



4919 Ashby St., NW
Washington, DC 20007

Telephone 202-298-6556
Email mts@sustainableproducts.com
Web www.capitalmarketspartnership.com
www.laceyducare.com

Special Report

MASSACHUSETTS

Existing, Partial Resilience

Costs

November 5, 2017

Capital Markets Partnership

SPECIAL REPORT

MASSACHUSETTS ***Existing, Partial Resilience Costs***

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1. Resilience Costs are Systemic, Extraordinary, Greatly Understated & May Get Out of Control.

The American Security Project Blog below, prepared at the request of the Defense Department, documents the very real *positive feedback loops* understating and accelerating dangerous climate change and resilience damages, that are not taken into account in the IPCC assessments or US Climate Assessment Report. Considering the S&P Credit Rating Downgrade slide below, with development led by Massachusetts Senator Ed Markey's and other U.S. Senate staff, unless comprehensive national resilience financing is established very soon, a downgrade or major litigation over damages can trigger financial contagion. This presents a substantial and unreasonable risk to Massachusetts.

These major damage categories herein are expected to increase and expand to new categories given that (1) atmospheric CO2 concentrations have risen above 400 parts per million (ppm), (2) are continuing to rapidly rise, (3) 350 ppm and below are recognized as the safe level by the leading scientists, (4) higher than 350 ppm is the dangerous level (*Green Bond Business Case* 2014), and (5) IPCC and US Climate Assessment Report did not incorporate in their assessments, the *positive feedback loops* / accelerators identified above at the request of the Defense Department. Further, there is so much latent power of existing CO2 in the atmosphere that the damages calculated herein are not dependent on future CO2 reductions (*Economic Impacts of Projected Climate Change in Pennsylvania: Report to the Department of Environmental Protection*, 2009 at 2).

Accordingly, Massachusetts buildings, homes, infrastructure, public health and economy must be made resilient to deal with these growing, unprecedented damages that are extraordinarily expensive and present an unreasonable risk.

American Security Project Blog Article *Wanted Alive: Private Sector Solutions to the Climate Bubble / Crash Protecting the Global Economy & National Security*

Developed at recommendation of Pentagon Climate Officers Briefing (Aug. 12, 2014), & decided not to be published by DoD Comptroller's Office due to potential to trigger financial contagion since there is no climate solution in place

Connecting the dots on recent public announcements raises likely near term unacceptable national and economic security risks:

Pending Climate Bubble, Crash, Contagion (economic panic) warning by Former Republican Treasury Secretary Hank Paulson (using Wall Street *Green Bond Business Case* released at NYSE & updated by leading economists 2013)

Planned Climate Credit Downgrades by Standard & Poor's credit rating agency (May 15, 2014)

Lack of Insurance for climate change damages (*Green Bond Business*, Fireman's Fund Allianz July 1014, National Association of Insurance Commissioner Survey, Aug, 2014)

Accelerating Systemic Climate Damages in all economic sectors (*Green Bond Business Case*)

Rising Seas' Systemic Damages including Miami Beach sunny day flooding (July 2014 NYTimes & Guardian) with no solution due to porous limestone bedrock that can permanently undermine the City's credit rating. Miami and all other South Florida coastal cities have similar risks.

Lack of Needed Market Confidence in Solutions Stopping the Bubble by reducing 18 gigatons of carbon pollution in the near term costing \$2 trillion and preventing *unmanageable* dangerous climate change (*Green Bond Business Case*)

The Climate Bubble is Permanent unlike all prior bubbles going back to the 11th Century where there was economic recovery (See *This Time is Different* 2011)

Military Sea Level Base Ongoing Relocations Hampered by lack of appropriations adversely affecting military readiness since Congress doesn't recognize climate change (GAO July 2014)

JPMorgan Calling Unmanageable Dangerous Climate Change a High Probability Near

Term Black Swan Statistical Event (*Green Bond Business Case*)

Accelerating Dangerous Climate Change Positive Feedback Loops including -

- methane permafrost and ocean hydrates releases
- ocean limit exceedance of CO2 absorption
- Greenland glacial melt moulins & tsunamis
- West Antarctic Ice Sheet collapse
- greater warming from loss of albedo reflective capacity from decreased sea and glacial ice
- rising sea and land surface temperatures intensifying climate and weather events
- unknown positive feedback loops due to paramount climate system complexity

"Climate Change ... May Act as an Accelerant of Instability or Conflict. ... Managing the National Security Effects of Climate Change Will Require DoD to Work Collaboratively, Through a Whole-of-Government Approach, with Both Traditional Allies and New Partners. ... Climate change, energy security, and economic stability are inextricably linked" (Defense Department Quadrennial Reviews Mar. 4, 2014 & 2010).

These preceding factors raise serious unacceptable near term domestic national and economic security risks from planned US climate credit downgrades required by law to warn investors due to accelerating systemic climate damages. Without a climate solution in place, downgrades can trigger contagion.

Fortunately, institutional investors with over \$70 trillion in assets under management are starting to deploy funds that can stop the Bubble (*Green Bond Business Case*).

Are there private sector announcements that can be made on solutions to the Bubble / Crash to boost market confidence as the necessary antidote to contagion?

Solving Climate Credit Rating Downgrades

Challenge: Near Term Climate Bubble / Crash Can Be Triggered by

- Pending climate credit downgrades, and / or
- Imminent litigation over collapse of coastal property values from faster rising seas.

Accelerating Forces

- Lack of insurance for climate damages / resilience
- Several trillion dollars must be spent on near term solutions.
- JPMorgan predicts unmanageable dangerous climate change is a near term high probability *Black Swan* statistical event.
- Time is of the essence: triggers can happen now.

Solution:

Rating Agencies Use Consensus Criteria Entities Can Achieve to Avoid Downgrades **BEFORE** They are Issued.

Accelerating Forces

- S&P criteria use can serve as underwriting for new insurance products, brand improvement, 30 yr. profitable business models.
- Government action not required.
- Capital markets have more than enough investor funds to pay for solution including through green + resilient bonds.
- Green bond growth is explosive.
- Rating agencies acknowledge higher ratings for energy efficiency.
- Improves public health & environment.
- Rebuilds / protects built environment.
- Creates estimated \$800B in new wages / 400,000 new jobs.
- Consensus criteria rating agencies helped initiate are available & similar to existing bond criteria.



Data From Capital Markets Partnership (CMP) Green Bond / Sustainable Investment Business Case & RELI Consensus Underwriting Standards Supported by U.S. Conference of Mayors (2008), Peer-reviewed & Released at NYSE (2009), Updated by Leading Economists (2013), & Used by Former Republican Treasury Secretary Hank Paulson Announcing Climate Bubble (NYTimes, WSJ 2014). Slide Developed With US Senate Staff and CMP as a Result of US Senate Staff Briefing on Climate Credit Rating Downgrades (Feb. 6, 2015).

2. Commonwealth's *Existing*, Partial Costs of \$2.46 Trillion.

- Long term and systemic climate fraud prevented the Commonwealth's ability to ameliorate now well-documented, accelerating resilience damages including S&P and Moody's planned climate credit rating downgrades, by using the National Consensus Resilience Standard (RELI) approved by OMB and Homeland Security for critically needed resilience financing to reduce damages, and prevent financial contagion and national security threats identified by the Defense Department (*Standards and Finance to Support Community Resilience 2016*). These calculated damages herein are: sea level rise, increased Lyme disease costs, resilience grants and expenditures, more intense storms, hurricanes, precipitation and floods, and ski, cod, maple syrup & dairy industries decline.

2.1 Costs of Resilience Inaction are Substantial & Lasting. Resilience Must Address Correlative Risk.

"The costs of inaction are persistent and lasting. Benefits from climate change may be brief and fleeting - for example, climate does not stop changing once a farm benefited from temporarily improved growing conditions. In contrast, costs of inaction are likely to stay and to increase." (*Severe Climate Change Costs Forecast For Pennsylvania, North Carolina, Tennessee, North Dakota, And Other U.S. States*, U. of Md. 2008).

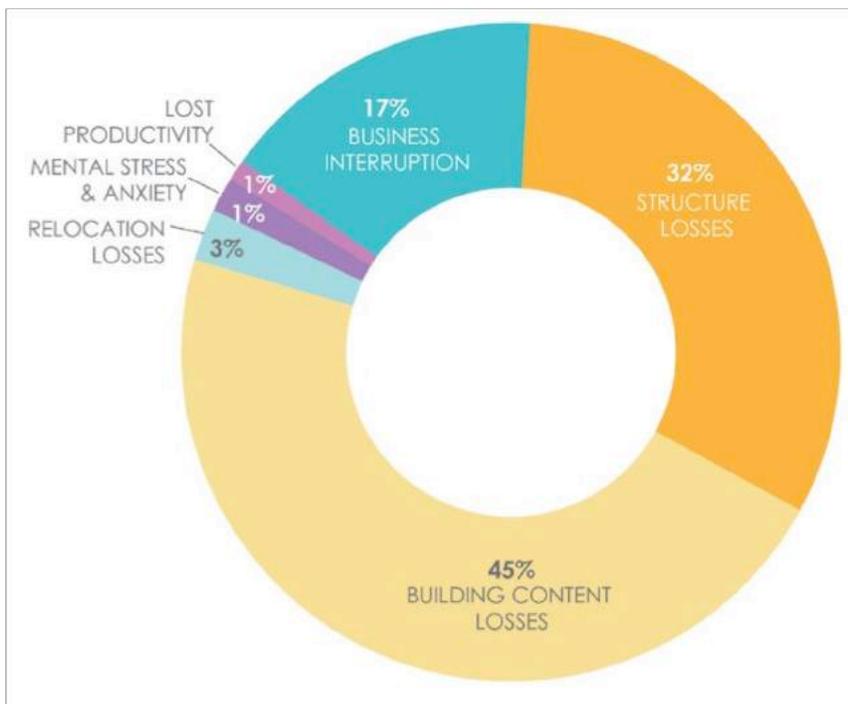
Moreover, to be effective, resilience must take a regional approach and reduce correlative risk, whereby one risk factor can shutdown an entire region, e.g., wastewater treatment plant shutdown from flooding means hospitals can't operate (*RELi National Consensus Resilience Standard 2014 application to Corpus Christi*). Insurers will not come back into the resilience market without a mechanism countering correlative risk.

