CLIMATE READY BOSTON

Climate Projections Consensus

ADAPTED FROM THE BOSTON RESEARCH ADVISORY GROUP REPORT

MAY 2016

WHAT'S IN STORE FOR ***BOSTON'S CLIMATE?***

SEA LEVEL RISE

STORMS

EXTREME TEMPERATURES

EXTREME PRECIPITATION

Bostonians need to understand the likely impacts of climate change in order to plan for a strong, resilient future.

To help us understand climate change impacts at the local level, the City of Boston and Green Ribbon Commission convened a working group of the region's top climate scientists. The Boston Research Advisory Group (BRAG), overseen by the University of Massachusetts-Boston School for the Environment, developed this consensus about how Boston's climate will change over the course of the 21st century.

The Climate Project Consensus projects future climate impacts in the Boston region, including extreme temperatures, sea level rise, heavy precipitation and coastal storms.

This document is a summary the Climate Projection Consensus Report. See **climateready.boston.gov/findings** for more information.

INTRODUCTION

The longer-term impacts of climate change are largely dependent on our success at curbing global emissions of greenhouse gases.

Because we do not know how well we will do, scientists use multiple emissions scenarios as the bases for their projections. Climate projections for the next few decades are relatively consistent, regardless of which emissions scenario they rely on. However, the projections become increasingly different the further we look into the future. This is because the past 200+ years of burning fossil fuels and clearing forests have already changed our climate and will continue to do so, but our actions going forward will have an important impact on whether climate change accelerates or slows down.

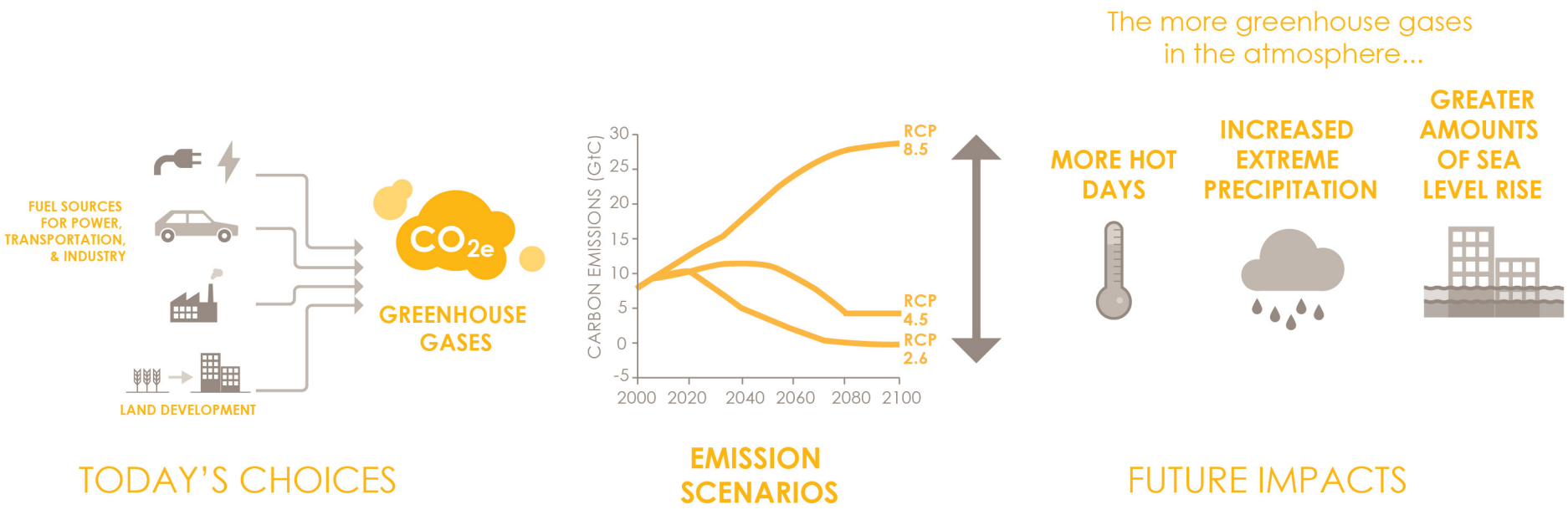
These projections use three emissions scenarios from the International Panel on Climate Change, which are called "representative concentration pathways" or RCPs.

RCP 8.5 is a high-emissions trajectory and is often characterized as a continuation of "business as usual."

RCP 4.5 assumes that emissions remain around their current levels through 2050, then are slowly reduced in the second half of the century.

