure to control runoff)⁴⁰ • Number of roads that cross tidal flood zones

		<ul style="list-style-type: none"> • Number of maintenance projects addressing vulnerability of tunnels to seismic activity • Number of transportation routes that are vulnerable to flooding • Number of lane-miles reconstructed or resurfaced⁴¹ • Percent of transportation assets adapted for climate change resiliency Public transportation plans <ul style="list-style-type: none"> • Boston Transportation Department incorporates climate change concerns into all planning • Boston Transportation Department coordinates with other transportation authorities
7. Food, Water, Sewer, & Protective Infrastructure		
Food availability	Boston residents have access to food during climate-related events <ul style="list-style-type: none"> • Food plans • Food capacity 	Food plans <ul style="list-style-type: none"> • Development of a comprehensive food security plan for use during emergency events • Urban agriculture is expanded and resilience of our regional food system is studied Food capacity <ul style="list-style-type: none"> • Likely ability to continue to feed population (e.g., in event of emergency)⁴² • Number of grocery stores and food distribution centers with backup power supplies, including generators or quick connect for generators⁴³ • Number of grocery stores or food markets per square mile, with special attention to low-income neighborhoods
Water availability	Good quality water delivery is unimpeded to Boston residents during climate-related events <ul style="list-style-type: none"> • Water availability throughout the year and during extreme events 	Water availability <ul style="list-style-type: none"> • Size of reservoir stock • Water customer service days at risk of loss⁴⁴ • Designated critical asset service days (e.g., hospitals) at risk of loss from water failure • Cost of restoration of service • Water quality • Water delivery unimpeded throughout year and during extreme events • Combined Sewer Overflows (CSOs) decoupled • Capacity for cleaning up contaminated water supply from CSO events and salinization
Stormwater and sewer infrastructure	Stormwater and sewer infrastructure are prepared for climate change and related risks <ul style="list-style-type: none"> • Vulnerability of stormwater and sewer infrastructure & adaptation measures • Stormwater and sewer infrastructure plans 	Vulnerability of stormwater and sewer infrastructure & adaptation measures <ul style="list-style-type: none"> • Sanitation customer service days at risk of loss⁴⁵ • Designated critical asset service days (e.g., hospitals) at risk of loss from sanitation failure • Community-wide stormwater fee is instituted • Pavement-to-parks/water absorption plan for neighborhoods is created and implemented • Cost of restoration • Adaptation measures are being implemented to reduce vulnerability of identified “at-risk” utility structures (e.g., elevation of Deer Island) • Number of/Percentage of water/sewer infrastructure identified as vulnerable to climate change events • Identified measures for climate-change resiliency of health institutions are being implemented • Ratio of number of vulnerable sites identified/# of sites with plans in place to reduce vulnerability • Number of water pipes vulnerable to weather-related damage

		<ul style="list-style-type: none"> • Number of or volume of combined sewer overflows • Percentage of pumping stations hardened for increased flood risk • Percentage of wastewater treatment facilities linked to backup power generation • Number of storm drain upgrades in areas with reoccurring floods • Percentage of Boston water/sewer infrastructure assets adapted for climate change resiliency • Number of waste water facilities assets protected or raised above the 100-year floodplain⁴⁶ <p>Stormwater and sewer infrastructure plans</p> <ul style="list-style-type: none"> • Capital asset plan for city's stormwater and sewer system considers climate change • Policy measures developed (and implemented) to reduce vulnerability of water/sewer infrastructure
Protective infrastructure	Protective infrastructure safeguard against climate change and related events <ul style="list-style-type: none"> • Protective infrastructure • Maintenance 	<p>Safeguard against climate change and related events</p> <ul style="list-style-type: none"> • Adequacy of protective infrastructure (e.g., ecosystem services providing protection, levees, flood barriers, sea walls)⁴⁷ • Number of riparian or natural buffers in capital projects and development • Measures implemented to reduce flood risk for coastal infrastructure (e.g., sand bags, stockpiling barriers) • Estimated dollars saved through flood protections projects <p>Maintenance</p> <ul style="list-style-type: none"> • Effectiveness of maintenance (process exists to maintain protective infrastructure)⁴⁸
8. Telecommunications		
Telecommunications	Telecommunications system is prepared for climate change and related events <ul style="list-style-type: none"> • Vulnerability of telecommunications & adaptation measures • Telecommunications plans 	<p>Vulnerability of telecommunications & adaptation measures</p> <ul style="list-style-type: none"> • Number of climate-resilient temporary charging stations per square mile • Number of critical telecommunications facilities implementing climate resilience measures • Communications service days at risk of loss⁴⁹ • Designated critical asset service days at risk of loss from communications failure (e.g., police/armed forces, water and energy systems, traffic control) • Cost of restoration of communications services • Identified measures for climate-change resiliency of telecommunications systems are being implemented • Number of/percentage of critical telecommunications facilities/systems identified as vulnerable to climate change and related events • Percentage of Boston's telecommunication system transitioned to fiber optics or other more resilient cables <p>Telecommunications plans</p> <ul style="list-style-type: none"> • Percentage of telecommunication providers with business continuity plans for Boston