The \$1.63 trillion in Commonwealth partial Resilience existing, systemic damages are in 11 categories calculated below and aggregated in the Damage Table on page 22. These damages are identified by the Commonwealth, its municipalities, constituents, federal government, and leading researchers.

2.2 Lack of Insurance / Reinsurance Exacerbates Damages.

The impact of these damages is far greater since insurers and reinsurers have pulled out of the resilience insurance market, determining that climate change is an uninsurable risk (*Green Bond Business Case 2014*). Instead reinsurers are marketing catastrophe bonds which on a project-by-project basis, are a form of reinsurance that spread out reinsurance risk and costs to investors and away from the reinsurers.

CITY OF BOSTON ANNUALIZED LOSSES
36 INCH SEA LEVEL RISE CONDITION



Boston City Resilience, City of Boston 2016

2.3 Substantial, Partial Existing Massachusetts Climate Impacts & Damages.

The following are some of the key Commonwealth resilience damages in addition to floods and storms, however, many other exist that are not included herein, since additional research is required to quantify damages.

- Accelerating sea level rise of 2' – 6'
- 71% increased intensity of precipitation, storms, and 9% increased peak floods
- Losses to fisheries including loss of the cod industry
- Increased cost of health care including from increase Lyme due to warming
- Losses to maple syrup production

- Losses to the ski industry from less snow
- Losses to agriculture including dairy

2.4 Massachusetts Resilience Damage Assessment and Calculation. The US Climate Assessment Report (2014) documents the following four primary recognizable existing climate damages to the Commonwealth:

1. **71% more intense precipitation**
2. **~ 9% higher peak floods**

“As the sea level continues to rise, the likelihood of major floods will increase from a 1% annual chance to a monthly reality.” (Climate Ready Boston, City of Boston 2016 at 23).

* * *

“Coastal and riverine flooding can disrupt the Critical infrastructural systems—including transportation, energy, communication, and essential facilities—on which Bostonians rely.” Boston City Resilience, City of Boston 2016 at 26).

* * *

“Stormwater flooding and extreme heat are evaluated as frequent or chronic hazards 1 that gradually degrade personal and economic well-being and directly expose parts of every neighborhood in Boston. Coastal and riverine flooding is expected to be an acute hazard for much of the remainder of the century, experienced through major storm events with immediate and long-lasting impacts. Moreover, as sea levels continue to rise, coastal flooding from high tides is expected to become a chronic hazard, potentially flooding many low-lying neighborhoods along the waterfront on a monthly basis. This is in addition to acute storm events, which are expected to become more severe and cause greater damage over time.” (Climate Ready Boston, City of Boston, 2016 at 13).

3. **Higher coastal storm surges from more intense storms primarily due to increasing sea surface temperatures, a key engine of hurricanes and other storms (US Climate Assessment Report Extreme Weather, Introduction):**

“Coastal flooding is predominantly caused by storm surges that accompany hurricanes and other storms that push large seawater domes toward the shore. Storm surge can cause deaths, widespread infrastructure damage, and severe beach erosion. Storm-related rainfall can also cause inland flooding and is responsible for more than half of the deaths associated with tropical storms. Climate change affects coastal flooding through sea level rise and storm surge, and increases in heavy rainfall during storms.”

4. **2’-6’ accelerating rising seas**

These preceding major damage categories are expected to increase and expand to new major categories given that (1) atmospheric CO2 concentrations have risen above 400 parts per million (ppm), (2) are continuing to rapidly rise, (3) 350 ppm and below are recognized as the safe level, (4) higher than 350 ppm is the dangerous level (Green Bond Business Case 2014). and (5) IPCC and US Climate Assessment Report did not incorporate in their assessments, the *positive feedback loops / accelerators* identified above at the request of the Defense Department. Further, for Massachusetts sea level rise, it is also being accelerated by naturally occurring subsidence (Massachusetts Climate Change Adaptation Report Sept. 2011).

The Commonwealth concluded that its economic sea level rise damages will be unprecedented:

“Since a large percentage of the state’s population, development, and infrastructure is located along the coast, the impact of this change will be significant, putting the Massachusetts economy, health, natural resources, and way of life at risk.” Id. at 2)

* * *

“A sea level rise of 0.65 meters (26 inches) in Boston ... could damage assets worth an estimated \$463 billion.” (Id. at 2).

* * *

“Regarding infrastructure, the most significant vulnerability of existing structures stems from the fact that they were built based on historic weather patterns, not taking into account future predicted changes to sea level, precipitation, or flooding. This puts the infrastructure at increased risk of future damage and economic costs (Id. at 4).

* * *

“Boston ranks fourth among U.S. cities with the greatest predicted risk of asset exposure due to sea level rise” (Id. at 23).

* * *

“Responding to these impacts with solutions such as large-scale engineering would require significant capital investments, which would be costly to residents, businesses, and governments alike. Difficult decisions and trade-offs will potentially need to be made, therefore, about abandonment, relocation, and fortification of the state’s natural and manmade systems. The construction of seawalls, which is one way to counter the effects of sea level rise (Lenton, 2009), could cost \$5 to \$21 million per linear mile (Union of Concerned Scientists, 2009)— and would come at the cost of other important natural processes. A physical barrier such as a sea wall can deprive beaches of necessary sediment that flows in with the tide, and many recreational beaches can be lost. Other structural solutions would also be expensive. For example, elevating a single family home by two feet could cost \$22 to \$62 per square foot (Union of Concerned Scientists, 2009) depending on a building’s foundation type (Jones et al., 2006). Another option— managed retreat (allowing the coastline to move inland in specified locations as a response to sea level rise)—would affect property values as land and structures are subsumed by the rising sea. (Id. at 24).

Accordingly, Massachusetts buildings, homes and infrastructure must be made resilient now to deal with these growing damages that are extraordinarily expensive.

“STORMWATER FLOODING

Without improvements, the existing stormwater system will not be capable of conveying a 10-year, 24-hour rainfall event, causing untreated stormwater runoff to pond in the streets. Further, the system currently struggles to convey the current 10-year, 24-hour rainfall event.” (Climate Ready Boston, City of Boston, 2016 at 41.)

* * *

“Office, retail, and service-based commercial buildings are among the top impacted buildings in terms of numbers for all sea level rise conditions. (Id. at 57).

2.5 Sea Level Rise Protection Costs of \$326 Billion. The urgency of protection from sea level rise is underscored by new peer-reviewed findings that during the last glacial melt 10,000 years ago, sea level rise was extremely rapid, rising about six feet in 10 years (*Scientific American / Nature Communications*, “Oceans Can Rise in Sudden Bursts,” Oct. 19, 2017).

The Commonwealth has 1,519 miles of tidal coastline according to NOAA, about half of which is urbanized (US Census Bureau Map 2010) with a mature built environment where the most expensive resilience costs exist. Massachusetts coastline population density averages more than 1,000 people per square mile, which along with Rhode Island, New York and New Jersey, is the densest in the US (*Coastal Population Trends in the US: 1960 – 2008*, US Census Bureau 2010), thus increasing resilience costs for sea level rise. Boston’s coastal population increased by more than 250 people per square mile from 1960 to 2008, and was 3.4 million in 2008. There are 1,466,029 coastal housing units in the Commonwealth (*Id.*).

Sea Walls or Comparable Remedies. About one half of the Commonwealth’s 1,519 miles of coastline or 760 miles of urbanized tidal coastline, need to be protected by sea walls or natural systems or a combination thereof. Seawalls cost about \$.06 million to \$44 million per linear mile (*Sea Walls*, Climate TechWikki / UN Environment Program 2010). This totals from \$456 million to \$33 billion. The \$33 billion figure is used since such a massive and complex construction undertaking has never been done before in the US and the uncertainties and resultant cost increases will occur. Also, maintenance costs are expensive and are not included in this estimate.