RCP 2.6 is a stringent emissions reduction pathway, and the pathway most consistent with the net-zero emissions in the second half of the 21st century envisioned by the 2015 Paris Agreement on climate change.

The amount of future changes depends on our actions today



Our choices about transportation, energy, and land use determine the level of greenhouse gases in the atmosphere. As greenhouse gases increase, the impacts of climate change like sea level rise, extreme precipitation, and extreme temperatures increase. We don't know the exact amount of changes because the amount of future emissions is uncertain. Will we take actions now that will help minimize future change?

EXTREME TEMPERATURES KEY FINDINGS

Average temperatures in the Northeast have been slowly rising for over a century.

Temperatures in the Northeastern United States increased by almost two degrees Fahrenheit between 1895 and 2011.

The rate of increase in average temperatures is accelerating.

While over the past century, temperatures in the Northeast rose about two degrees, the increase over the next century may be greater than ten degrees.

As an urban area, Boston tends to be hotter than surrounding communities that are more suburban or rural.

Urban areas generally tend to be hotter than nearby rural areas because concrete, steel, and other building materials retain more heat than vegetation. This phenomenon, known as the "urban heat island effect", is compounded by climate change.

EXTREME TEMPERATURES KEY FINDINGS

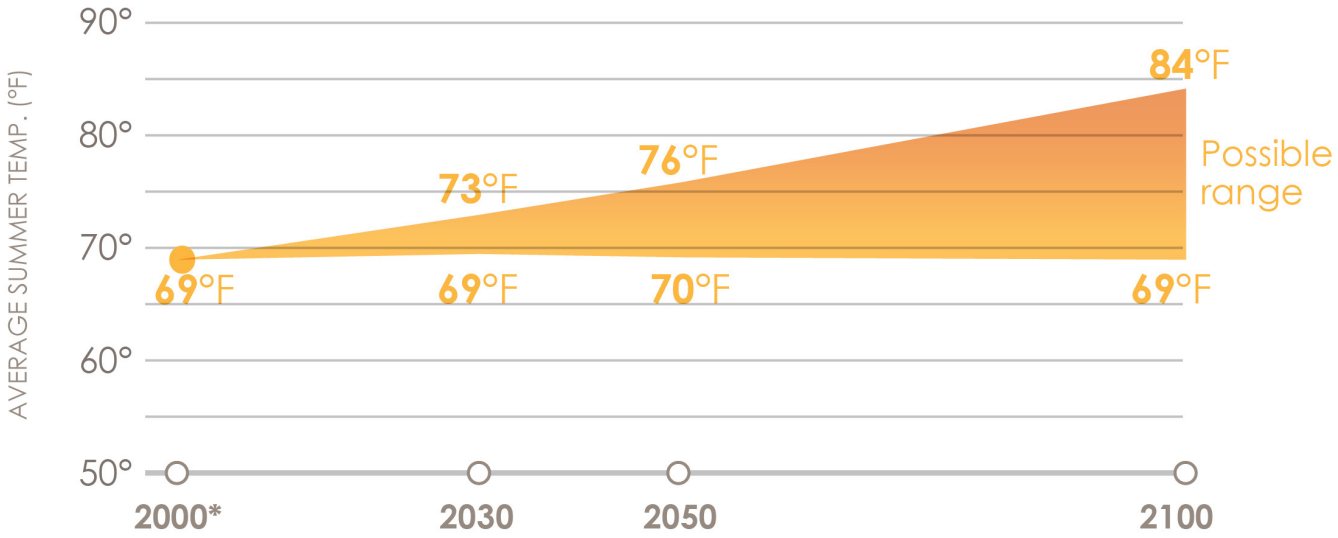
Boston's summers are getting hotter.

While the average summer temperature in Boston from 1981 to 2010 was 69 degrees, it may be as high as 76 degrees by 2050 and 84 degrees by 2100.

Future temperatures in Boston will depend on how much we are able to cut our greenhouse gas emissions.

The rise in temperatures between now and 2030 is largely consistent between all emission scenarios. However, the scenarios show that cutting emissions now can greatly slow the rise in temperatures in the second half of the century.

AVERAGE SUMMER TEMPERATURE WILL INCREASE



* Baseline represents historical average from 1981-2010
Upper values from high emissions scenario. Lower values from low emissions scenario.