9. Electricity & Fuel		
Electric grid	<p>Electricity is unimpeded to Boston because of climate change or related events</p> <ul style="list-style-type: none"> • Vulnerability of electric grid & adaptation measures • Electric grid plans 	<p>Vulnerability of electric grid & adaptation measures</p> <ul style="list-style-type: none"> • Identified measures for climate-change resiliency of the electric grid system are being implemented • Electricity customer service days at risk of loss⁵⁰ • Designated critical asset service days at risk of loss from energy failure (e.g., essential for operation of some part of city, water treatment plant)⁵¹ • Cost of restoration • District energy, combined heat and power, and other types of distributed energy and storage (particularly in districts with critical facilities) are expanded • Renew Boston's energy program and its outreach activities includes climate preparedness • Percentage of electricity generated within the 500 year floodplain able to remain online after a 500 year flood event⁵² • Maximum percent of peak load that could be lost due to failure of any one substation⁵³ • Percentage of critical services that can meet minimum daily demand if their primary production/treatment plant non-functional • Population with access to reliable electricity⁵⁴ • Percent energy at risk⁵⁵ • Time for critical service providers to reach 90% restoration of services under certain weather events • Percentage of assets at or above their loading limits during peak demand periods⁵⁶ • Percentage of customers with alternative power in case of outage • Percentage of overhead lines rerouted underground or strengthened against wind • Critical supplies are available for staff and constituents • Number of/percentage of critical electricity facilities/systems identified as vulnerable to climate change and related events <p>Electric grid plans</p> <ul style="list-style-type: none"> • Number and percentage of critical services (wastewater treatment facilities, watersheds, telecommunication providers, public utilities, transit systems animal rescue) that have integrated preparedness into planning documents, budgeting, training, and manpower responsibilities
Fuel	<p>Fuel availability is unimpeded because of climate change or related events</p> <ul style="list-style-type: none"> • Vulnerability of gas pipes & adaptation measures • Fuel plans 	<ul style="list-style-type: none"> • Vulnerability of gas pipes and adaptation measures • Safety and integrity of gas system⁵⁷ • Likely availability of fuel (during emergency events) • Gas customer service days at risk of loss⁵⁸ • Designated critical asset service days at risk of loss from a gas supply failure • Cost of restoration of service • Number of gas pipes/fuel lines considered vulnerable to climate change and related events • Identified measures for climate-change resiliency of gas pipes are being implemented • Percent of gas pipes hardened against water infiltration from sea level rise, storm surge, flooding • Number of miles of cast iron and bare steel gas mains in the 500-year floodplain⁵⁹ • Percentage of liquid fuel assets in the floodplain hardened against flood events

		<ul style="list-style-type: none"> Percentage of Liquid fuels facilities with anchored storage tanks that are 50 gallons or larger Percentage of gas stations with quick-connects for generators⁶⁰ Fuel plans <ul style="list-style-type: none"> Program or plan for allocating fuel supplies to emergency responders first
10. Community Outreach & Public Engagement		
Public awareness and participation (public input and response)	Stakeholders are aware of and provide input into preparing for climate change and related events <ul style="list-style-type: none"> Stakeholder engagement <ul style="list-style-type: none"> Inform policymaking Access to information (meetings, education materials, networks, schools) 	Stakeholder engagement <ul style="list-style-type: none"> The degree to which the public and specific stakeholders are aware of and provide input into preparing for climate change and related events Quality of stakeholder engagement in decision-making to address climate change⁶¹ Information on climate change resiliency is available for public, property owners and tenants (website, meetings, school curriculum) Neighborhood-based programs are developed to increase climate preparedness Public, property owners and tenants are aware of their climate change vulnerabilities Mechanisms are researched to provide property owners financial and technical support for increasing preparedness Number of jobs created or number of job training sessions top help address climate change preparedness Social connectedness and neighborhood cohesion (e.g., likeliness that residents will be contacted after an event to confirm safety, issues)⁶² Public outreach is conducted to neighborhood groups to motivate all sectors of the community around preparedness and better understand needs/priorities Exposure of public to education and awareness materials/messaging Validation of effectiveness of education Availability and take-up of training Accessibility of education and training to all linguistic groups in city Number of/Attendance at training courses, workshops and seminars presented to residents, property owners, and city officials Number of neighborhoods where public opinion is used to identify where key vulnerabilities exist
		<ul style="list-style-type: none"> Percentage of Public that accept climate change needs to be addressed Visits to website on climate change adaptation and preparedness Percentage of meetings for xyz purposes are well attended Awareness among stakeholders of climate change issues, risks and responses⁶³ Visits to website on climate change risk or publicizing publications regarding reducing risks Curriculum developed on climate change and preparedness; Regulation implemented to require teachers to teach about climate change and preparedness; # of teachers provided with curriculum on climate change and preparedness Number of individuals pledging to make key preparedness measures in their homes and businesses Individuals are equipped to take action against climate change impacts

