New Buildings

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Introduction

According to the U.S. Department of Energy, buildings produce nearly 38% of total greenhouse gas emissions in the US. Based on current projections, the University is expected to add about 0.75% to its building area each year, for a total of 24% by 2050. This growth provides an opportunity to reduce overall emissions by setting ambitious standards for low emitting buildings that will continue to pay financial and carbon dividends to the University over their life span.

This chapter on new buildings and major renovations lays out the issues to be addressed in new construction for the Climate Action Plan and the systems and policies needed to address them. Boston University's Facilities Management & Planning Department has systems in place for Project Planning & Delivery that utilize Design & Construction Standards to deliver high quality projects to the BU community. These existing systems provide the mechanism by which the Climate Action Plan can be integrated and delivered for new and renovated buildings. The goals for new buildings are to design and build facilities that deliver:

A. **Energy Efficient, High Performance Buildings**: especially with regard to the envelope, lighting, HVAC systems, sub-metering, and labs
B. **Resilient Design**: for flooding, strong winds, and rising temperatures; addressing storm water management, heat island reduction, and minimizing flood risk exposure on lower levels
C. **Supply Chain Improvements**: build the capacity to understand carbon intensity of construction materials and methods; implement policies and provide the systems to support furniture reuse, and fixture & equipment energy and water efficiency standards
D. **Waste Diversion**: provide Zero Waste infrastructure in new buildings and divert construction waste for all construction and renovation projects on campus.

All these issues are addressed in the Climate Action Plan in various ways and are brought together here through recommendations to provide an integrated approach to address new construction and major renovation. The intent is to strengthen existing and emerging systems used at Facilities Management & Planning and by formally integrating Green Building Certification into the process now and to utilize these certification systems to stay abreast of industry improvements as building technology means and methods evolve over time. Build on the following systems, policies, and procedures:

1. **Project Planning & Delivery Process:** integrate Green Building Certification and high-performance building policies, procedures, and checklists into the process from the beginning to embed CAP related Owners Project Requirements and life cycle cost analysis for each project

2. **Design & Construction Standards:** incorporate LEED Certification criteria into the standards and further integrate the recommendations outlined in this section into the standards for all construction projects regardless of size or certification
3. **Green Building Certification**: implement a LEED Gold policy that maximizes energy performance by aligning with the Architecture 2030 Challenge for Energy Use Intensity; provides onsite renewable energy to reduce demand on the grid; implements resilient design strategies through RELi; diverts at least 90% of construction waste from all projects on campus; and explores Zero Net Energy and low carbon construction techniques
4. **Campus Planning:** integrate the recommendations of the Climate Action Plan into the University's planning process, especially addressing transportation, resilience, green infrastructure, heat island reduction, energy, and waste

Where we are today

1. Project Planning & Delivery

An outcome of FM&P's strategic planning efforts is the Project Planning & Delivery Process. The document nearing completion, provides clarification and documentation for an official Project Planning & Delivery Process designed to clarify and streamline new construction and renovation project delivery. The document currently does not envision guidelines related to energy efficiency, resiliency, and waste. The Project Planning & Delivery Process will provide another framework to integrate sustainable design goals to meet the University's climate commitments.

Working with Facilities Management & Planning (FM&P) and the design team, *sustainability*@BU develops communications for new building occupants so they can understand how their new building works, what to expect with new technology and controls, and what they need to do to use these new systems in order to take advantage of their sustainable design features. This is a good start, but more needs to be done.

2. Design & Construction Standards

From an initiative recommended by the Sustainability Committee's Sustainable Buildings & Operations Working Group, FM&P developed and maintains building design guidelines and construction standards. These provide standard specifications that are followed by design and construction teams across project types. They establish best practices, and provide for continuous improvement. They provide standards for building design and construction and equipment requirements that support energy efficiency, but don't directly address energy use intensity. Additionally, they do not currently address resilient design, supply chain, or waste diversion needed to align with the recommendations in this Climate Action Plan. These guidelines and standards are a living document that gets updated on an ongoing basis and provides the vehicle to provide policies, standards and practices for sustainable design. They also provide the vehicle to integrate the University's commitments established in the Climate Action Plan.

3. *Green Building Certification*

The goal for green building certification is to bring design and construction teams together around an established industry-recognized process with a clear set of criteria that are aligned with the recommendations of the Climate Action Plan. The US Green Building Council's Leadership in Energy and Environmental Design (LEED) certification system is recommended as the primary baseline certification system for the Climate Action Plan. We do hope however, that as opportunities present themselves more challenging systems such as Zero Net Energy, Passive House, and Living Building Challenge are used.

Boston University incorporates sustainable building practices for large construction projects. Since 2010, nearly two thirds of new construction and major renovation projects have been LEED certified. The University has completed 12 LEED projects totaling over 654,000 square feet, 86% of which has achieved Gold. With 660,000 square feet of projects registered for LEED, certification remains an important strategy, especially for new construction.

While the University has a good track record for LEED certification, more is needed to add clarity to the LEED certification process with specific credit criteria to insure the commitments in the Climate Action Plan are met. Goal-oriented policies and LEED (and other) certification are necessary to address these issues for building design and construction teams to focus and meet the objectives of the Climate Action Plan.

A. Energy Efficient, High Performance Buildings

New buildings have been designed to meet the Massachusetts Stretch Code which requires buildings be at least 20% more energy efficient than the base building code. Based on the building energy model results from the LEED Building Design + Construction projects completed at BU, they average 26% better than the base building code, with the Alan & Sherry Leventhal Center modeled to perform 36% better than code. These efforts during the design and construction process greatly improve building energy performance for new construction, however actual building energy performance often falls short of modeled projections. There are many reasons for this, and the problem is not unique to BU. The most commonly cited issues include: value engineering, lack of skilled staff or occupant education, and underestimated hours of operation.

- Value engineering is the process projects go through to reduce construction costs in order to meet the project budget. This often compromises systems and strategies designed to save energy and money over the long term.

- High performance buildings require qualified staff that are trained to operate and maintain the sophisticated systems installed. These systems also require a higher level of maintenance at more frequent intervals to achieve and maintain the high levels of energy performance for which these buildings were designed.

- Adequately educating and engaging building occupants to understand what to expect from high performance buildings and what is expected from them to allow automations and schedules to optimize building performance. New building occupant brochures are provided when major projects are completed and occupants are encouraged to get Green Office Certified through *sustainability*@BU.

- During the planning process for new projects, the operational schedules are carefully developed by the University and are provided to the design team for the development of the Basis of Design and the energy model used to analyze the design for energy performance.

B. Resilient Design

With a changing climate, buildings are becoming more vulnerable to sea level rise, flooding, higher temperatures, and more intense storms. Climate Ready BU, a climate-risk assessment developed in 2014 for both campuses revealed to decision makers risk exposure of assets at different time scales. The assessment was developed by *sustainability*@BU with the Director of Emergency Planning, Facilities Management & Planning, Risk Management, and the University's insurer, FM Global. Climate Ready BU provides recommendations to be prepared for the climate threats across a range of time scales. While this document provides a strong basis of information to build on, the Climate Action Plan refines them and explores more deeply the financial risks associated with the threats climate change will amplify over time. These recommendations are provided in the chapter on Climate Preparedness.

These Climate Ready BU recommendations informed the design process for the Rajen Kilachand Center for Integrated Life Sciences and Engineering as it was being planned. Completed in 2017, the Center was the first building on campus to be built without a basement (where a building's electrical and mechanical equipment is typically located). These critical functions were located on the second and third floors to avoid exposing them to flooding. The Climate Ready BU recommendations have also informed the renovations to Myles Standish Hall and the planning and design efforts currently underway for additions to the Questrom School of Business and the Henry M. Goldman School of Dental Medicine.

C. Supply Chain Improvements

Building construction constitutes approximately 20% of the University's annual addressable spend. The University does not currently have the capacity to quantify emissions related to building construction, and the methodologies that have been developed and are currently available lack the science-based rigor needed for the University to develop actionable recommendations to address construction-related emissions. That said, there is an effort within the building industry to use low carbon construction materials and methods, shifting from emissions that are embedded in the extraction, manufacture and transportation of construction materials such as aluminum, cement and steel to renewable, lower carbon intense materials, especially wood, demountable systems, and materials reuse.

The *sustainability*@BU Exchange is a service that allows employees to swap items with colleagues around the office and throughout the University. It's a way to reuse supplies & furniture no longer needed by a department, but useful to others. An online form is available on the sustainability website. Additionally, the University manages a furniture reuse program whereby University departments can shop for surplus and remanufactured furniture through the Terrier Marketplace.

D. Waste Stream

Construction waste constitutes approximately 25% of the annual municipal waste stream in the US. For its part, Boston University has shown it can divert a significant portion of its construction waste from landfills. For LEED projects seeking credit for construction waste diversion, the University has achieved an average construction waste diversion rate of 92%, with a high of 97% at the Alan & Sherry Leventhal Center. However, the University does not currently have a policy or program for construction waste diversion. Consequently, for projects that do not seek LEED certification, construction waste is not diverted for recycling.