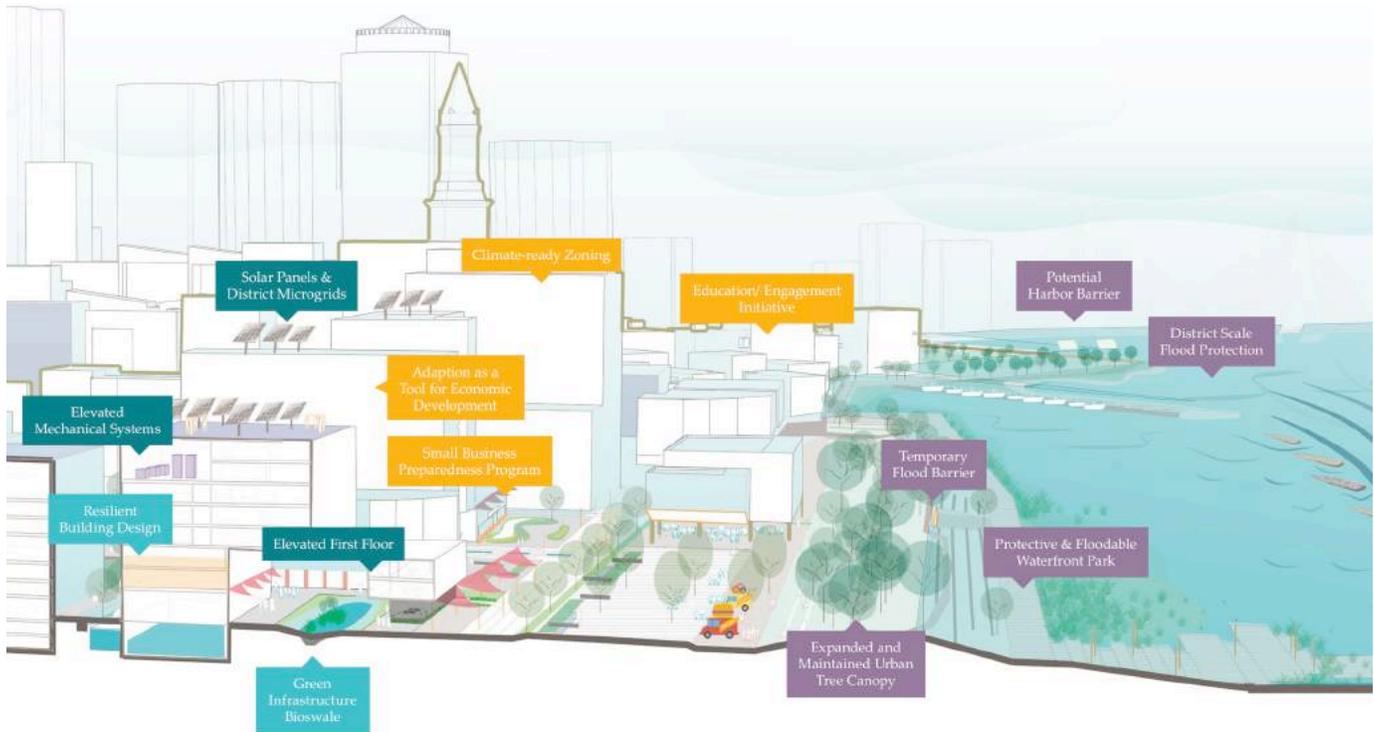
For those non-metropolitan coastal areas where sea walls are cost prohibitive, Massachusetts 2008 home size was 2,091 square feet (Census Bureau 2010), and the preceding quoted Union of Concerned Scientists' cost estimates for elevating a single family home are \$22 to \$62 per square foot. Assuming that one third of the 1.5 million coastal homes are outside the area that is cost-effective for sea walls, some 488,676 coastal homes need to be elevated if feasible. This totals \$22.5 billion - \$63 billion. The \$63 billion figure is used since such a massive and complex construction undertaking has never been done before in the US and the uncertainties and resultant cost increases will occur.

This cost will need to be doubled to \$44 billion - \$126 billion to account for wastewater treatment since these homes are predominantly in areas without sewers, and conventional septic systems will not function in inundated ocean areas and the systems would need to be somehow made resilient but this may be technically infeasible (*Sea-Level Rise to Reduce Effectiveness of Home Septic Systems* Sept. 8, 2016 ecoRI News).

Further cost increases of \$22.5 billion to \$63 billion are required for drinking water which is primarily provided by wells in these areas, since those wells will have to be deepened if feasible, to prevent salt water intrusion.

Accordingly, the costs for sea level rise for homes within areas outside sea walls is so expensive and questionable technically, that the homes will very likely need be removed to higher ground. This stranded asset cost is substantial since Zillow documents that waterfront homes in 2015 are worth twice that of non-waterfront (*What is Waterfront Worth?* 2014). Massachusetts ocean front home sale prices outside dense urban areas average \$600,000 for Sept. – Dec. 2016 (*Mass. Home Prices*, Trulia Real Estate 2017). Stranded costs of the 488,676 coastal homes without sea walls or comparable protection that have to be removed, average \$293.2 billion.

Also, for those areas where sea walls or comparable protection are not cost effective, existing coastal structures other than homes will either need to be made resilient such as elevating where feasible, or removed. Where those facilities are manufacturing, refining, storage, brownfields, or similar properties containing hazardous substances, inundation will cause the release of hazardous substances or other pollution mandating cleanup pursuant to Commonwealth hazardous and regulated substance statutes. The property owner is strictly, jointly, severally, and retroactively liable for those costs which can be very substantial.



Boston City Resilience, City of Boston 2016

2.6 New Financing Mechanisms Are Needed for Bond Debt Service

Because the Cost is Too High. There was a consensus by the multitude of resilience and financial experts at the Oct. 2015 Ballard Spahr Philadelphia Infrastructure Conference, that even with the numerous financial advantages of green + resilient bonds, the public will not be able to afford the debt service due to the unprecedented costs, and thus additional financing mechanisms are needed now. The Ballard Spahr Conference Green Bond Session, mapped for participants with *Surging Seas*, near term inundation from accelerating rising seas of Philadelphia’s tidal areas along the Delaware River:

- Philadelphia Airport
- City’s primary wastewater treatment plant
- City’s waterfront
- By salt water of the City’s drinking water intake requiring relocation upstream

Similarly, the *Surging Seas* maps of Boston below show inundation within the US Climate Assessment Report’s documentation of minimal sea level rise already *in the pipeline* due to the latent effect of warming, to affect about half of the City’s shoreline valued between \$10 million to \$100 per acre, with a sizable amount of City tidal shoreline valued at over \$100 million per acre. Urban Land Institute (ULI) Boston reports on this valuable Boston property that will be inundated unless resilience measures are financed (*Living with Water* 2014 at 24):

“The Back Bay holds some of Boston’s most valuable real estate. Without changes to current infrastructure

the neighborhood is vulnerable to flooding from both Fort Point Channel and the Charles River Dam.” Boston’s historic Back Bay is one of the most walkable mixed-use neighborhoods in the nation – an integration of residential, retail, office, civic uses, and open spaces with easy access to the rest of the city on foot, on bicycles, and by mass transit. It is also among the most valuable real estate in the city. The Back Bay sits on marshland that was filled in over the course of the 19th century. Much of this new land lies less than four feet above today’s high tide.”

Rising seas’ damages have been calculated for Miami Beach by engineering feasibility studies as presented by Plaintiffs at the White House Resilience Conference (Sept. 2016) and at the capital markets’ meeting at S&P Headquarters (Jun. 30, 2015). S&P confirmed to the US Conference of Mayors, its planned climate credit rating downgrades required by law to warn investors of accelerating systemic damages that are well documented by the investor and insurance communities, government, S&P (*Green Bond Business Case 2014*) and Moody’s (2016). Near term engineering costs total an estimated \$1 trillion for Miami Beach alone, with comparable costs for the other urbanized areas of South Florida.

2.7 Partial Damages of \$156 Million to Massachusetts Healthcare. There are a plethora of additional damages that need to be prevented by resilience that have yet to be monetized:

“Predicted impacts of climate change on human health include the potential for increased heat stress; increased respiratory and heart diseases; elevated levels of ozone and particulate matter; higher pollen counts; increased vector-borne diseases; more outbreaks of water-borne diseases; and degraded surface water quality and increased shellfish pathogens. Extreme weather events can disrupt power, sanitary and health care services, and access to safe and nutritious food, while damaging homes and property. The public and private healthcare systems can address climate change-related demands by going through a network-wide climate change needs assessment that examines enhancing regionalization efforts to address nonemergency situations, developing and increasing responsive capacity through collaboration and improved coordination, and potentially relocating vulnerable health care facilities. In addition, there is a need to improve capacity to adequately detect and treat against pests and diseases, achieve and maintain ambient air quality standards, increase outreach to and support for vulnerable populations, and improve indoor air quality.”

“Climate change is also expected to affect many aspects of Massachusetts’ economy and all levels of government. Climate change impacts will put greater stress on governments by increasing demand for emergency and other services. Among industries expected to be affected are weather dependent activities such as agriculture, forestry and fisheries, and other industries such as manufacturing (which includes computers, electronic equipment, fabricated metal, and machinery) and service industries, such as real estate management, tourism and recreation, and health care. Examples of impacts include ... less winter precipitation in the form of snow, which could adversely affect recreation; and higher temperatures adversely affecting outdoor workers, agricultural output, the maple syrup industry, and fisheries populations. ((Massachusetts Climate Change Adaptation Report Sept. 2011 at 4-5).