Data source: Houser et al 2015

EXTREME TEMPERATURES KEY FINDINGS

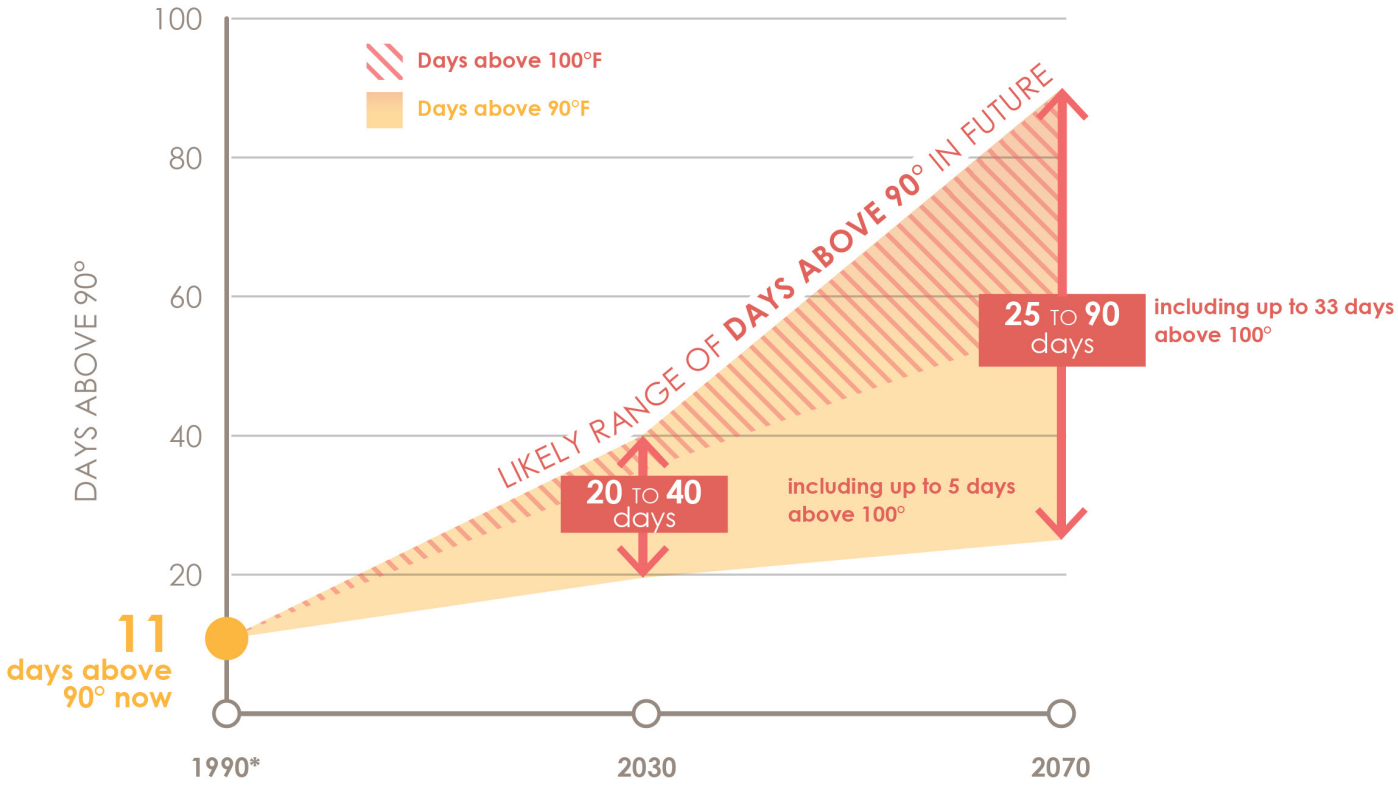
There will be more days of extreme heat.

Compared to the period from 1971 to 2000, when there were 11 days per year over 90 degrees, there may be as many as 40 by 2030, and 90 by 2070 – nearly the entire summer.

Heat waves will become more common, last longer, and be hotter.

The City of Boston defines heat waves as periods of three or more days above 90 degrees, and heat waves are a leading cause of weather-related mortality in the United States.

THE NUMBER OF VERY HOT DAYS WILL INCREASE



* Baseline represents historical average from 1971-2000
Upper values from high emissions scenario. Lower values from low emissions scenario.