4. Campus Planning

For the City of Boston, the University provides an Institutional Master Plan (IMP) that addresses the current and future physical form of the institution, its systems, impacts, and benefits. This Institutional Master Plan is updated on a ten-year cycle. The IMP addresses campus sustainability through operations, new construction, and metrics including climate impacts through greenhouse gas emissions reporting.

Where We Want to Be

Summary Recommendations

For new buildings to meet the commitments of the Climate Action Plan, integrate Green Building Policies into the Project Planning & Delivery Process and into the Design and Construction Standards. Implement a LEED Gold policy that maximizes energy performance, provides onsite renewable energy, implements resilient design strategies, diverts at least 90% of construction waste from all projects, and explores low carbon construction techniques. The University has shown it can regularly achieve LEED Gold for new buildings, but lacks the policy to build the knowledge, culture, and commitment to these standards. LEED certification provides a process and system that integrates the sustainable design strategies that will support the Climate Action Plan's objectives and bring the Plan to fruition with the criteria and processes necessary to focus design and construction teams on specific goals laid out in the Plan. These recommendations include:

- Green building certification:
  - LEED Gold minimum, strive for Platinum, for new construction and major building renovations over 5,000 sf or $10 million
  - LEED Gold for renovations and interior projects over 5,000 sf or $2.5 million
  - Seek design firms and construction companies with deep experience in green building certification and measured energy performance showing a successful track record of meeting or exceeding the Architecture 2030 Challenge
  - Provide staff training and occupant education on building systems to enable high performance buildings to operate at their potential
  - Explore and pilot Zero Net Energy certification by 2025
- Energy efficient, high performance buildings
  - Minimize EUI in new construction with an average new construction EUI of 40 kBtu/sf/yr to align with the Architecture 2030 Challenge
  - Maximize building envelope performance using Passive House standards to the extent possible
  - Minimize lighting energy consumption utilizing the latest lighting and controls technology
  - Minimize HVAC energy consumption utilizing the low air change rates and optimizing the latest controls technology
  - Minimize labs energy consumption and maximize safety utilizing the low air change rates and optimizing the latest controls technology
  - Incorporate onsite renewable energy to reduce demand on the grid
  - Provide the metering, sub metering, and monitoring necessary to measure, verify, and manage building energy performance
  - For building heating, source energy from renewables, air, and ground sources rather than fossil fuels to the extent possible
- Resilient design
  - Design to reduce project and campus urban heat island effects
  - Reduce storm water runoff through campus, site, and building level green and gray infrastructure
  - Locate critical building infrastructure above 20' BCB (8.8: above MHHW). (Boston Planning and Development Agency is proposing 17.5' BCB plus 24" = 19.5' BCB for critical infrastructure) – essentially, this means no critical infrastructure would be placed in basements on the Medical Campus or east of the BU Bridge on the Charles River Campus

- Resilient design certification:
  - Include the RELi[1] standard during the LEED Certification process to provide resilience metrics, measures and indicators for resilient buildings, neighborhoods and communities.
- Supply chain improvements
  - Build capacity to understand and implement low carbon construction techniques utilizing the campus as a living learning laboratory
  - Pilot low carbon construction materials and methods
  - Prioritize used and refurbished furniture, to the extent that it conforms to current health and fire codes
- Waste Diversion
  - Set a campus-wide standard for at least 90% construction waste diversion for all construction projects
- Design & Construction Standards
  - Apply the recommendations outlined in this section, as they relate to project scope, to all new construction and renovation projects
  - Integrate sustainable design policies into the standards
- Project Planning & Delivery
  - Incorporate Owner's Project Requirements and Basis of Design into the concept and schematic design phases to synthesize the commitments of the Climate Action Plan before project budgets are set
  - Provide the capacity to integrate Life Cycle Assessment and Life Cycle Cost Analysis into all phases of projects
  - Provide the capacity to analyze the effectiveness of the systems, technologies, and strategies employed in projects five years after substantial completion. Develop and manage a database with these post-occupancy evaluations to learn from and track how well these efforts work.

1. Project Planning & Delivery

It is important to establish high-performance building policies to embed best practices for energy efficiency into the University's Project Planning & Delivery Process. This begins when space allocation and building programs are being developed and design teams are being selected. Choose design teams that have a deep understanding of sustainable design and have a strong track record with LEED certification, Zero Net Energy, Living Building Challenge, and have measured energy performance showing a successful track record of meeting or exceeding the Architecture 2030 Challenge[2]. While these systems are not the answer in themselves, they provide the rigor necessary for the project design and delivery team to build to the standards required for high performance buildings and they keep the team focused on the task of delivering sustainable, low carbon projects.

This starts with strong Owner's Project Requirements for sustainable, energy efficient design and includes the metering, monitoring, and control systems to enable building staff to manage the energy use and achieve the energy savings projected during the design process.

The planning and design phases are when fundamental decisions are made that have a lasting impact over the building's life span, from the emissions a building will produce to the climate risks it will be exposed to. Meeting our climate commitments will require policies for new buildings that integrate energy efficiency standards into the University's Design & Construction Standards and Project Planning & Delivery Process, including LEED Certification, and clear Owner's Project Requirements and Basis of Design.

Address these issues through the Project Planning & Delivery Process:

- Build the capacity to integrate life cycle cost assessment into the Process to reduce the impact value engineering has on energy cost performance over the long term.
- Hire and integrate qualified staff during the construction process that are trained to operate and maintain the sophisticated systems installed in order to achieve the high levels of energy performance for which a building was designed.
- Build the capacity to educate and engage building occupants to understand what to expect from high performance buildings and what is expected from them through education, training and Green Office Certification programs.
- Develop a way to analyze building energy use history as compared to modeled design performance for new construction on campus to establish a factor or process to address the challenge in optimizing accuracy in building energy models.

Integrating Life Cycle Assessment and Life Cycle Cost Analysis into the process from start to finish will enable a more informed and nimble decision-making process throughout, and especially during the value engineering process. Through training and recruitment, raise building management expertise. Integrate building operations staff into the commissioning process. Provide the capacity to analyze the effectiveness of the systems, technologies, and strategies employed in projects five years after substantial completion. Develop and manage a database with these post-occupancy evaluations to learn from and track how well these efforts work.

Provide programs to educate building occupants and users to new buildings as buildings are being turned over and occupied for the first time. Provide clear guidance on what users should expect with the new technologies and what is expected from occupants to best use these new systems as they were intended.

2. *Design & Construction Standards*

Incorporate the Green Building Policies outlined below into the Design & Construction Standards for all construction projects regardless of project size or certification.

3. *Green Building Policies*

Set policy for new construction and major renovations over 5,000 square feet to achieve LEED Gold and strive for Platinum under Building Design + Construction. For interior projects over 5,000 square feet and $10 million, pursue LEED Gold under Interior Design + Construction. Maximize the credits to achieve targeted energy performance. This includes Level 4 and Level 5 projects to be implemented through the forthcoming Project Planning and Delivery Process.

Strategy and credit recommendations to pursue under LEED Building Design + Construction version 4:

LEED Certification	Achieve Gold
Energy efficiency	Pursue Architecture 2030
Enhanced commissioning	Provide
On site renewables	Pursue credits
Heat island reduction	Pursue credits
Resilient design pilot & RELi credits	Pursue credits
Materials sourcing	Pursue credits
Construction waste diversion	90%
Zero Waste infrastructure	Provide to meet USZWBC certification
Low carbon building practices	Explore strategies
Zero Net Energy	Pilot
Combustion-free heating (electrify building heating, source from renewables)	80%

A. Energy Efficient, High Performance Buildings

This section describes in detail, programs to address energy performance in new construction and major renovations by setting policies for Energy Use Intensity, the building envelope, HVAC systems, labs, lighting systems, and sub-metering, measurement and verification.

New construction as modeled, contributes 188,000 $MTCO_2e$ to the emissions reductions by 2050 as laid out in the BU Bold scenario. Setting ambitious goals using Passive House and Zero Net Energy standards for non-lab buildings and a new building average EUI of 40 kBtu/sf/yr has the potential to provide far greater reductions, on the order of 400,000 $MTCO_2e$.

Commissioning is an essential tool for optimizing energy performance. Building commissioning is the process for testing, analyzing, and documenting the mechanical and electrical systems in a building to optimize the building energy performance and confirm they meet the design intent. Enhanced commissioning as defined by LEED, brings the commissioning authority into the design process early and reviews building operations ten months after substantial completion to improve the process and require the contractor to provide system adjustments during the warrantee period. Envelope commissioning is specific to the building's thermal envelope in accordance with ASHRAE Guideline 0–2005 and the National Institute of Building Sciences (NIBS) Guideline 3–2012, Exterior Enclosure Technical Requirements for the Commissioning Process, as they relate to energy, water, indoor environmental quality, and durability.