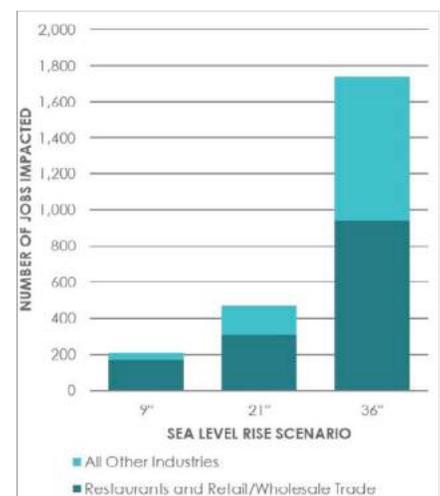
• Existing critical infrastructure, including energy generation, transmission, and distribution; communication networks; drinking and wastewater facilities; roads and highways; railways and subways; shipping, transportation, and cruise terminals; ferry and water transportation terminals and facilities; dams, levees, flood barriers, jetties, and breakwaters; and health care facilities

• Economic sectors, including agriculture and aquaculture, fishing, health care and life sciences, technology, financial services, manufacturing, education, government, and tourism

• Vulnerable groups or populations, including economically disadvantaged communities; densely-populated areas (i.e., urban areas); the elderly, infirmed, and young; and non-English speaking or English-as-second language groups • Natural habitats and ecosystems, including forested, freshwater aquatic, coastal, and marine ecosystems

Climate Ready Boston, City of Boston 2016

EMPLOYMENT IMPACTS OF COASTAL FLOODING



- Community-specific analyses, including local hazards and threats; critical local facilities; local public and private water supplies; businesses; homes and the built environment; cultural and historical sites; and crucial local natural resources” (Id. at 28).

* * *

ANNUALIZED IMPACT TOTALS BY NEIGHBORHOOD AND CITYWIDE BUSINESS INTERRUPTION

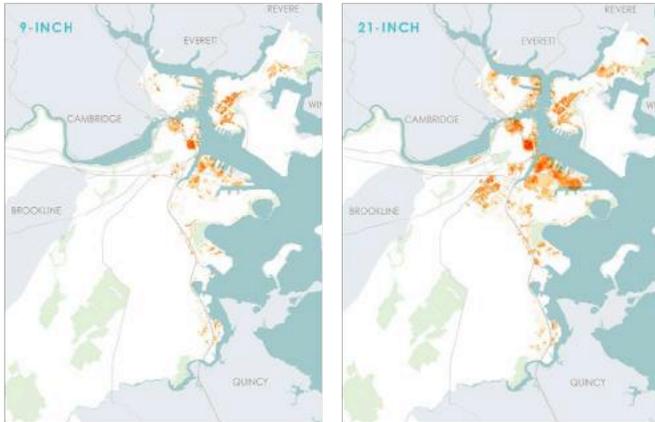
Neighborhood	9" SLR		21" SLR		36" SLR	
	\$	% Boston Total Losses	\$	% Boston Total Losses	\$	% Boston Total Losses
South Boston	\$64.6M	48%	\$191M	37%	\$450M	27%
Downtown	\$44M	31%	\$104M	20%	\$289M	17%
East Boston	\$13.3M	8%	\$87.1M	17%	\$179M	11%
Charlestown	\$8.9M	6%	\$42.8M	8%	\$120M	7%
Dorchester	\$6.2M	4%	\$26.9M	5%	\$92.5M	6%
South End	\$27k	<1%	\$2.2M	<1%	\$218M	13%
Roxbury	<\$1k	<1%	\$189K	<1%	\$33.8M	2%
Back Bay	<\$1k	<1%	\$72K	<1%	\$7.4M	<1%
Allston	<\$1k	<1%	\$254K	<1%	\$7.1M	<1%
Fenway/Kenmore	<\$1k	<1%	<\$1k	<1%	\$1.6M	<1%
Harbor Islands	\$252k	<1%	\$284K	<1%	\$328K	<1%
Citywide Business Interruption	\$19.7M	13%	\$63.8M	12%	\$283M	17%
Boston Total	\$157M		\$518M		\$1.68B	

Climate Ready Boston, City of Boston 2016

ANNUALIZED DIRECT PHYSICAL DAMAGE, STRESS FACTORS, AND DISPLACEMENT COSTS FOR THE 36" CLIMATE CONDITION BY NEIGHBORHOOD

	DIRECT PHYSICAL DAMAGE	STRESS FACTORS	DISPLACEMENT COSTS	TOTAL
South Boston	\$431M	\$4.7M	\$14.3M	\$450M
Downtown	\$276M	\$5.4M	\$7.3M	\$289M
South End	\$193M	\$14.1M	\$10.9M	\$218M
East Boston	\$163M	\$10.2M	\$6.4M	\$179M
Charlestown	\$115M	\$2M	\$3.4M	\$120M
Dorchester	\$86M	\$3.2M	\$3.4M	\$92.5M
Roxbury	\$32.6M	\$240K	\$970K	\$33.8M
Back Bay	\$6.6M	\$470K	\$310K	\$7.3M
Allston	\$7M	\$30K	\$120K	\$7.1M
Fenway	\$1.5M	\$120K	\$50K	\$1.6M
Harbor Islands	\$320K	-	\$10K	\$330K
Boston Total	\$1.3B	\$40.4M	\$47.1M	\$1.4B

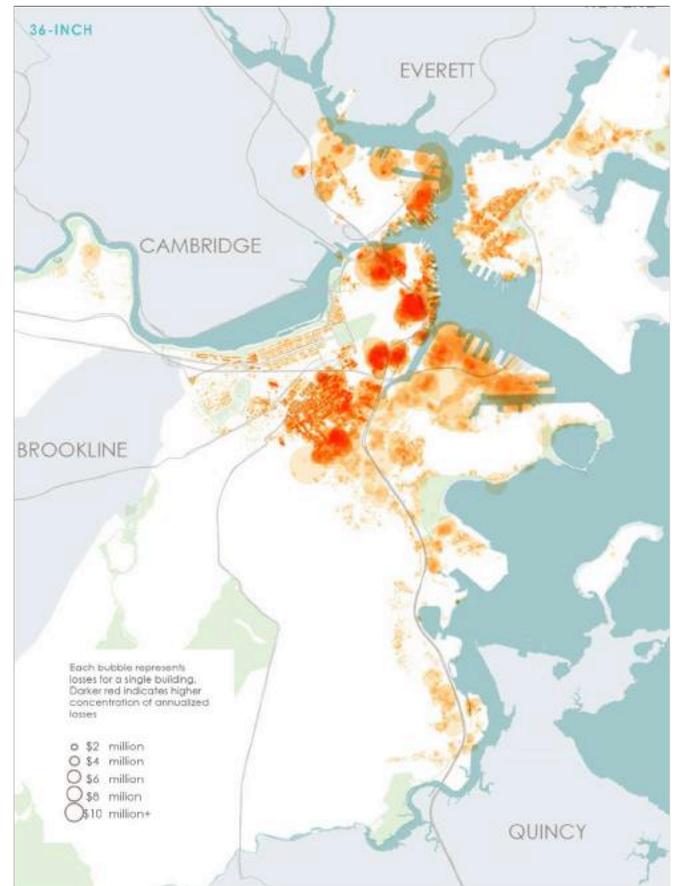
ANNUALIZED LOSSES FROM BUILDINGS,
9-INCH, 21-INCH, AND 36-INCH SEA LEVEL RISE CONDITIONS



The above map demonstrates expected annualized structure and contents losses per building for the 36-inch sea level rise condition.⁸⁰

⁸⁰ These expected losses only address the building stock current to 2016 and do not take into consideration development changes or adaptation. Each bubble depicts a single structure, with the size of the bubble demonstrative of the magnitude of expected impacts to that structure. Concentrations of loss are depicted with darker colors.

High-rise buildings, concentrated in Downtown and South Boston, show heavier impacts for several reasons. Not only are these structures larger, but they typically penetrate more deeply into the earth to accommodate their size and have more sophisticated and costly mechanical, electrical, and plumbing systems, often located in the basements of these structures. Impacts to residential structures, however, should not be discounted. The majority of loss expected throughout the city will be to residential properties.



Climate Ready Boston, City of Boston 2016

*“In general, public health impacts from climate change are predicted to include **increases** in:*

- *Number of residents experiencing heat stress*
- *Exacerbation of respiratory and cardiovascular diseases*
- *Exacerbation of asthma and allergies*
- *Illnesses associated with degraded water quality*
- *Geographic range and frequency of vector-borne diseases*

Vulnerable populations - especially those with pre-existing health problems (e.g., asthma, cardiovascular disease), limited resources, and in close proximity to areas of greater risk (e.g., flood zones, living on the coast) - are most at risk to climate-related impacts. DPH/BEH is working with local health and municipal partners and other state and federal agencies to address the environmental and community health impacts of climate change.” (Mass. Environmental Public Health Tracking – Climate Change, Mass. Dept. of Public Health 2016).