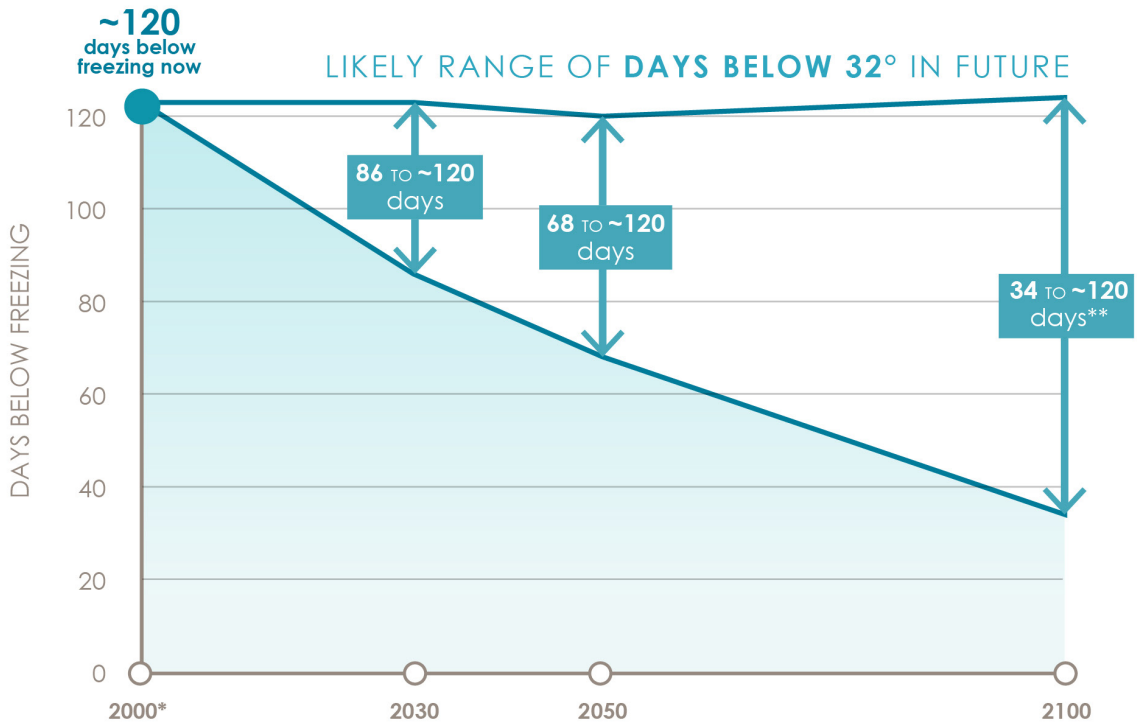
Data source: Rossi et al. 2015

EXTREME TEMPERATURES KEY FINDINGS

Although winters will likely be warmer, the risk of frost and freeze damage and cold snaps will continue.

While from 1981 to 2010, Boston reached below-freezing almost one out of three days per year, by the end of the century this may happen only around one in ten days.

THE NUMBER OF VERY COLD DAYS MAY DECREASE



* Baseline represents historical average from 1981-2010

** Upper values from high emissions scenario. Lower values from low emissions scenario.

Data source: Houser et al 2015

SEA LEVEL RISE KEY FINDINGS

Sea level rise is caused by a combination of land-ice melting, thermal expansion, and changes in land water storage.

Land-ice melting includes the melting of mountain (alpine) glaciers, ice caps, and the continental-scale ice sheets on Greenland, West Antarctica, and East Antarctica. Thermal expansion describes the phenomenon that, as water warms, it generally occupies a greater volume. Land water storage describes activities that affect the amount of water stored on land, such as holding water in reservoirs and/or behind dams or pumping out underground water for irrigation and use by people.

The relative sea level in Boston Harbor has risen over the past century.

From 1921 to 2015, the overall trend in relative sea level rise was about 0.11 inches per year. Relative sea level is the difference in elevation between the sea surface and land surface at a specific place and time, so relative sea level rise can be a combination of changes in the sea surface and changes in the land surface. In Boston, the sinking of the land surface – called "subsidence" – is relatively minor compared to changes in the sea level.

The pace of relative sea level rise is accelerating. Over the entire 20th century, sea levels rose about nine inches relative to land.

Another eight inches of relative sea level rise may happen by 2030, almost three times faster. By 2050, the sea level may be over as much as 1.5 feet higher than it was in 2000, and as much as 3 feet higher in 2070.

SEA LEVEL RISE KEY FINDINGS

As sea levels rise, a deeper harbor will mean higher and more powerful waves.

Although Boston remains relatively protected from Atlantic waves by Winthrop, Hull, and the Harbor Islands, stronger waves are more likely to damage sea walls and erode beaches. The outer islands and peninsula shorelines of Boston Harbor are likely to experience these impacts to a greater extent than the Boston proper shoreline.

A major reduction in global greenhouse gas emissions can have a tremendous impact on the future of Boston Harbor.