Energy Use Intensity

Site Energy Use Intensity (EUI) addresses total building energy consumption at the building level. The University's current site Energy Use Intensity is 131 kBtu/sf/yr including all facilities owned and occupied in the US. For the purpose of developing the scenarios, we have conservatively estimated EUIs for Good, Better, and Bold. It is important, however, to set ambitious goals to realize energy savings in new construction. The EUI targets set out below reflect the requirements to participate in the Architecture 2030 Challenge[3], which calls for an 80% fossil fuel reduction standard compared to US average in 2020 for emissions reduction. For BU, this leads to the following EUI goals divided into building categories:

Site EUI guideline recommendations using Architecture 2030 goals as the standard to pursue:

Use	Current US Avg (kBtu/sf)[4]	BU FY06 Avg (kBtu/sf)	BU FY16 Avg (kBtu/sf)	**Arch 2030** (kBtu/sf)[5] **(guideline)**
Laboratory	293[6]	263	226	**111**
Recreational	41	181	141	**20**
Activity Center	45	157	149	**20**
Educational	131	145	113	**23**
Residence	74	138	108	**24**
Office	104	127	105	**31**
CAMPUS AVERAGE	120	150	131	**40**

Building Envelope

Energy efficiency in new construction begins with the building envelope – the windows, walls, roof, foundation and lowest floor. Building this exterior envelope to minimize air leaks and energy transfer through these exterior systems has always been important, but with rising temperatures this will become increasingly important to minimize the rising need for cooling. Develop design guidelines to reduce thermal transfer through the building envelope.

- Set standards for the percentage of total window area to wall area with a goal to achieve 40% and establish minimum R values for all elements of the building envelope to reduce thermal transmission using Passive House standards as a guide.
- Use triple glazed window systems where glass curtainwall is specified.
- Conduct building envelope commissioning during the construction and commissioning process

HVAC Systems

Heating, ventilation, and air conditioning (HVAC), according to the Energy Information Administration, constitutes 44% of a building's energy consumption. Provide HVAC systems and controls designed to maximize building energy performance and minimize greenhouse gas emissions. This includes combustion-free heating through air and ground source heat pump technology as the preferred method of heating. This will electrify heating in buildings so that the source of energy can shift to renewables.

Labs

Labs have the highest energy use intensities of buildings on any campus. One of the reasons is that for safety, labs require higher air change rates than other buildings and lab equipment such as low temperature freezers are big energy users. New lab design such as the recently completed Center for Integrated Life Sciences and Engineering, provides an opportunity to address these issues from space layout and allocation to airflow optimization, plug load management, and occupant engagement.

Establish a policy in the University's Design & Construction Standards for lab design criteria:

- Establish reduced lab hood air change rates with controls consistent with lab safety and energy efficiency requirements
- Low temperature freezer efficiency and operating standards to minimize energy consumption
- Establish plug load budgets for labs
- Develop a lab occupant training and Green Labs certification program under My Green Lab[7]

Lighting Systems

Lighting, according to the Energy Information Administration, constitutes 10% of a building's energy consumption. Set policies to require lighting levels consistent with ASHRAE/IES 90.1[8] for light power densities (LPD) by space type and at a minimum require LED lighting with occupancy and daylighting controls in all spaces except for special uses where LED technology is not yet available.

Sub-metering, Measurement & Verification

While building level meters exist for much of campus, three groups of buildings are served through meters that are shared with other buildings. The John Hancock Student Village along with Agganis Arena, FitRec, Student Village I and II are all served through the same electric meter and water meter. Heating is provided by the West Campus Steam Plant which also serves the West Campus dorms and Buick Street administrative buildings. BU's original iconic buildings from Stone Science to Metropolitan College along with the George Sherman Union, Law complex, and Warren Towers are all served from the same meter. We can't manage what we don't measure, so as we implement the energy conservation strategies, building level metering will be essential. Integrated with the building management systems and a web-enabled analytics platform, sub metering will enable the University to:

- Provide a campus wide system for measurement and verification
- Improve accounting workflow for energy, water, and waste
- Report through dashboards resource and waste data for senior management
- Access building energy, water, and waste data for download to faculty and students to support the campus as a Living Leaning Laboratory
- Engage the community through gamification by displaying building energy, water, and waste data to allow us to raise awareness and run competitions between dorms

Longer Term Strategies

Recognizing the University's resources are limited for achieving the commitments set out in the Climate Action Plan, we have prioritized these strategies to be addressed in the short term and longer term. For the purpose of the Climate Action Plan these longer-term strategies are more capital intensive so the funding for them can be augmented from the savings generated in the Climate Action Investment Fund as outlined in that chapter. These longer-term strategies include: 1) combustion-free heating using air and ground source heat pump technology, 2) transitioning from steam to hot water systems, 3) building Zero Net Energy buildings, 4) piloting Living Building Challenge buildings, and 5) piloting low carbon construction techniques.

B. Resilient Design

This section describes policies for new buildings and their associated site development to help the University prepare for the impacts from climate change it cannot avoid. These impacts include flooding, higher temperatures, and more intense storms. More detail is provided in Climate Preparedness chapter.

Synergies exist between preparing for climate change and mitigating our own impacts. While efficiency is integral to reducing emissions, and planning a resilient building, providing energy and water collection and storage capacity on site can help provide continuity of operations after an event. Refer to the Climate Preparedness chapter for detailed recommendations. In general, these include protections against flooding, higher temperatures, and more intense wind-driven rain events. Where it is not possible to avoid these hazards, provide for temporary protections.

LEED is designed to evolve over time and uses pilot credits to refine requirements before adopting them in future versions of LEED. In this effort, the US Green Building Council has established three pilot credits for climate resilience and announced on November 14, 2017 the adoption of the RELi standard for resilience. Credits will evolve over time, but currently these three credits are designed to ensure that a design team is aware of vulnerabilities and are able to address the most significant risks in the project design, including functionality of the building in the event of long-term interruptions in power or heating fuel. Incorporate these pilot credits and the RELi standard into the Project Planning and Delivery Process:

- **Assessment and Planning for Resilience**: This credit encourages designers, planners and building owners or operators to assess and then plan for a wide range of natural disasters or disturbances as well as consider longer-term trends affecting building performance such as changing climate conditions.
- **Climate Resilient Planning or Emergency Preparedness Planning**: Recognizing that climate change will increase some vulnerabilities in the years and decades ahead, this calls for completing a vulnerability assessment of impacts associated with climate change - or the project is designed to ensure that emergency preparedness has been considered.
- **Design for Enhanced Resilience:** This is designed to ensure that each of the top hazards identified in Credit 1 are addressed through specific mitigation strategies.[9]

Flooding

One characteristic of being an urban campus is that much of the land area is made up of hard surfaces impervious to water penetration. During periods of heavy rain, flooding occurs because rain water can't work its way into the ground and is concentrated into storm drainage systems that are not designed to accommodate the heavier storms projected in the coming decades[10]. Hard, impervious surfaces make up 81% of the land area on the Charles River Campus and 84% of land area on the Medical Campus.

- Develop a strategic campus resilience plan for each campus to manage flooding from sea level rise and more intense rain events to provide stormwater runoff reduction and control at the campus, site, and building level.
- Develop guidelines to address flooding based on elevation, geotechnical, and groundwater conditions.
- While basements can provide capacity for flood storage and reduce water inundation in areas not designed to take on water, avoid building new

basements for critical systems. Locate critical building infrastructure above 20' Boston City Base (BCB), or 8'-8" above Mean Higher High Water (MHHW). In general, this means no critical infrastructure in basements anywhere on the Medical Campus or most of the Charles River campus east of the BU Bridge.

Higher temperatures

The urban heat island effect is another growing concern since it will exacerbate the already rising temperatures. In urban areas, darkly colored surfaces like roofs and pavement absorb incoming solar energy and heat up to temperatures higher than those in the atmosphere. As that heat is reradiated into the air, it creates large pockets of warmer air around cities making them urban heat islands. Two thirds of Boston's increase in temperature since 1850 has been caused by the heat island effect[11].

To reduce the impacts from the urban heat island effect:

- Maximize tree canopy where possible
- Install white or green roofs and light-colored hardscapes with a solar reflectance index (SRI) consistent with LEED criteria. SRI is a measure of the surface's ability to reject solar heat. It is defined so that a standard black roof has an SRI of 0 and a standard white roof has an SRI of 100. These strategies reduce the ambient air temperature and the demand on energy for air conditioning.
- For new projects on campus, the University is already incorporating heat reflective materials in landscape and roof design with an SRI consistent with LEED criteria.

The need for air conditioning in new buildings will grow as temperatures rise over time.

- Plan for low carbon, energy efficient air conditioning systems using air or ground source heat pumps where possible.
- To reduce demand on air conditioning, provide natural ventilation in new buildings where possible.

More intense storms

According to the New England Weather Services, the intensity of hurricanes and other extreme storm events is increasing.[12] Extreme precipitation has increased by 67% in New England over the past 60 years. This trend is projected to continue, creating a growing threat of freshwater flooding, particularly in watersheds with extensive impervious surface cover.[13] Additionally, there has been an increase in the frequency of severe storms in the last 50 years from 1 in 50 years to 1 in 5 years.[14]

In addition to the financial burden of these extreme weather events, one storm like Hurricane Sandy can impact a broad range of issues from operations to the reputation of the University, depending on how prepared it is and how well it responds. The extent to which BU can phase in a prepared and proactive approach to these climate impacts will determine how effective it will be in maintaining a comfortable and safe campus community. To prepare the campus for the impacts of major storm events:

- Develop tight building envelope construction and maintenance policy
- Continue to increase the quality of the building envelope systems for new construction
- Develop geothermal HVAC strategy to reduce risk to rooftop equipment and transition HVAC systems from rooftop to geothermal
- Increase roof insulation to prevent the development of ice dams

C. Supply Chain Improvements

While energy consumption impacts the University's direct emissions, more needs to be understood about its indirect contributions to emissions it compels from the construction process. In FY2016, construction on campus represented 20% of the University's addressable spend. Addressing the supply chain has clear shorter term and longer-term strategies.