* * *

“EXTREME HEAT IMPACTS

With climate change, Boston will experience both increasing average temperatures and increasing frequency, duration, and intensity of heat waves. While temperatures are hottest in areas of the city that experience localized urban heat island effects, on very hot days, the entire city is at risk for the negative impacts of extreme heat.

Extreme heat can cause negative health impacts, including direct loss of life, increases in respiratory and cardiovascular diseases, and challenges to mental health. In the baseline period (1985 to 2016), the heat-related mortality rate was about 2.9 per 100,000 people in Boston. During the 2020s, this rate is expected to more than double. By the 2080s, this rate may more than triple to 10.5 per 100,000 people under a moderate emissions reduction scenario or reach as high as 19.3 per 100,000 under the business-as-usual emissions scenario. Climate change can also harm air quality, leading to increasing risks for diseases such as asthma. Health impacts will be especially significant for populations such as older adults, children, and the medically ill.

Heat can have negative consequences for Boston's infrastructure, presenting further challenges for health and quality of life. Power failures are more likely during heat waves due to the increased demand for electric power for air conditioning, as well as the added stress of the heat on mechanical and electrical assets. High temperatures can also cause thermal expansion in roads and railroad tracks, leading to damage or requiring speed reductions. As rising temperatures lead to a potential increase in tree mortality, any loss of canopy coverage or green space will only contribute to the urban heat island effect, reduced air quality, increased stormwater runoff, and decreased quality of life." (*Climate Ready Boston, City of Boston 2016* at 24).

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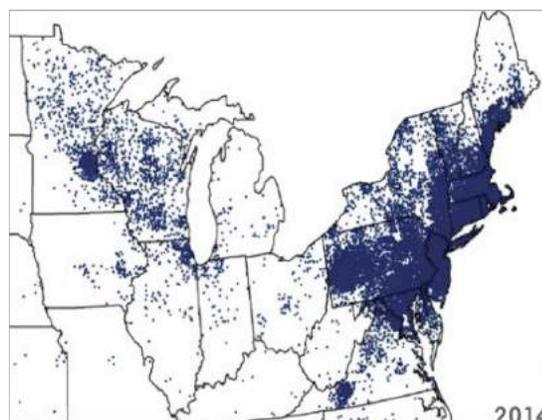
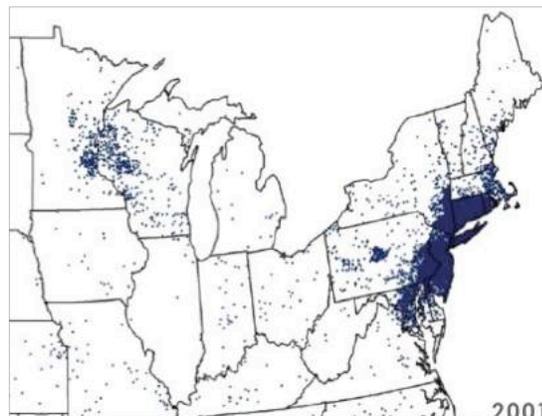
"Mortality rates due to extreme heat are expected to triple with the impacts of climate change in Boston." (*Climate Ready Boston, City of Boston, 2016* at 37).

* * *

"Changes in average temperatures can also impact transmission of vector-borne diseases.

Mosquitoes and the diseases they carry are highly sensitive to weather phenomena such as temperature, rainfall, and humidity. For example, rain provides still water for mosquitoes to breed, while drought conditions decrease survival; rising temperatures can enhance the rates of larval development, adult feeding behavior, and pathogen development within the mosquito. Climate change and associated warmer, wetter conditions may increase the risk of vector-borne disease infection, including Lyme disease. Of particular concern are potential future impacts related to the diseases carried by the mosquito *Aedes albopictus*, which is present in the northeastern United States but has not thrived to date because of the constraining influence of cold winters. This mosquito transmits dengue fever and chikungunya and may also carry Zika virus." *Id.* at 39).

Climate Ready Boston, City of Boston 2016



CHANGES IN LYME DISEASE CASE REPORT DISTRIBUTION

Maps show the reported cases of Lyme disease in 2001 in 2014 for the areas of the country where Lyme disease is most common (the Northeast and Upper Midwest). Both the distribution and the numbers of cases have increased. (Figure source: adapted from CDC 2015)

Existing \$156 Million Added Cost of Lyme Disease From Warming. Massachusetts incidence of Lyme was 32,696 confirmed cases from 2004 to 2015 (*Reported cases of Lyme disease by state or locality, 2005-2015, Centers for Disease Control (CDC), Lyme Disease Home, Statistics.* "Lyme disease has been a nationally notifiable condition in the United States since 1991"). Lyme is undiagnosed by 20-40% and underreporting of confirmed case is 90% since:

1. CDC states that doctors fail to report the confirmed case which is similar to other disease reporting.

"Each year, approximately 30,000 cases of Lyme disease are reported to CDC by state health departments and the District of Columbia. However, this number does not reflect every case of Lyme disease that is diagnosed in the United States every year. Surveillance systems provide vital information but they do not capture every illness. Because only a

fraction of illnesses are reported, researchers need to estimate the total burden of illness to set public health goals, allocate resources, and measure the economic impact of disease. CDC uses the best data available and makes reasonable adjustments—based on related data, previous study results, and common assumptions—to account for missing pieces of information.” (How Many People Get Lyme Disease? Lyme Disease Home, Statistics. CDC)

2. Disease symptoms are similar to other well-known diseases making diagnosis difficult.

(See Lyme Overlap With Other Diseases, Columbia University Medical Center Lyme and Tick-Borne Disease Research Center: "Are there any diseases that can be misdiagnosed as Lyme disease? Lots of diseases could be misdiagnosed as Lyme disease. This of course makes sense when you know that Lyme disease itself may manifest as a multisystemic disorder that can mimic other diseases. This means that just as the Lyme disease might be "missed" in some cases, some individuals may be misdiagnosed as having Lyme disease when in fact they have another disease").

3. It usually takes from 3 - 30 days after being bitten by a tick to develop the initial symptoms of Lyme disease (*id.*) and thus the delay in symptoms can cause a lack of association of the tick bite with the resulting disease.

4. Also making diagnosis difficult is the fact that only about 60-80% of Lyme disease cases have the bulls-eye skin rash known as erythema migrans -- latin for migrating redness. "According to the Centers for Disease Control (2008), erythema migrans occurs in 60-80% of Confirmed cases" (*What percent of cases of reasonably proven Lyme disease present without erythema migrans? Columbia University Medical Center Lyme and Tick-Borne Disease Research Center*).

5. Further and *[c]*ontrary to popular opinion, only about 10% to 15% of erythema migrans rashes are true bull's-eyes," Shapiro told Infectious Disease News. "About two-thirds are uniformly red or they have enhanced central erythema, but they don't necessarily have that clear area around it; some do, but it's relatively uncommon." (*Lyme disease underreported, incidence still on the rise, Infectious Disease News, Jan. 2014. Eugene Shapiro, MD, is professor of pediatrics and epidemiology at the Yale School of Public Health*).

"Blood tests for Lyme disease have "very good sensitivity," according to the CDC, meaning they're quite good at detecting antibodies produced by the body in response to the infection. But like most medical tests, they have their limitations. Because the two tests look for antibodies, they can give false negative results during the first few weeks after exposure to the bacterium -- a window of time during which the body is still mounting its response to the infection. That's why the tests should be performed four to six weeks after a tick bite." (Myths About Lyme Disease, Kate Moisse, ABC News Aug. 21, 2013).

* * *

"The CDC clinical criteria for Lyme Disease which exist for the purpose of monitoring the rate of Lyme disease nationally are quite narrowly defined in order to ensure a high degree of specificity in the diagnosis. These criteria are mainly useful for the early stages and rheumatological presentations of Lyme Disease, such as when a patient appears with an erythema migrans rash, arthritis, a Bell's palsy, or early central neurologic Lyme disease (meningitis or encephalitis). The CDC criteria are not very helpful for helping the clinician to detect late stage neurologic Lyme Disease. For example, the most common manifestation of late neurologic Lyme Disease is cognitive dysfunction (often referred to as "encephalopathy"). A patient who presents with new onset encephalopathy and a positive blood test for Lyme Disease would not be considered by the CDC to be a case of Lyme disease. Although the CDC recognizes that Lyme encephalopathy exists, encephalopathy is not part of the "surveillance case definition". Hence, physicians who rely on the narrow surveillance case criteria of the CDC for clinical diagnosis will fail to diagnose some patients who in fact do have Lyme disease; in these cases, the patient's treatment will either not occur or be delayed. Such delay in treatment may result in an acute treatable illness becoming a chronic less responsive one." (THE LYME DISEASE CONTROVERSY, Columbia University Medical Center Lyme and Tick-Borne Disease Research Center

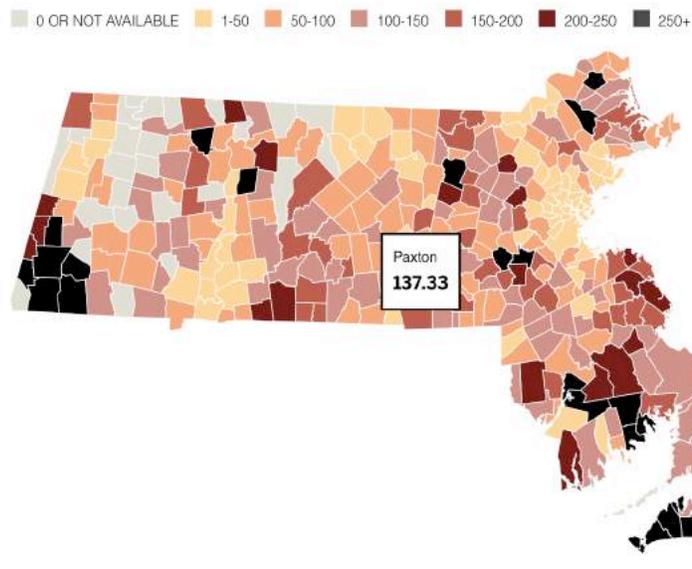
Given the preceding data that the 32,696 cases of Lyme in the Commonwealth is low due to 20% - 40% of cases are undiagnosed, and only 10% of the confirmed cases are reported, a conservative estimate is that there are actually 50% more cases. Thus the real number of cases is 32,696 plus 50% more or 49,044 cases.