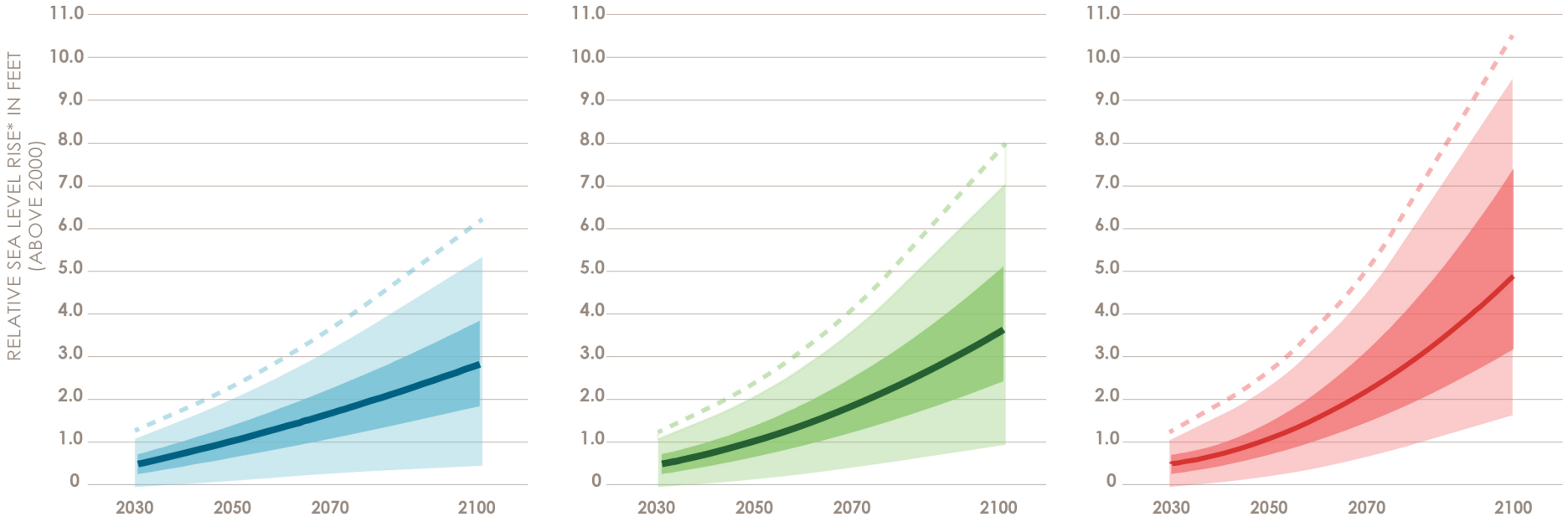
While sea level rise projections for 2030 are consistent across all emission scenarios, in later years there are big differences between scenarios. With a sharp emissions reduction, we may be able to keep end-of-century sea level rise to under two feet, while higher emissions may result in over seven feet of sea level rise.

EMISSIONS REDUCTIONS IMPACT FUTURE SEA LEVELS

LOW EMISSIONS SCENARIO
(MAJOR EMISSIONS REDUCTION)

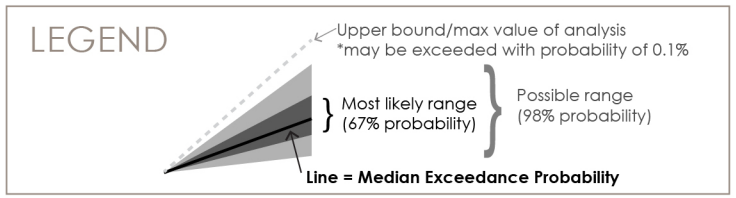
MEDIUM EMISSIONS SCENARIO
(MODERATE EMISSIONS REDUCTION)

HIGH EMISSIONS SCENARIO
(BUSINESS AS USUAL)



* Relative sea level rise is the change in sea level resulting from a combination of increases in ocean height and decreases in land surface elevation ("subsidence").