In the near term:

- Source building materials locally to the extent possible
- Incorporate low life cycle impact materials into building projects to the extent possible
- Build capacity to understand the emissions impacts of building construction
- Build capacity to pilot low carbon construction techniques utilizing the campus as a living learning laboratory
- Prioritize used and refurbished furniture, to the extent that it conforms to current health and fire codes
- Prioritize energy and water efficient (EnergyStar and WaterSense where applicable) fixtures and equipment

In the longer term:

- Implement low carbon construction materials and methods as this body of knowledge develops

D. Waste Diversion

Set a campus-wide standard for at least 90% of construction waste diverted from landfills for all new construction, renovation, and interior fit-out projects (regardless of LEED certification status) and provide Zero Waste infrastructure. See the Supply Chain & Waste Stream chapter for additional detail.

4. Campus Planning

Integrate the recommendations outlined in this section into the campus planning process from framework development through master planning and Institutional Master Planning.

Context

The City of Boston requires all new buildings over 20,000 square feet be certifiable under the US Green Building Council's Leadership in Energy & Environmental Design (LEED) certification system, and meet the Massachusetts Stretch Energy Code which requires they be designed to be 20% more efficient than the base building code. The base code is updated every few years. The most recent update has significantly upgraded the standards for energy performance so the Massachusetts Stretch Energy Code has been modified for new buildings to demonstrate energy use per square foot at least 10% below the energy requirements of ANSI/ASHRAE/IESNA 90.1-2013 APPENDIX G. The Boston Planning & Development Agency (BPDA) also requires these buildings to consider climate resilience in the design and entitlements process through a climate resilience questionnaire. As these requirements inform the design process, Boston's Building Energy Reporting & Disclosure Ordinance (BERDO) addresses existing buildings and requires annual reporting of building energy and water performance for buildings over 35,000 square feet. These buildings are required to be Energy Star or LEED certified, or achieve a reduction of greenhouse gas emissions by 15% every five years. These strategies have contributed to the City leading the country on energy efficiency and climate resilience planning. The American Council for an Energy-Efficient Economy (ACEEE) has rated the City of Boston the most energy efficient city in the country for each of the three years (2013, 2015, and 2017) they have rated cities. From the perspective of preparing for the climate impacts that can't be avoided, Boston is also a leader. Of all the cities in the country that have not yet been directly impacted from a major storm event, Boston has the most advanced planning process in place.

Peers

The BU Bold scenario is intended to position the University among the leaders in our peer group. Some of our peers have set the bar high for green buildings. On Cornell's Roosevelt Island Campus, they have several buildings that will meet Passive House Standards and achieve Zero Net Energy. Many peer institutions regularly achieve LEED Platinum and some are piloting Zero Net Energy and Living Building Challenge certification.

Appendix

Green building certification systems were developed to improve the ability for the building industry to achieve energy efficiency and other sustainable building practices. These systems provide a necessary framework for organizations to establish clear project goals for their design, building, and operational teams to deliver. The US Green Building Council[15] was formed in 1993 with a mission to transform the way buildings and communities are designed, built and operated, enabling an environmentally and socially responsible, healthy, and prosperous environment that improves quality of life. To achieve this mission, they created the LEED (Leadership in Energy and Environmental Design) green building rating system. In 2002, Architecture 2030[16] was formed with the mission to rapidly transform the global built environment from being a major contributor of greenhouse gas (GHG) emissions to a central part of the solution to the climate crisis. These two organizations have galvanized the building industry to address climate change while constructing buildings and communities that are more healthy, safe, and productive, places for people to live, learn, work, and play.

Today there are many policies and programs available that encourage emissions reductions and support sustainable building design. For the purpose of the Climate Action Plan, we will discuss four: LEED, Zero Net Energy (ZNE) buildings, Passive House, and Living Building Challenge (LBC). All address emissions impacts from the building sector. LEED and LBC also emphasize health and wellbeing, waste minimization, and resilient building design.

Leadership in Energy & Environmental Design - LEED

LEED is an internationally recognized green building rating system, providing third-party certification that a building was designed and built using strategies aimed at improving performance across a set of important metrics: energy savings, water efficiency, greenhouse gas emissions reduction, improved indoor environmental quality, and stewardship of resources and sensitivity to their impacts. Developed by the U.S. Green Building Council, LEED provides building owners and operators a concise framework for identifying and implementing practical and measurable green building design, construction, operations and maintenance solutions. The LEED point system scores green building design and construction practices. The more points awarded the higher the level of certification achieved including Certified, Silver, Gold, and Platinum. LEED covers a broad range of construction and use types. Energy performance under LEED is based on energy cost savings from energy models used during the design process. These models allow design teams to weigh different sustainable design strategies to optimize energy performance during the design process. LEED certification requires buildings to report their annual energy and water performance through Energy Star Portfolio Manager, the same tool used for BERDO reporting. The level of certification is awarded after a building project is complete. LEED is designed to evolve with building technology. As the building industry improves, LEED is updated with a new, more stringent version released every several years. All LEED projects certified and registered at BU have used version 3 or earlier. Version 4 is now required. The recommendations for the Climate Action Plan are based on LEED Version 4. As the CAP is updated, the level of certification will need to be revisited to explore the appropriateness of setting Platinum as the standard.

Zero Net Energy - ZNE

Zero net energy (ZNE) buildings are ultra-efficient new construction and deep energy retrofit projects that consume only as much energy as they produce from clean, renewable resources. ZNE is supported by the New Buildings Institute, a nonprofit organization whose mission is to drive better energy performance in commercial buildings. They "work collaboratively with industry market players—governments, utilities, energy efficiency advocates and building professionals—to promote advanced design practices, innovative technologies, public policies and programs that improve energy efficiency."

Passive House

Passive House Certification focuses on the building envelope and ventilation. Initially intended for small residential construction, Passive House is now being used in high rise residential construction. Passive building comprises a set of design principles used to attain a quantifiable and rigorous level of energy efficiency within a specific quantifiable comfort level. "Maximize your gains, minimize your losses" summarizes the approach. To that end, a passive building is designed and built in accordance with these five building-science principles:

1. Employs continuous insulation throughout its entire envelope without any thermal bridging.
2. The building envelope is extremely airtight, preventing infiltration of outside air and loss of conditioned air.
3. Employs high-performance windows (typically triple-paned) and doors.
4. Uses some form of balanced heat- and moisture-recovery ventilation and a minimal space conditioning system.
5. Solar gain is managed to exploit the sun's energy for heating purposes in the heating season and to minimize overheating during the cooling season.

Passive building principles can be applied to all building typologies – from single-family homes to multifamily apartment buildings, offices, and skyscrapers. Passive building principles offer the best path to Net Zero Energy and Net Positive buildings by minimizing the load that renewables are required to provide.

Living Building Challenge - LBC

The Living Building Challenge is a highly advanced green building rating system that includes *imperatives*, rather than points. There are no levels of certification. A building either meets the imperative requirements or it is not eligible for certification. Rather than relying on building energy models, buildings are LBC Certified when they show they have successfully met the imperative requirements based on actual building performance using a year's worth of building data. Buildings that meet the Living Building Challenge criteria are regenerative spaces that connect occupants to light, air, food, nature, and community. They are self-sufficient and remain within the resource limits of their site. The specific requirements range depending on the site location from Natural Habitat Preserve to Urban Core. Living Buildings produce more energy than they use and collect and treat all water on site. Living buildings give more than they take, creating a positive impact on the human and natural systems that interact with them.

Preparing for Climate Change

Flooding

Boston's original landform, known as the Shawmut Peninsula, was connected to the mainland by a narrow, low-lying causeway approximately where Washington Street is located today (see Figure 1).