Average per person 2015 costs for Lyme are \$10,343 based on CDC data and include treatment, insurance, and lost productivity, but not pain and suffering. In 2002, the annual cost per person was \$8,712. Average cost from 2004 - 2015 is \$9,528.

Given that the substantial recorded growth of climate impacts including annual average temperature increases since 2000, the growth of Lyme due to climate impacts including warming creating a more conducive environment for ticks, has been a primary cause of the doubling of

Lyme disease rates in Massachusetts

A town-by-town look at reported confirmed & probable cases per 100,000 residents between 2010 and 2014.



Massachusetts Dept. of Public Health 2015

Northward Range Expansion. Vector & Vector Borne Diseases | Climate & Health Assessment," Climate & Health Assessment, GlobalChange.gov, US Global Change Research Program (2014); "Effects of Climate on Variability in Lyme Disease Incidence in the Northeastern United States," American Journal of Epidemiology (Mar. 15, 2003); "The Rise in Tick-Borne Diseases: Is Climate Change Responsible?" ("Although data support a link between climate change and increased transmission of tick-borne diseases, there are numerous confounding variables.") Clinical Correlations, NYU Langone Online Journal of Medicine (June 4, 2014); "In a warmer world, ticks that spread disease are arriving earlier, expanding their ranges," Cary Institute of Ecosystem Studies (Feb. 18, 2015); "Climate change may spread Lyme disease. Balmy seasons have already expanded the territory of the ticks that carry the bacteria," Science News (Mar. 19, 2014); "CLIMATE CHANGE INCREASES IN THE NUMBER AND GEOGRAPHIC RANGE OF DISEASE-CARRYING SECTS AND TICKS," CDC & American Public Health Association (Circa 2014)).

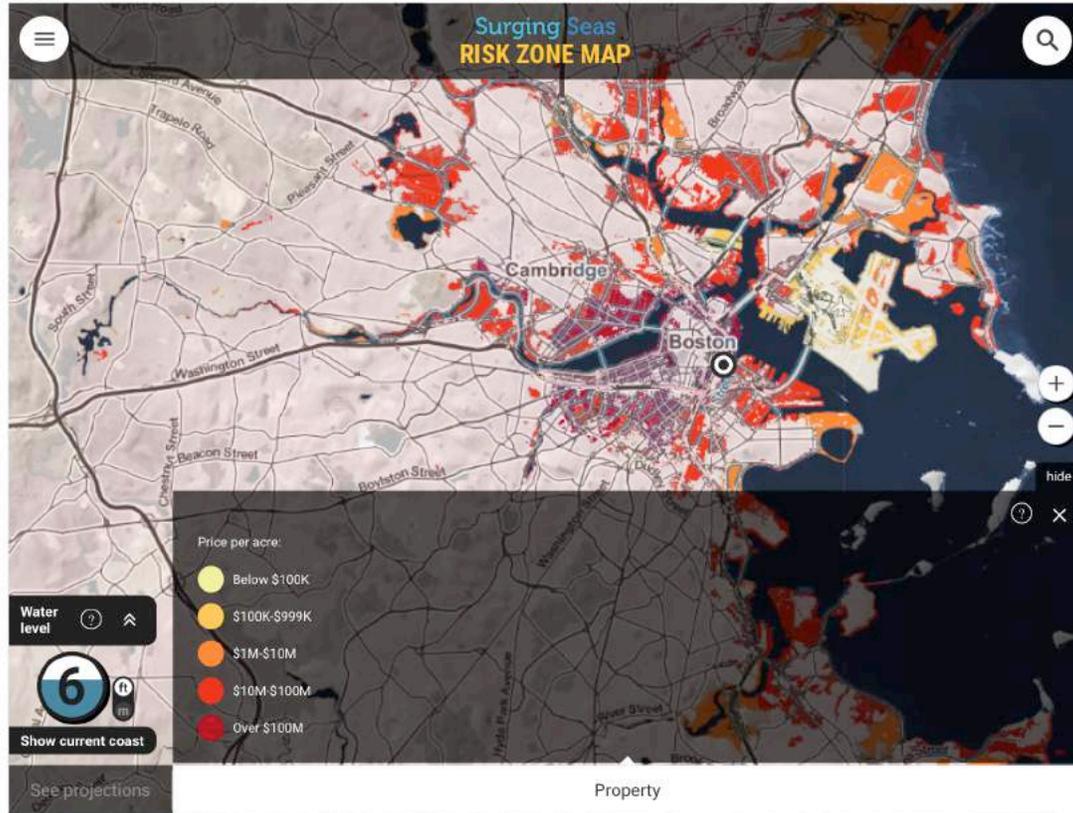
Thus a conservative assumption is that 50% of the 32,696 cases in Massachusetts were attributable to warming, or 16,348 cases.

Since RELi includes Community Quality of Life - COMPREHENSIVE ADAPTATION + MITIGATION FOR A RESILIENT PRESENT + FUTURE (RELi Action List 2015) which can cover increased disease, this Lyme damage calculation is relevant and appropriate. Total damages equal the number of cases (16,348) times the average cost per person (\$9,528) or \$155.764 million.

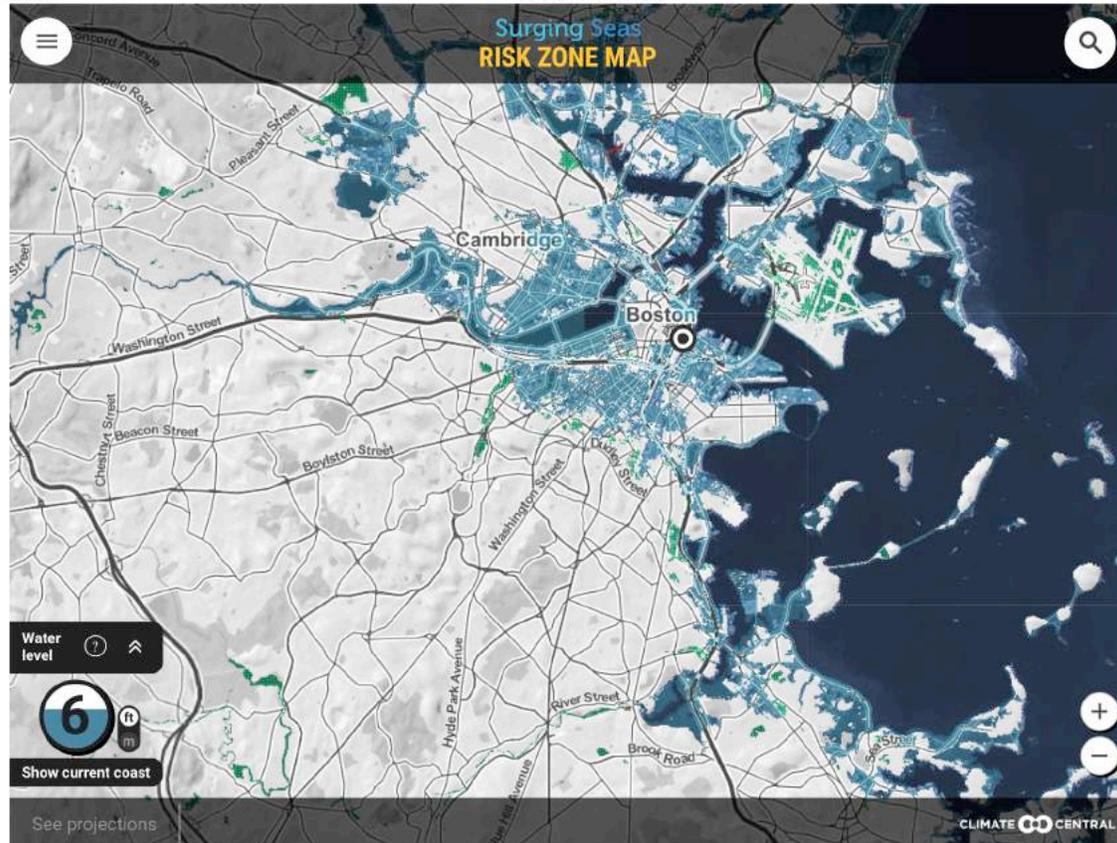
2.8 About \$300 Million in Resilience Grants and Bond Expenditures. The Commonwealth provided \$9 million to communities for resilience finance planning grants (Coastal Zone Mgt. Program 2016), and enacted legislation in 2014 appropriating \$150 million for environmental bonds for coastal infrastructure improvements and resilience (*Rising Tides and Costly Damage*, South Coast Today, Dec. 21, 2015). Another \$50 million was spent for resilience grants and infrastructure repair as announced by Governor Deval Patrick (*Massachusetts Governor Unveils State Climate Action Plan*, Triple Pundit Jan. 15, 2014). Thus, total Massachusetts resilience grants and bonds that have been reported are \$209 million.

confirmed Lyme cases from 2004 – 2015.