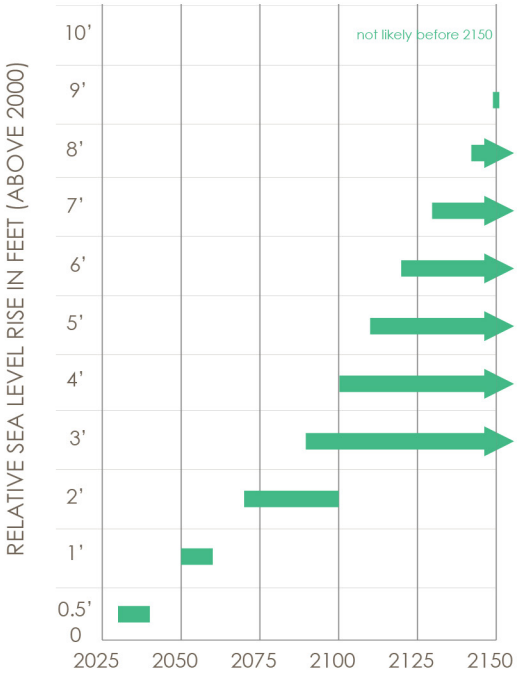
Data Source: BRAG Report



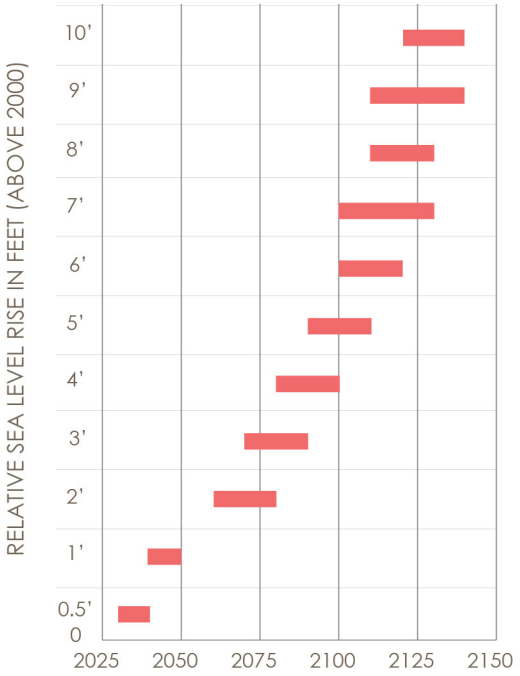
SEA LEVELS IN BOSTON WILL CONTINUE TO INCREASE

LOW EMISSIONS SCENARIO
(MAJOR EMISSIONS REDUCTION)

MEDIUM EMISSIONS SCENARIO
(MODERATE EMISSIONS REDUCTION)



HIGH EMISSIONS SCENARIO
(BUSINESS AS USUAL)