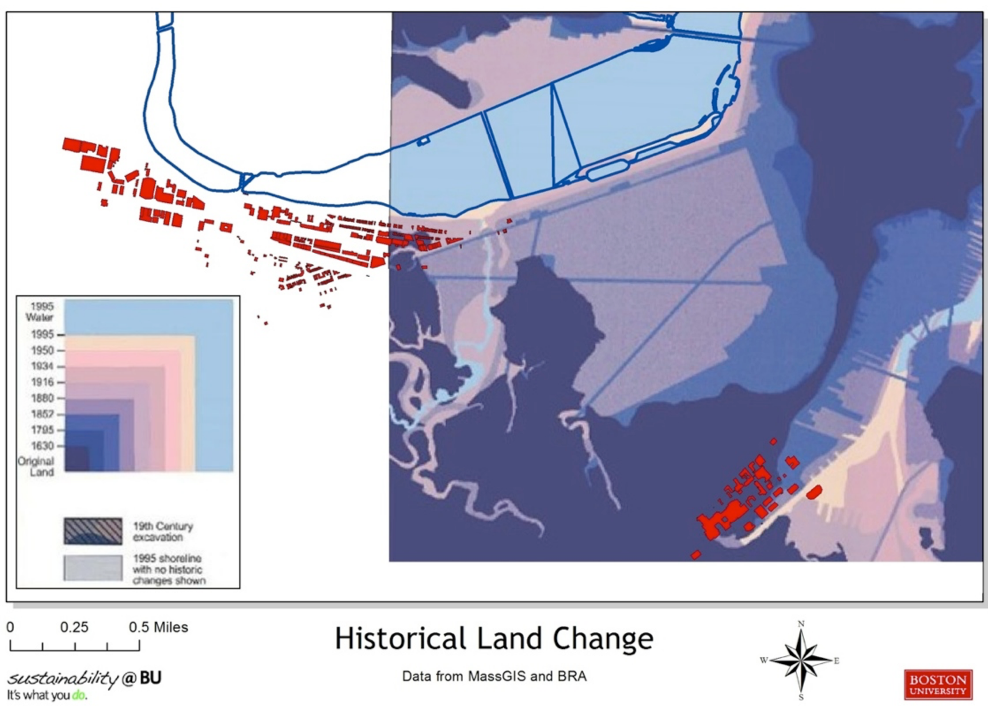


Figure 1 | Boston's original filled tide lands [1]

The Climate Ready BU report two areas of concern where the ocean's waters can find their way to both campuses before the Charles River Dam (MHHW + 6.8 feet) is overtopped. The first area is along the western edge of the Fort Point Channel seawall, who's top is at elevation MHHW + 4.2 feet and is located adjacent to the Massachusetts Turnpike where it descends into the Central Artery. The Turnpike provides a clear conduit for seawater to flow to the Charles River Campus.

Much of Boston is built on flat, low-elevation, filled tidelands 4 to 6 feet above today's, MHHW. The second area of concern is where coastal floodwaters can cross the original causeway to reach the Muddy River and the Charles River Campus from Fort Point Channel once sea levels reach MHHW + 5.8 feet. Figure 2 also shows the original causeway doesn't need to be crossed to reach the Medical Campus.

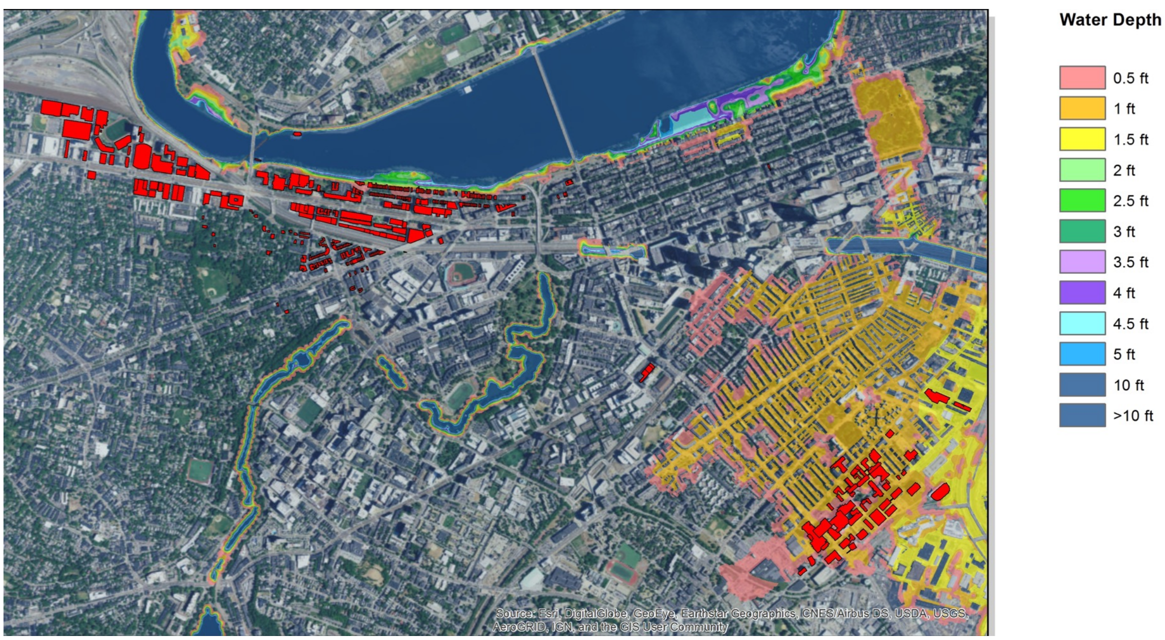


Figure 2 | Boston flooding with a probability of in 2070 1% [1]

Sea level rise will increase the extent storm surge flooding into the city. The map shown above was developed using the GIS layers for scenarios developed by the Woods Hole Group for Climate Ready Boston in 2016. The Charles River Campus will see some flooding, but Medical Campus will see significant flooding from a 1% storm event in the latter part of the decade.

Flooding risk is not limited to sea level rise. Extreme precipitation has increased by 67% in New England over the past 60 years. This trend is projected to continue, creating a growing threat of freshwater flooding, particularly in watersheds such as the Charles River Watershed with extensive impervious surface cover.[17]

Urban areas are particularly vulnerable to freshwater flooding during heavy rain or snow events due to the large expanses of impermeable surfaces. These events can cause significant damage, such as in 1996 when the Muddy River overflowed into the Kenmore MBTA Station. Impervious pavement prevents storm water absorption, concentrates runoff and pollutants, increases erosion, and stresses storm water and sewer systems. The University can help decrease these impacts by decreasing the amount of impervious pavement on campus. Reducing impervious pavement will also reduce the amount of sewage in the streets during flooding events. As rainstorm intensity increases in the coming decades, the need to reabsorb floodwater will become increasingly important.

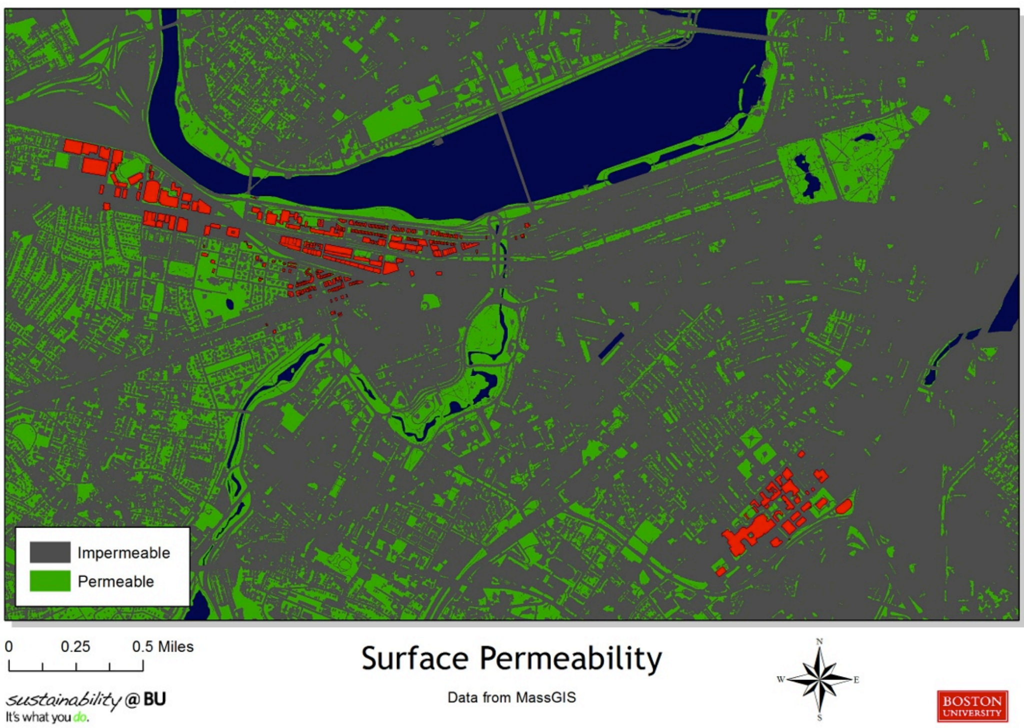


Figure 3 | Surface Permeability: 80.7% of the CRC and 83.4% of the BUMC are impervious.