("Climate change is speeding up the spread of Lyme disease," STAT, (July 1, 2016) (with links to Journal of Medical Entomology studies); "Effect of Climate Change on Lyme Disease Risk in North America," Ecohealth. 2005 Mar; 2(1): 38–46; "With Climate Change, Ticks Are Moving On Up, Spreading Lyme Disease And Other Tick-Borne Diseases To New Parts Of The Country," Medical Daily (May 11, 2015) ("it's likely that warming temperatures have and will spread ticks to more parts of the world; we don't have a firm grasp of how and where exactly this will happen."); "Climate change may affect tick life cycles, Lyme disease," Oregon State University News, News and Research Communications (Feb. 17, 2015); "Key Finding 2: Earlier Tick Activity and



<http://ss2.climatecentral.org/#12/42.3559/-71.0596?show=property&projections=0-RCP85-SLR&level=6&unit=feet&poi=hide>



<http://ss2.climatecentral.org/#12/42.3464/-71.0384?show=satellite&projections=0-RCP85-SLR&level=6&unit=feet&poi=hide>

2.9 More Intense Winter and Summer Storms are Being Experienced

Costing an Added \$442 Billion. NASA reports from the MIT recognized expert on the subject Kerry Emanuel, that Atlantic hurricanes are 60% more powerful than in 1970 including from well-documented rising sea surface temperatures (*In a Warming World, the Storms May Be Fewer But Stronger*, NASA 2016). The February 2015 extreme snowstorm in Massachusetts had damages exceeding \$1 billion (*Billion-Dollar Weather and Climate Disasters*, NOAA 2016).

Using damages from Hurricane Sandy as the most recent Atlantic hurricane to strike land in the Northeast with the epicenter in New Jersey, Sandy costs for New Jersey were \$36.9 billion (*Christie Administration Releases Total Hurricane Sandy Damage Assessment of \$36.9 Billion*, Governor's press release Nov. 28, 2012). Sixty percent of \$36.9 billion is \$22.1 billion which is the amount attributable to warming. Assuming one summer storm and one comparable winter storm every ten years for 100 years, total hurricane and storm damages to the Commonwealth are \$442 billion.

2.10 Added Cost of \$1.63 Trillion to Massachusetts' Built Environment from Existing & Accelerating 71% More Intense Precipitation & 9% Increased Peak Floods.

Only about 10% of Boston is inundated by a 24 inch sea level rise based on the *Surging Seas* two foot sea level rise map, but this inundated portion of the City's built environment is valued at \$463 billion (*Massachusetts Climate Change Adaptation Report* Sept. 2011 at 2). Based on the total area of this inundated area of the city to the total city area, total Boston built environment value is \$4.63 trillion and is subject to the more intense precipitation and peak floods.

Boston comprises 11% of Massachusetts' population with Census Bureau 2014 population of Massachusetts at 7 million including cities near Boston and its populated suburbs, and Boston has 645,966 people (2013). Using this ratio, the value of Massachusetts' built environment is roughly \$21.6 trillion based on Commonwealth data.

Upgrades to ensure this built environment can withstand existing and accelerating 71% more intense precipitation and 9% higher peak floods, must either resize the built environment, and / or construct natural remedies to reduce the more intense flows. The Cost of this substantial upgrade including for greater future climate intensity, is estimated at about 10% of the built environment value, or \$2.16 trillion.

Validating Calculation. The 2016 assessed value of downtown Boston commercial real estate in the Business Improvement District (BID) is \$9.9 billion plus market value including residential with over 4,711 new apartment and condo units added since 2000 with over \$1 billion in assessed value (*Transformation of Downtown Crossing*, a report from the Downtown Boston Business Improvement District, 2016). Market value of downtown real estate averages 20% more than assessed value (see *Towering numbers: Boston's highest-valued commercial real estate*, Boston Business Journal Aug. 14, 2014; *Assessed Value vs Market Value*, Sotheby's Boston June 28, 2012).

Downtown Boston Improvement District 2015 population was 8,000 (*Doing Business Downtown*, Boston Business Improvement District (BID) 2017). Boston 2015 population according to the Census is 617,594 about 77 times greater. Thus the value of Boston built environment excluding infrastructure is about \$762 billion based on population ratio. Massachusetts 2015 Census population was 6.8 million or 11 times greater than Boston's bringing Massachusetts built environment value excluding infrastructure to about \$8.4 trillion based on this population ratio.

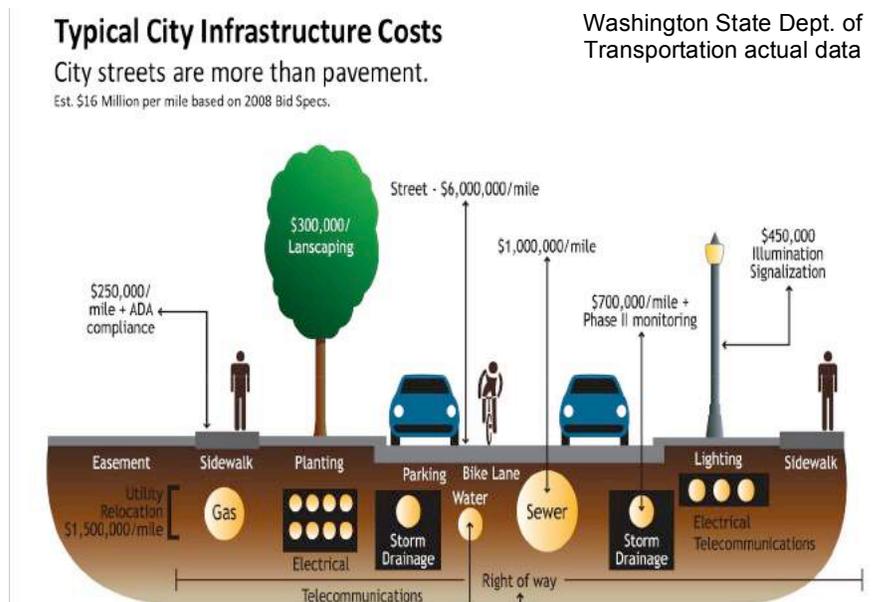
Massachusetts infrastructure in 14 categories needs to be made resilient from well-documented, existing and accelerating more intense precipitation and floods, and higher winds, and includes (Mass. 2013 Infrastructure Report Card):

1. Sewers including storm and combined and natural systems to reduce flows
2. Wastewater & drinking water treatment plants
3. Roads & highways
4. Bridges
5. Airports
6. Rail, subway & stations
7. Ports
8. Inland waterways
9. Dams & levees
10. Solid waste recycling & disposal facilities
11. Parks
12. Schools
13. Telecommunications & IT including overhead and underground wires
14. Energy, electrical including overhead and underground electrical wires, substations, and generating facilities

According to our research and NYU cited in Bloomberg (IS U.S. INFRASTRUCTURE MORE EXPENSIVE? NYU Marion Institute June 2, 2015), data on average US infrastructure costs are sparse. Consequently, actual data are used herein for the calculations. The Boston Business Improvement District Map shows 17 streets in a north - south direction (2.4 miles long), and 22 streets in an east – west direction (2.4 miles long). Boston BID is a

rectangular area in the center of the downtown peninsula between the Boston Harbor and the Charles River. The total of street miles in the BID is 17 x 2.4 miles (41) + 22 x 2.4 miles (53), or 94 street miles. Actual data on city infrastructure costs as shown in the preceding Figure are \$16 million per mile excluding rail, subway, treatment facilities, stations and operating facilities as well as airports and schools. Thus this partial infrastructure cost is very conservative and is \$16 million times 94 miles or \$1.5 billion for the value of infrastructure in the BID.

Based on a population ratio above whereby Boston’s population is 77 times greater than BID, Boston infrastructure value is 77 times \$1.5 billion or about \$116 billion. Massachusetts population is 11 times greater than Boston, thus total Massachusetts infrastructure value \$116 billion times 11 or about \$1.276 trillion.



Importantly, this value excludes the cost of operation and maintenance (O&M). Using Congressional Budget Office 2000 – 2019 calculations of \$53 billion for US O&M costs for water and wastewater infrastructure and \$30 billion for capital costs, capital costs are 57% of O&M costs, thus O&M costs are 43% greater (*Future Investment in Drinking Water and Wastewater Infrastructure* May 2002). Forty-three percent of \$1.276 trillion value of Massachusetts infrastructure is \$549 billion, thus total Massachusetts infrastructure value is about \$1.825 trillion.