LEGEND

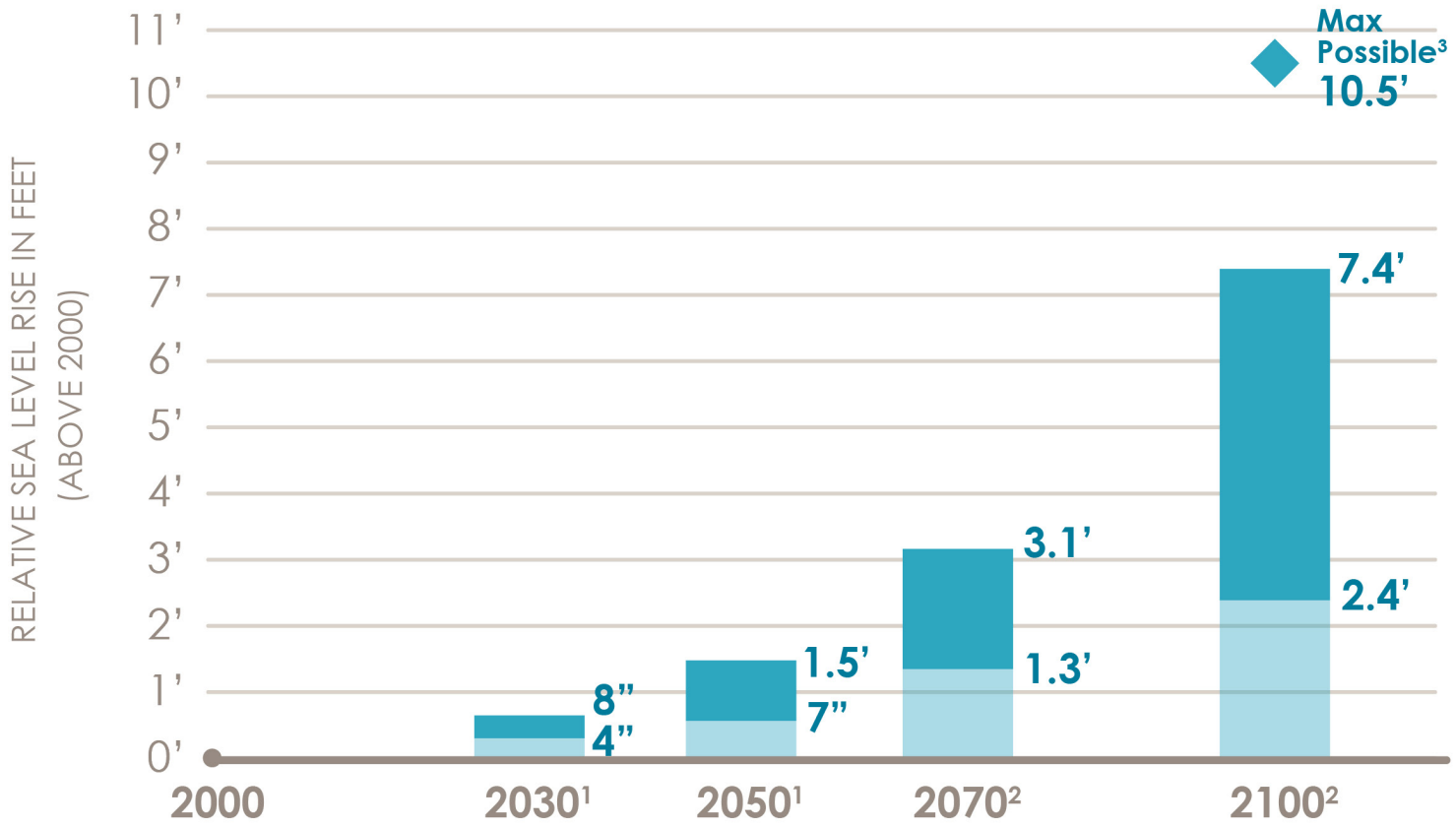
Probability of SLR by year*

Most likely range
(approx. 67% probability)

* Projection data only available by decade

Data Source: BRAG Report

SEA LEVELS IN BOSTON WILL CONTINUE TO INCREASE



1 - Likely under all emission scenarios
2 - Likely under moderate to high emission scenarios
3 - Low probability under high emission scenario

EXTREME PRECIPITATION KEY FINDINGS

In the Northeast, there has already been a very large increase in the intensity of extreme rain and snow.

From 1958 to 2010, there was a 70% increase in the amount of precipitation that fell on the days with the heaviest precipitation. This increase is greater in the Northeast than for any other region of the country.

The increase in extreme precipitation is expected to continue.

As the climate warms, more ocean water evaporates into the air, and warmer air can hold more water, supporting heavier precipitation events. Heavy precipitation events will continue to increase in Boston. However, due to the complexity of the processes underlying precipitation as well as natural variability, the magnitude of this increase is not yet clear.

While the total amount of annual snowfall will decrease, there may still be some heavy snow events through the end of the century.

Based on regional projections, total snow accumulations could decrease 31-48% by 2100, and the start to the snow season is expected to be delayed. However, changes in daily heavy snowfall events can be quite different from changes in annual snowfall. Expected changes to individual heavy snow events, ice storms, and drought are not clear.