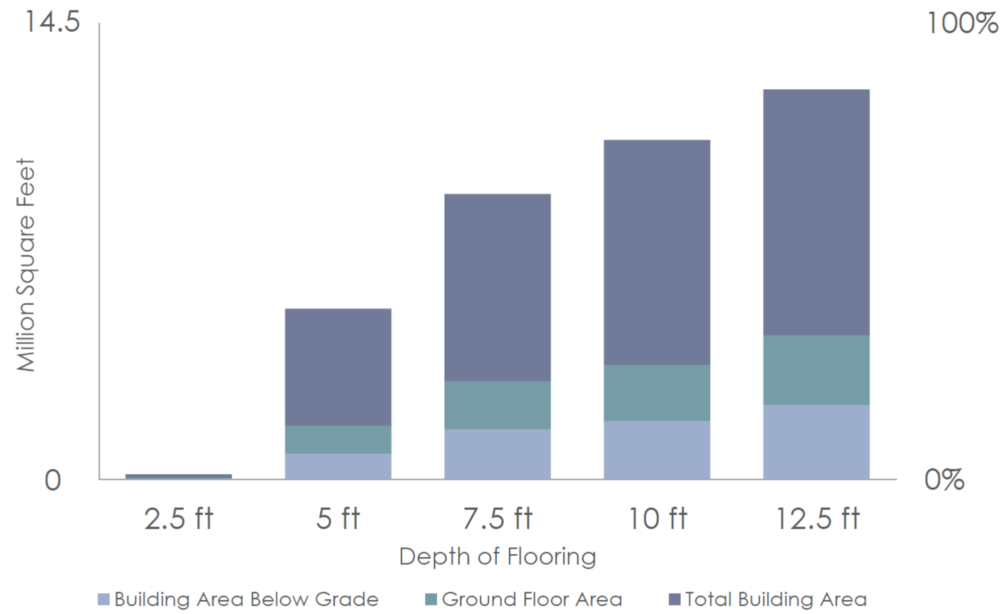
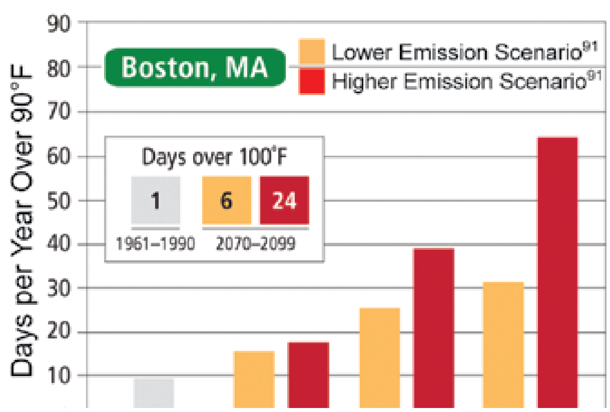


Figure 4 | Building Area Impacted by Flooding Depths.

Based on the static GIS mapping completed for Climate Ready BU, a significant portion of BU's properties will be impacted by flooding with five feet of sea level rise. It is estimated that 12% of the Charles River Campus and 29% of the Medical Campus will see some flooding and will impact 47% of the University's gross building area.

Higher temperatures

Globally, the summer of 2016 was the warmest summer on record and the year 2016 was the warmest full year on record[18]. These temperatures are projected to increase. By the end of the century, the first month of school will have mean temperatures that are equivalent to those of the warmest summer month today[19]. Extreme heat and declining air quality are likely to pose increasing problems for human health, especially in urban areas[20]. Hot summer city temperatures have serious health impacts, including heat stress during heat waves, and dangerous ground-level ozone levels on the hottest days of the year. Higher summer temperatures also stress the electricity grid as air conditioner use soars.[21]



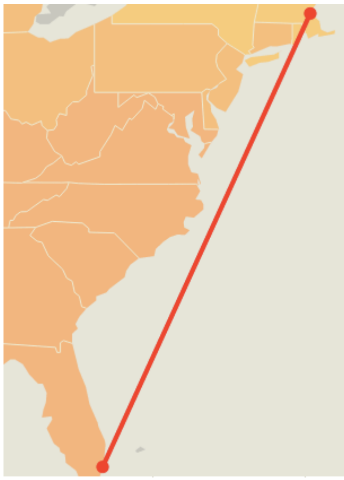


Figure 5 | Under current emissions scenarios, by the end of the century Boston can expect summer temperatures like those currently in North Miami Beach, FL, going from approximately 78.98˚F to 89.11˚F[22].

Figure 6 | Currently, Boston experiences 13 days per year with temperatures over 90⁰F [23] up from fewer than 10 before 1990.[24] We can expect the number of days per year with temperatures over 90 degrees to increase three to four times by 2050.

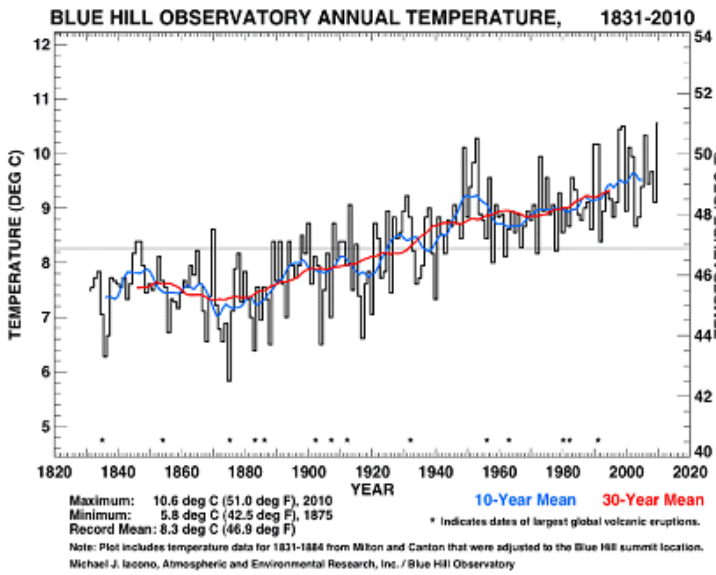


Figure 7 | Blue Hill Observatory Annual Temperatures;[1]

The results in Figure 8 suggest approximately 1 in every 2-3 days during the five-month period from May 1 to Oct 1 will be above 90F and 1 day a week will be above 100. Though direct heat-induced health risks primarily affect elderly populations, heat is still a threat to the University population, especially for staff that work outside or in non-air-conditioned spaces. With increased heat, air quality will decrease as ground-level ozone and smog increase, which poses a threat to lung function and can worsen asthma attacks[25]. Additionally, heat extremes can put stress on health infrastructure, environmental resources, and energy demand for cooling buildings. This means we can expect a 124% increase[26] in the need for cooling demand unless we actively mitigate urban heat island effects.

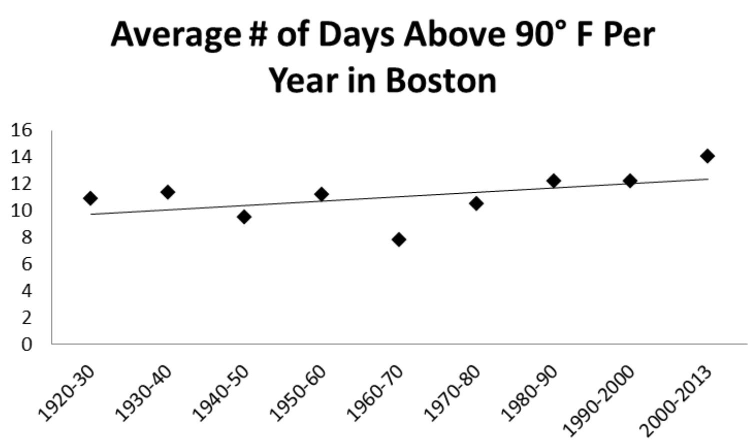


Figure 8 | Average Number of Days in Boston Above 90 degrees F[1]

By 2050 we can expect between 25 and 40 days/year over 90^{0}F and by 2100 that will increase to 30-60 days/year, with days over 100 degrees becoming a common event.[27] Rising average temperatures will increase the amount of cooling we need in our buildings and reduce the amount of heat in during the cooler months. This will shift the University's energy consumption from natural gas toward electricity.

The urban heat island effect is another growing concern since it will exacerbate the already rising temperatures. In urban areas, darkly colored surfaces like roofs and pavement absorb incoming solar energy and heat up to temperatures higher than those in the atmosphere. As that heat is reradiated into the air, it creates pockets of warmer air around cities making them urban heat islands. Two thirds of Boston's increase in temperature since 1850 has been caused by the heat island effect[28].

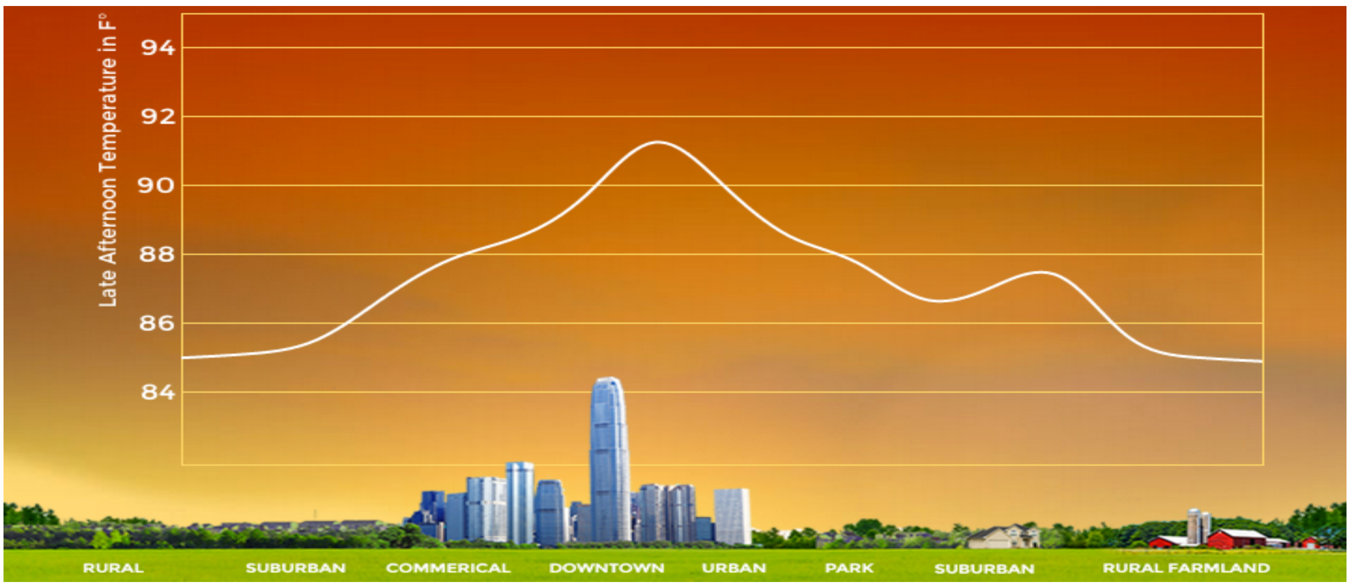


Figure 9 | Urban Heat Island Effect[29]