However, Massachusetts infrastructure ranks 42d out of 50 States in quality of infrastructure with a #50 ranking as the worst (*America's Top States for Business 2016*, Infrastructure Category, CNBC):

- Bridges
- Stormwater
- Wastewater
- Drinking Water
- Roads
- Transit
- Waterways

This existing deficiency in existing critical infrastructure adds about 30% to infrastructure resilience costs since so much is failing now and resilience upgrades can't be effective without making the existing infrastructure functional.

An additional 30% to resilient infrastructure costs from existing critical deficiencies raises \$1.825 trillion of Massachusetts infrastructure value for purposes of resilience total to about \$2.373 trillion. The value of Massachusetts built environment excluding infrastructure calculated above is about \$8.4 trillion. Thus, total Massachusetts built environment value is about \$10.773 trillion.

Upgrades to ensure this built environment can withstand existing and accelerating 71% more intense precipitation and 6% higher peak floods, must either resize the built environment, and / or construct natural remedies to reduce the more intense flows. The Cost of this substantial upgrade including for greater known future climate intensity based on its well-documented latency, is estimated at about 10% of the built environment value, or \$1.0773 trillion.

Final Calculation. Taking the mean of the two preceding calculations, the estimated average cost of this substantial Massachusetts upgrade is \$1.63 trillion.

2.11 Damages of \$110 Million From Maple Syrup Losses. Massachusetts 2016 maple syrup production was 77,000 gallons and the price averaged \$50.5 / gal. as a \$3.9 million / yr. industry (*NORTHEAST MAPLE SYRUP PRODUCTION*, USDA NATIONAL AGRICULTURAL STATISTICS SERVICE June 15, 2016). Using University of Maryland damages data below, a mean 28% reduction from well-documented warming causes \$1.1 million in damages over a 100 year period which is \$110 million in total damages.

Since RELi includes Community Quality of Life - COMPREHENSIVE ADAPTATION + MITIGATION FOR A RESILIENT PRESENT + FUTURE (*RELi Action List 2015*) which can cover economic losses from adversely impacted industries, this maple syrup damage calculation is relevant and appropriate.

2.12 Partial Damages of \$9 Billion for Losses to the Ski Industry. Massachusetts comprises about 15% of the Northeast ski industry, with a resulting mean regional revenue loss of \$608 million / yr. using University of Maryland data quoted below. Over 100 years for Massachusetts based on expected continued warming due to the latent effect of CO2 already in the atmosphere, this is \$9 billion in total damages.

“In the Northeast, the maple sugar industry – a \$31 million industry – is expected to suffer losses of between 15 and 40% (\$5-12 million) in annual revenue due to decreased sap flow. The region can expect a decrease of 10-20% in skiing days, resulting in a loss of \$405-810 million per year.” (The US Economic Impacts of Climate Change and the Costs of Inaction, University of Maryland, Oct. 2007 at 4).

Since RELi includes Community Quality of Life - COMPREHENSIVE ADAPTATION + MITIGATION FOR A RESILIENT PRESENT + FUTURE (RELi Action List 2015) which can cover economic losses from adversely impacted industries, this ski industry damage calculation is relevant and appropriate.

2.13 Partial Losses \$27.6 Billion to Fisheries. Massachusetts 2015 - 2011 cod fish revenue respectively was \$5.5 million, \$7.5 million, \$8.4 million, \$18.6 million, \$27.6 million (Massachusetts Division of Marine Fisheries 2014 & 2015 Annual Reports & National Marine Fisheries Service Annual Landings 2013 - 2011). Taking 2011 revenue of \$27.6 million over 100 years based on the documented collapse of the cod fishery over recent time from rising sea temperatures due to warming, total damages from cod loss are \$27.6 billion. Existing additional fisheries damages are documented, but have yet to be quantified:

“Sea level rise will inundate marshlands, which act as a buffer against waves, filter pollutants, and provide irreplaceable habitat for wildlife. New England’s marshlands act as nurseries for commercially important species such as lobsters, clams, scallops and herring, and they provide hunting grounds for bluefish and striped bass. In Massachusetts alone, the combined value of these marsh-dependent fish topped \$400 million in 2011. (HOW CLIMATE CHANGE JEOPARDIZES THE NORTHEAST’S ECONOMY AND ENVIRONMENT, Natural Resources Committee – Democrats, Oct. 25, 2012, at 9).

* * *

“Several studies have documented fish populations changing in response to long-term warming. Over the past decade, sea surface temperatures in the Gulf of Maine increased faster than 99% of the global ocean. The warming, which was related to a northward shift in the Gulf Stream and to changes in the Atlantic Multidecadal Oscillation and Pacific Decadal Oscillation, led to reduced recruitment and increased mortality in the region’s Atlantic cod (Gadus morhua) stock.” (Slow adaptation in the face of rapid warming leads to collapse of the Gulf of Maine cod fishery, Pershing et al., Science, Nov. 13, 2015).

Since RELi includes Community Quality of Life - COMPREHENSIVE ADAPTATION + MITIGATION FOR A RESILIENT PRESENT + FUTURE (RELi Action List 2015) which can cover economic losses from adversely impacted industries, this fishery industry damage calculation is relevant and appropriate.

2.14 Partial Losses to Agriculture of \$940 Million. Massachusetts 2014 dairy milk revenue was \$47 million (Mass. Dept. Ag. Resources 2014 Annual Report at 10). The 20% decline in milk production from warming according to the US Global Change Data below, shows reduced revenue of \$9.4 million, which taken over 100 years based on expected continued warming is a total of \$940 million.

“In parts of Connecticut, Massachusetts, New Jersey, New York, and Pennsylvania, a large decline in milk production, up to 20 percent or greater, is projected. Under the lower emissions scenario, however, reductions in milk production of up to 10 percent remain confined primarily to the southern parts of the region. (Report: Global Climate Change Impacts in the United States, U.S. Global Change Research Program) (Massachusetts Fact Sheet on Climate Change, EarthJustice.

Since RELi includes Community Quality of Life - COMPREHENSIVE ADAPTATION + MITIGATION FOR A RESILIENT PRESENT + FUTURE (*RELi Action List 2015*) which can cover economic losses from adversely impacted industries, this dairy industry damage calculation is relevant and appropriate.

2.15 Aggregated \$2.46 Trillion in *Existing*, Partial Damages & Assumptions. Calculated partial resilience costs for the preceding damages to Massachusetts are \$2.46 trillion in the Table below.

Damage assumptions for the following Table of *existing*, partial damages include the facts that:

1. Calculations are based on well-documented *existing* damages including from the US Climate Assessment Report.
2. Warming will continue for many years and thus damages will keep rising no matter what carbon pollution reductions are made due to latent effect of carbon pollutants in atmosphere. Also, leading scientists including the top scientist Jim Hansen, concluded in August 2017 that in addition to carbon pollution reductions, CO2 withdrawal from the atmosphere into stone is needed to keep below 1.5°C / unmanageable dangerous climate change.
3. Damages are very likely to be worse because IPCC and US Climate Assessment Report did not include well recognized *positive feedback loops* / accelerators.
4. Damages are more expensive due the lack of insurance / reinsurance.

2.16 Partial Massachusetts Resilience Costs

where data are available from just 11 out of hundreds of categories of damages

Damages	Basis of Calculation	Cost to the Commonwealth
Mass. Resilient Grant & Bond Programs	Total grants awarded & bonds issued	\$209 million
State Agency & City Resilience Report Costs & Expenditures	Estimated total costs expended	\$100 million
Sea Walls or Comparable Barriers to Rising Seas in Populated Areas	\$44 million per linear mile & 760 miles of populated coast	\$33 billion
Relocation of Coastal Homes in Less Populated Areas Where Sea Walls are not Cost Effective & Resilience is Technically Infeasible	488,676 coastal homes at \$600,000 per home	\$293 billion
Hurricane & Winter Storm Damages	One winter and one summer storm every ten years for 100 years intensified 60% from warming	\$442 billion
Infrastructure & Built Environment Costs for Existing ~ 9% Higher Peak Floods & 71% More Intense Precipitation	Mass. built environment is valued at \$11.6 trillion from Commonwealth data. Extensive upgrades to deal with accelerating, more intense precipitation & higher peak floods over time will cost about 10% of this value.	\$1.63 trillion
50% Increased Lyme Disease From Warming	Average cost of treatment is \$9,528 and number of cases is 16,348	\$156 million
Total Ski Industry Revenue Losses from Warming	\$91.2 million / yr. in losses over 100 yrs. from a mean 28% reduction in annual revenue	\$9 billion
Total Revenue Loss From Collapse of the Cod Fishery from Warming	2011 revenue of \$27.6 million over 100 years from well-documented collapse of cod fishery over recent time from rising sea temperatures	\$27.6 billion
Total Maple Syrup Revenue Loss From Warming	Mean 28% reduction from well-documented warming causes \$1.1 million in damages over a 100 year period	\$110 million
Total Dairy Milk Production Revenue Loss from Warming	Documented 20% annual decline from warming of \$9.4 million, taken over 100 years based on expected continued warming	\$940 million
Total		\$2.46 trillion