EXTREME PRECIPITATION KEY FINDINGS

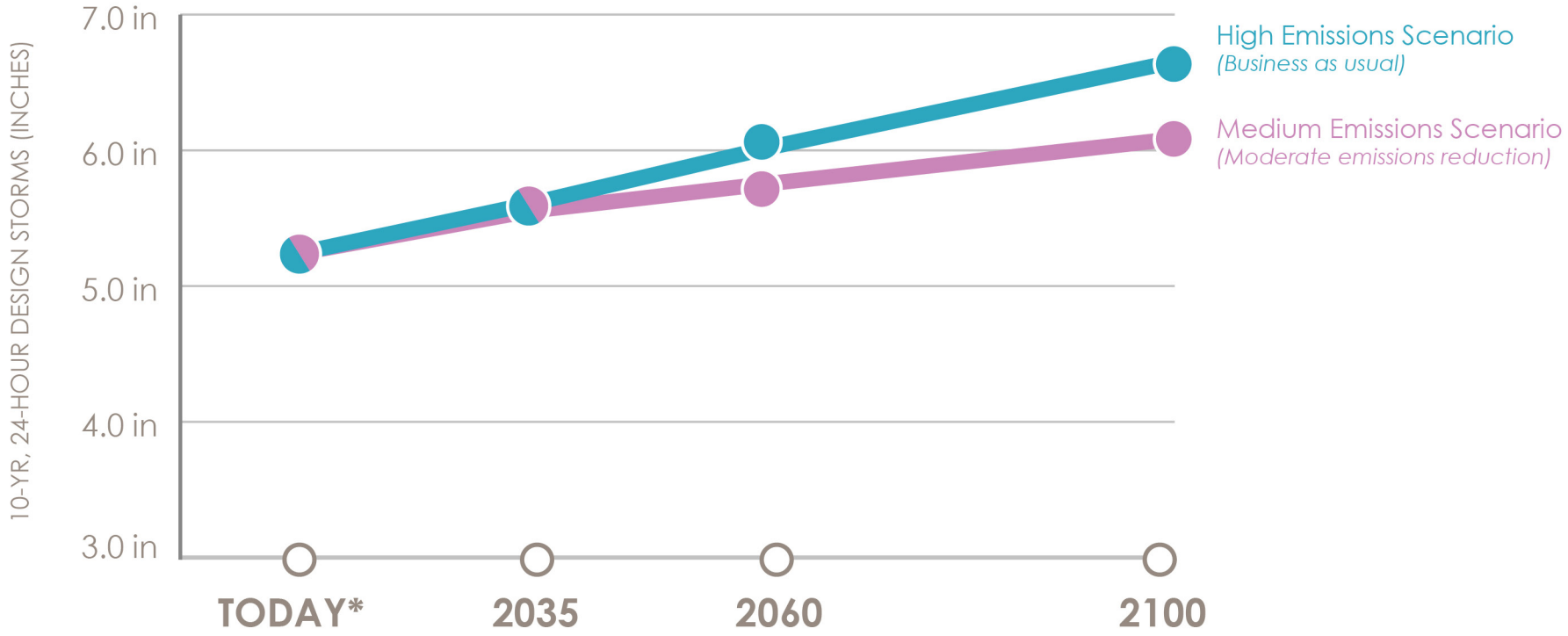
Both stormwater and riverine flooding are affected by extreme precipitation.

Boston's stormwater drainage system may be overwhelmed by major rain events. It may be further compromised by sea level rise as drain outlets are flooded by the rising ocean, reducing the ability of the drainage system to convey stormwater to the coast. River flooding is also likely to increase, but there are large uncertainties associated with river flooding due to the complexity of the climate and hydrological systems involved.

If we take action to cut global greenhouse gas emissions, we can prevent the most extreme precipitation projections from becoming a reality.

A commonly used measure of major rain and snow events is the amount of precipitation that has at most a one-in-ten annual chance of falling during a 24-hour period. While projections for these events are similar in the short term across different emission scenarios, by the end of the century the difference between medium and high scenarios is about ten percent.

RAINFALL FROM STORMS WILL INCREASE



* "Today" baseline represents historical average from 1948-2012
Confidence intervals are not available for these projections but are likely large, so these numbers should be considered as the middle of a large range

Data Source:
Boston Water & Sewer Commission

STORMS KEY FINDINGS

For Boston, the storms that are of greatest concern are "extratropical cyclones", followed by "tropical cyclones."

Extratropical cyclones, which are more common and longer-lasting in the Northeast than tropical cyclones, currently produce most of the storm-induced flooding in the Boston region and will continue to do so in the near future. These are storms that originate outside of the tropics and are sometimes called nor'easters. They can form during any time of the year but are most prevalent in the extended cold-season months. Tropical cyclones are storms that originate in the tropics and are called hurricanes once they reach a sustained wind speed of more than 74 miles per hour.

Current climate projections do not provide a clear projection of how the intensity, frequency, and trajectory (tracks) of tropical and extratropical storms will change.

There are large uncertainties about how climate change will affect future storms. This is particularly true for extratropical storms. For tropical storms, there is some evidence that their intensity has been increasing. If tropical storm intensity increases, there could be more frequent major hurricanes (Category 3 and greater), even if the total number of tropical storms does not increase.

Rising sea levels mean that any given storm will cause more flooding in the future than it would today.

During a storm, winds can blow ocean water towards the land, creating a "storm surge" on top of the baseline sea level. When storm surge is combined with tidal processes, the result is known as a "storm tide". With higher seas, it takes less precipitation and a less powerful storm surge to produce the same amount of flooding as a more powerful storm would produce when the seas are lower.

NEXT STEPS

*THE **INTEGRATED VULNERABILITY ASSESSMENT** WILL ANALYZE THE IMPACT OF THESE CHANGES ON OUR CITY, AND **RESILIENCE STRATEGIES** WILL INCLUDE PRELIMINARY IDEAS FOR PROJECTS, POLICIES, AND PROGRAMS TO HELP OUR NEIGHBORHOODS AND INFRASTRUCTURE RESPOND TO CLIMATE CHANGE AND BECOME MORE RESILIENT.*