Charles River Campus Temperature Gradient

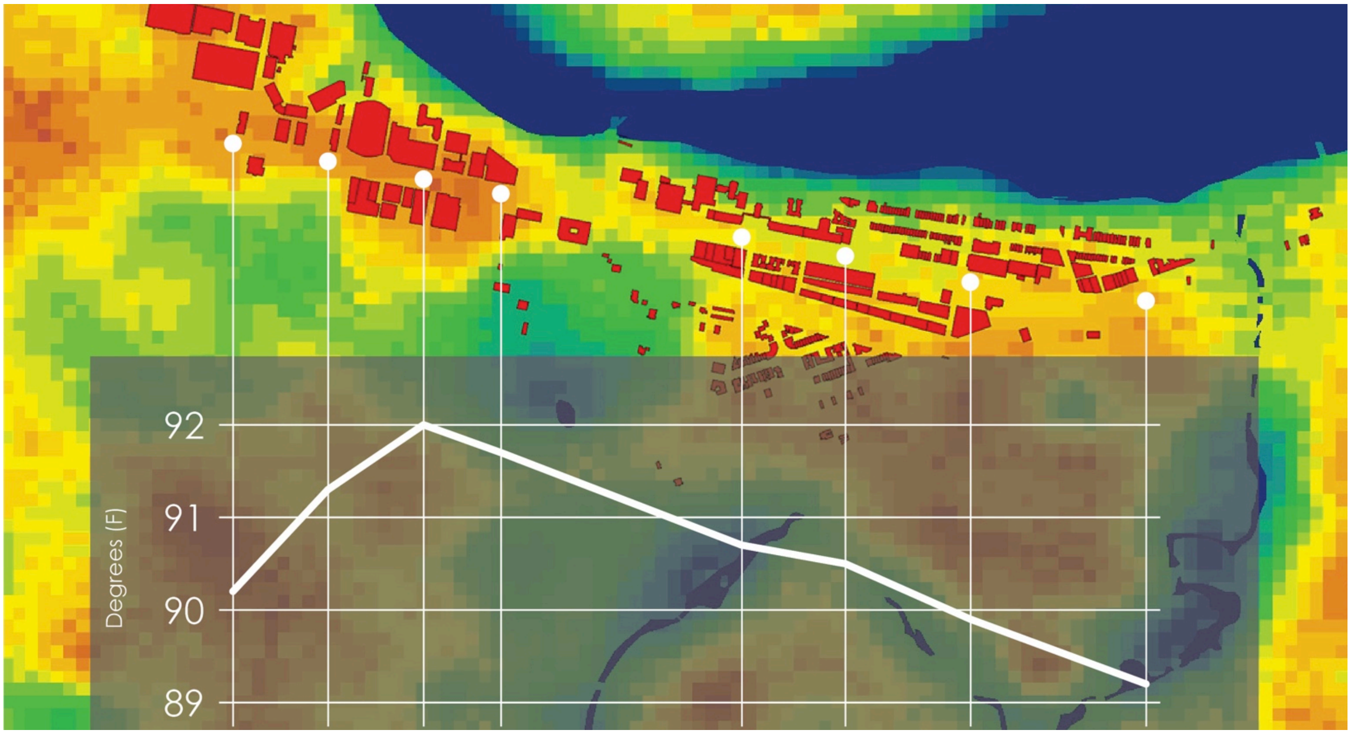


Figure 10 | Charles River Campus Temperature Gradient and Commonwealth Avenue Air Temperatures[30]

More intense storms

Mapping the wind speeds in Boston reveals portions of BU's campuses that are exposed to damage from Category 1[31] (sustained winds of 75 – 95 MPH) or greater hurricanes.

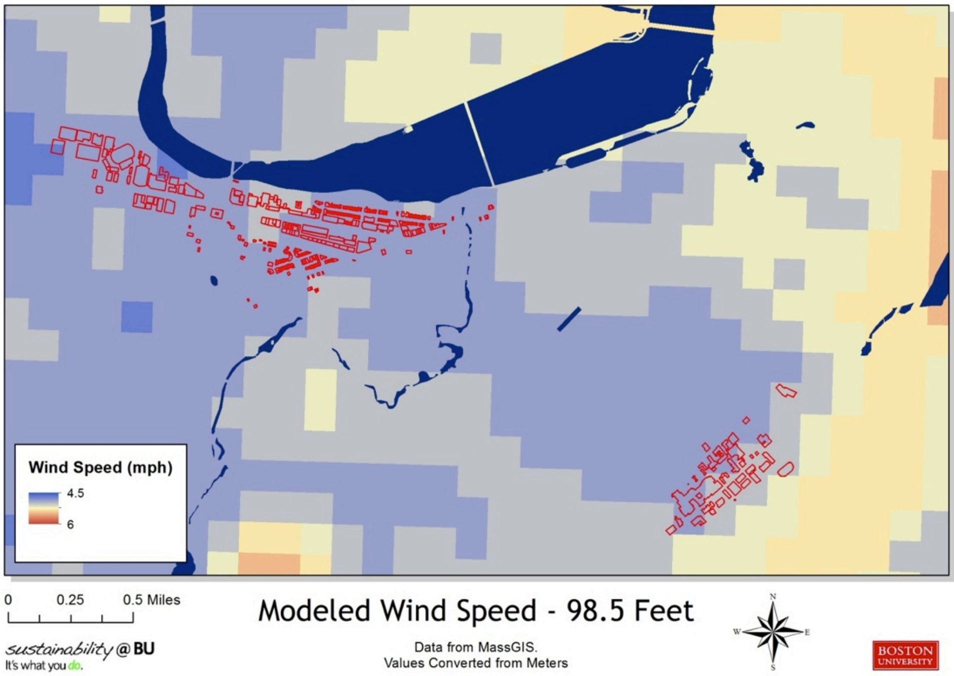


Figure 11 | Mean Sustained Winds Modeled for BU[32]

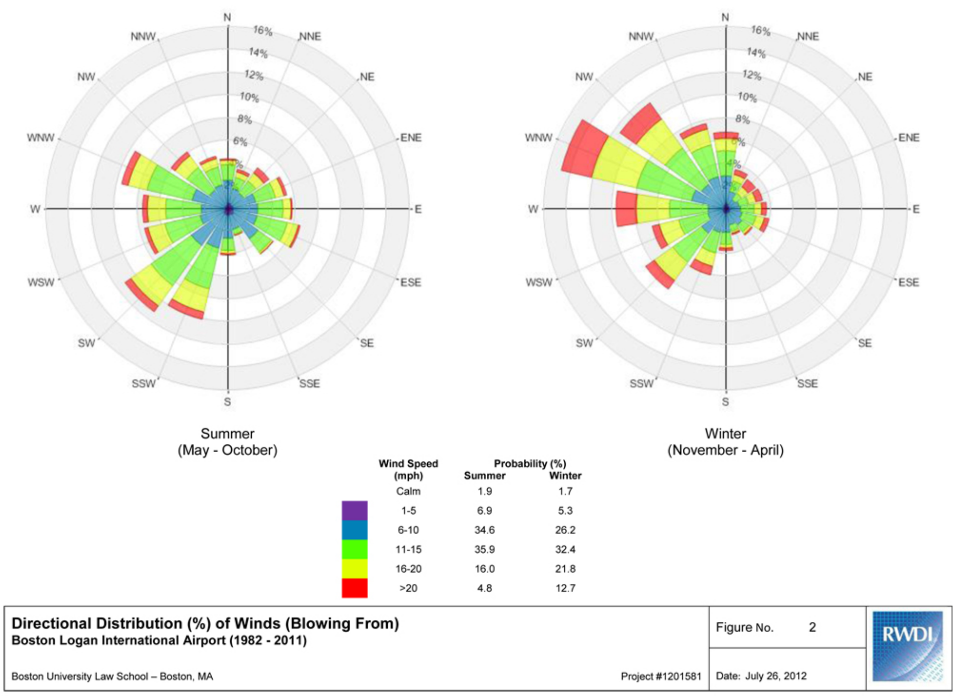


Figure 12| Directional Distribution of Winds for Boston. Each concentric circle represents a frequency of expected occurrence in a direction. The colors represent the speed at which the winds will be moving in each scenario.[33]

While the prevailing winds in Boston come from the West Northwest (and the Southwest in the summer), strong winter storms (Nor'easters) bring winds from the

Northeast. Hurricanes and tropical storms however, often come from the Southeast, but are rapidly rotating storm systems with wind directions on the ground changing during the course of the storm event. These storms are characterized by a low-pressure center, strong winds, and a spiral arrangement of thunderstorms that produce heavy rain. The unpredictability of these weather systems make them a particularly challenging threat for us to understand and manage.