Endnotes

- ¹ United Nations Office for Disaster Risk Reduction (UNISDR), 2014, *Disaster Resilience Scorecard for Cities, Working Document*, prepared by AECOM and IBM, available from: <http://www.unisdr.org/2014/campaign-cities/Resilience%20Scorecard%20V1.5.pdf>, 17.
- ² Ibid., 18, 55-6.
- ³ Ibid., 20.
- ⁴ Ibid., 20. Bours, D., C. McGinn, and P. Pringle, 2014, Guidance note 3: Theory of Change approach to climate change adaptation programming, SEA Change and UKCIP, February, available from: <http://www.seachangecop.org/node/2933>.
- ⁵ International Institute for Environment and Development (IIED), 2013, Indicator 1: Climate change integration into planning, available from: <http://pubs.iied.org/G03525.html>.
- ⁶ IIED, 2013, Indicator 6: Planning under Uncertainty, available from: <http://pubs.iied.org/G03536.html>.
- ⁷ UNISDR, 5.
- ⁸ Ibid., 11.
- ⁹ IIED, 2013, Indicator 5: Use of climate information, available from: <http://pubs.iied.org/G03535.html>.
- ¹⁰ UNISDR, 50.
- ¹¹ IIED, 2013, Indicator 2: Institutional coordination for integration, available from: <http://pubs.iied.org/G03526.html>.
- ¹² UNISDR, 6.
- ¹³ Ibid, 30.
- ¹⁴ Ibid., 30-1.
- ¹⁵ Ibid., 31.
- ¹⁶ Ibid., 31.
- ¹⁷ Ibid., 13.
- ¹⁸ The City of New York, 2014, *PlaNYC Progress Report 2014*, 89.
- ¹⁹ IIED, 2013, Indicator 3: Budgeting and finance, available from: <http://pubs.iied.org/G03527.html>.
- ²⁰ UNISDR, 11.
- ²¹ Ibid., 37.
- ²² Ibid., 15-6, 33, 36-7, 49.
- ²³ Ibid., 43.
- ²⁴ The City of New York, 89.
- ²⁵ Ibid.
- ²⁶ Ibid.
- ²⁷ IIED, 2013, Indicator 9: Vulnerability/resilience, available from: <http://pubs.iied.org/G03539.html>.
- ²⁸ UNISDR, 9, 39-41, 45.
- ²⁹ Ibid., 6.
- ³⁰ UNISDR, 53-4.
- ³¹ The City of New York, 89.
- ³² Ibid.
- ³³ UNISDR, 33.

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- ³⁴ Ibid., 33-4.
³⁵ UNISDR, 27.
³⁶ Ibid., 28.
³⁷ Ibid., 28-9.
³⁸ Ibid., 29.
³⁹ Ibid., 29-30.
⁴⁰ The City of New York, 89.
⁴¹ Ibid.
⁴² UNISDR, 48.
⁴³ The City of New York, 89.
⁴⁴ UNISDR, 25-6.
⁴⁵ Ibid.
⁴⁶ The City of New York, 89.
⁴⁷ UNISDR, 22-3.
⁴⁸ Ibid.
⁴⁹ Ibid., 23.
⁵⁰ Ibid., 24.
⁵¹ Ibid., 24.
⁵² The City of New York, 89.
⁵³ Ibid.
⁵⁴ Notre Dame Global Adaptation Index Overview (ND-GAIN), 2013, Detailed methodology report, 32-33, available from: <http://www3.nd.edu/~nchawla/methodology.pdf>.
⁵⁵ Ibid.
⁵⁶ The City of New York, 89.
⁵⁷ UNISDR, 26.
⁵⁸ Ibid., 26-7.
⁵⁹ The City of New York, 89.
⁶⁰ Ibid.
⁶¹ IIED, 2013, Indicator 7: Participation, available from: <http://pubs.iied.org/G03537.html>.
⁶² UNISDR, 10.
⁶³ IIED, 2013, Indicator 8: Awareness among stakeholders, available from: <http://pubs.iied.org/G03538.html>.