Figure 13 | Sidewalk next to Marsh Plaza piled high with snow.

In addition to rain and wind, snow and ice storms and subsequent accumulation pose another threat to Boston and BU. Though total global snow-covered area is continuing to decrease[34] winter storms have increased in intensity and frequency since the 1950's and their tracks have shifted northward[35]. Strong winter storms can cause power outages, physical damage to buildings, and increase the likelihood of flooding during spring. When snow and ice accumulate in catch basins (through natural processes or from being plowed), the natural pathways for water are blocked leading to increased chances of flooding. Additionally, when snow and rain do fall, they are likely to fall in more concentrated bursts, furthering the burden on storm water management systems[36].

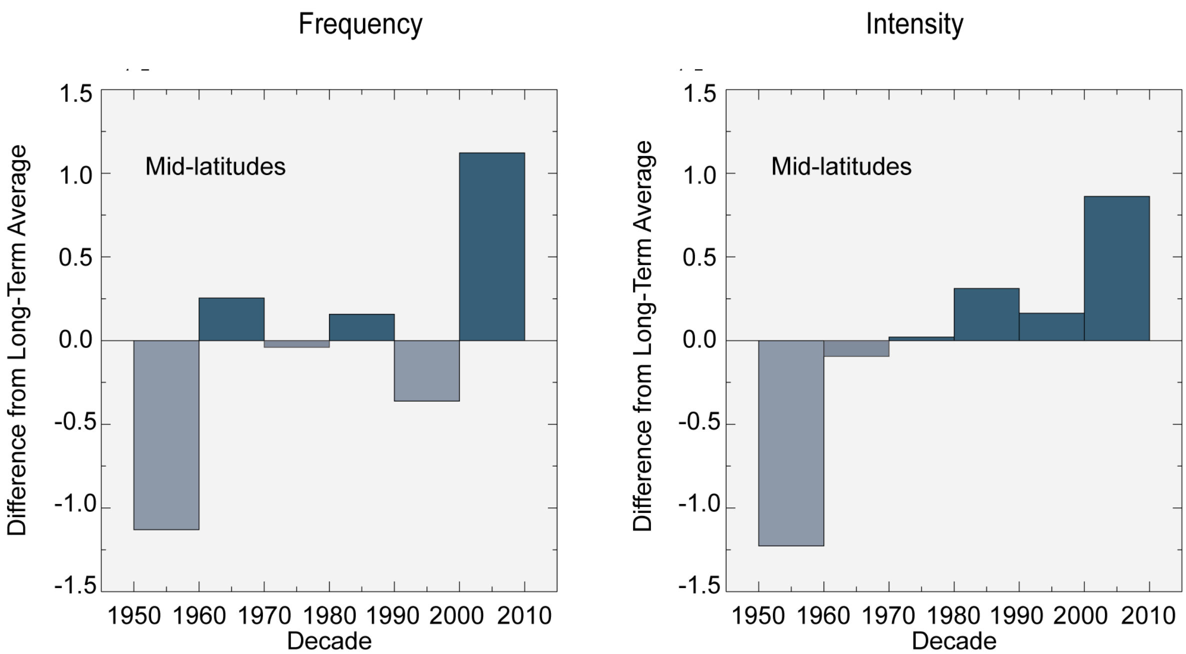


Figure 14 | Variation of Storm Frequency and Intensity during the Cold Season (November – March)[37]. Both winter storm frequency and intensity have increased in mid-latitudes (30-60°N).

Figure 15 | Kenmore Square Billboard Blown Down During Hurricane Sandy[38]

The University has observed, especially in recent years, that high winds can peel back roof membranes and force rain through the building envelope. Damage from high winds and wind-driven rain at BU over the past five years include:

Date	Storm	Insured	Rain	Wind	Notes
		Losses	inches	Max Gust (MPH)	
Feb 2010	Nor'easter		2. 4	60	
Mar 2010	Nor'easter	$2,650,000	7. 0	55	1
Mar 2010	Nor'easter		2. 3	60	
Jun 2010	Local Severe Storm		0. 7	68	2
Jul 2010		$140,000			3
Aug 2010	Hurricane Earl		0. 3	37	
Dec 2010	Nor'easter		1. 0	55	
Aug 2011	Tropical Storm Irene		1. 7	63	
Oct 2012	Super-storm Sandy	$225,000	1. 6	62	4
Dec 2012	Nor'easter		1. 9	55	
Jan 2013	Nor'easter		0. 3	60	
Feb 2013	Nor'easter		1. 9	66	
Jun 2013	Tropical Storm Andrea		3. 6	29	
Apr 2014	Nor'easter		0. 6	58	
	Total	**$3,015,000**			

Notes

1 Multiple Locations all over CRC and BUMC (esp. 700 Comm, 300 Babcock)
2 Downed historic & new trees on Comm Ave
3 Multiple Locations on CRC
4 Multiple Locations 860 & 856 Beacon St, 855 Comm Ave, 32 HAW, 10 Buick St.

Figure 18 | Cost of Top Fourteen Storms Since 2010. Cost includes insured losses only, as uninsured losses were not tracked. [39] [40]

The University's insurer, FM Global, conducted assessments of the Charles River Campus in 2012 and the Medical Campus in 2013. They covered a range of risks including the risks from wind-driven rain and flooding and recommended projects to reduce these risks. More than the frequency or duration of storms, the magnitude of these damages is due to the increase in the intensity of storms.

[1] http://www.gbci.org/reli

[2] Architecture 2030 is dedicated to reducing net greenhouse gas emissions from new construction to zero by 2030. Architecture 2030 asks the architecture and building community to adopt the 2030 Challenge to design and build to meet the goal of net zero emissions by 2030 and interim targets. Seek firms who have adopted the 2030 Challenge.

[3] http://www.architecture2030.org/files/2030ImplementationGuidelines.pdf

[4] https://portfoliomanager.energystar.gov/pdf/reference/US%20National%20Median%20Table.pdf except as noted

[5] https://2030ddx.aia.org/helps/National%20Avg%20EUI

[6] US EPA, DOE Labs21 Database

[7] My Green Lab http://www.mygreenlab.org/

[8] AAHRAE https://www.ashrae.org/resources--publications/bookstore/standard-90-1

[9] Resilient Design Institute: http://www.resilientdesign.org/leed-pilot-credits-on-resilient-design-adopted/

[10] Climate Ready Boston https://www.boston.gov/sites/default/files/document-file-12-2016/brag_report_-_final.pdf

[11] Primack, Richard. Walden Warming (pg. 50)

[12] The Boston Harbor Association, Preparing for the Rising Tide

[13] EPA, Framework for Sustainable Results in New England

[14] Robert Gilman, New England Weather Science

[15] US Green Building Council https://www.usgbc.org/about

[16] Architecture 2030 is dedicated to reducing net greenhouse gas emissions from new construction to zero by 2030. 2030 Challenge.

[17] EPA, Framework for Sustainable Results in New England

[18] NASA https://www.nasa.gov/press-release/nasa-noaa-data-show-2016-warmest-year-on-record-globally

[19] Bruce Anderson, Earth and Environment

[20] NOAA, Global Climate Change Impacts in the United States report, 2009.

[21] Climate Central, Hotter Boston temperatures mean air pollution

[22] Climate Central, 1001 Blistering Future Summers

[23] NOAA, Normals, Means, & Extremes

[24] B. Anderson et al. Northeast Climate Impacts Assessment (NECIA), 2007

[25] NOAA, Global Climate Change Impacts in the United States report, 2009

[26] Based on the difference in 5-year average cooling degree-days in Boston, MA vs Northern Florida – confirm reference from Bruce Anderson

[27] IPCC AR5, 2014, pg 209

[28] Primack, Richard. Walden Warming (pg. 50)

[29] Climate Central, Cities are hotter: Urban Heat Island

[30] Methodology follows Griend & Owe (1993)'s technique which involves estimating emissivity from NDVI, and estimating land surface temperature from the estimated emissivity. This is a widely practiced technique for estimating land surface temperature from Landsat imagery.

[31] NOAA National Hurricane Center

[32] Developed by BU GIS team based on MassGIS data

[33] Pedestrian Wind Study for BU Law School by Rowan Williams Davies & Irwin Inc., July 26, 2012

[34] IPCC Fourth Assessment Report: Climate Change 2007

[35] National Climate Assessment 2014, Changes in Storms

[36] Climate Ready Boston

[37] National Climate Assessment 2014, Changes in Storms

[38] BU Today October 29, 2012 Photo by Tom Daley

[39] Robert Gilman, New England Weather Science

[40] Boston University Risk Management