Climate Change and Flooded Cities: A Tale of Human Ingenuity
By: Brendan McCarthy

I. Thesis

We must redesign our coastal cities to mitigate the damage caused by increased storm frequency and severity. To do so, we must elevate environmental urban planning to the forefront of urbanization, so that we are able to adequately mitigate the resulting damage caused by rising sea levels, more powerful storms, and coastal flooding.

II. Introduction

Today, ten percent of the world's population lives in urban coastal areas, situated less than ten meters above sea level.[1] Nearly two thirds of the world population is projected to live in cities by 2050. Compared to around 55% of people today residing in cities, this demographic change showcases the continued urbanization of our world, and the growing need for sustainable urbanization practices.[2] An increase in urbanization is accompanied by the inevitable increase in greenhouse gas production. This leads to a more unstable climate, which in turn fosters increased storm occurrence and severity and flooding events along the coasts. An increase in hurricane frequency and extremity has been exacerbated by rising global temperatures and rising sea levels. Since 1880, global sea levels have risen by 8 to 9 inches. One third of that has happened within the last two and a half decades.[3]

[1] *Rising Seas Threaten Low-Lying Coastal Cities, 10% of World Population*, (Oct. 25, 2019), news.climate.columbia.edu/2019/10/25/rising-seas-low-lying-coastal-cities/.
[2] Author: Natalie Muller, *UN: 68 percent of world's population to live in cities by 2050 | DW | 17.05.2018*, www.dw.com/en/un-68-percent-of-worlds-population-to-live-in-cities-by-2050/a-43818167.
[3] Rebecca Lindsey, *Climate Change: Global Sea Level*, NOAA Climate.gov (Feb. 16, 2022), www.climate.gov/news-features/understanding-climate/climate-change-global-sea-level.

An increase in sea level leads to an increase in the tide marker, which contributes to a greater degree of storm surge. This is defined by how far water can travel inland when a storm occurs.

As urbanization continues to grow, the desire to live near coastal lying cities will grow as well, which places these populations in danger of climate-related events. In response to this trend, we must therefore consider how we build along our coasts, and how we mitigate damage from storms, higher tides, and flooding.

We must integrate environmental practices into our urban planning strategies. Of course, this idea is often met with a degree of skepticism, specifically about how implementing methods to enact these changes would entail an entire reconstruction of cities to serve the purpose of utilizing environmental projects to reduce the damages of severe weather incidents. However, we are well equipped to incorporate these environmental practices in our existing infrastructure.

Cities are often given the name "concrete jungles" for their artificial build-up; and yet, there is arguably nothing unnatural about manipulating our environment to better suit how we live. Ants make anthills, beavers make dams, robins build nests. None of these housing units occur naturally, they are built. Humans carry out the same practice, but on a much larger scale, and this makes for slightly more complex city-wide plans to mitigate environmental occurrences, such as increased rainfall and flooding. This paper will discuss our relationship with water, and how we may change this relationship to better suit our future interests, as well as the various methods coastal cities may employ to adapt to a changing climate.

III. Environmental Urban Practices

A. Sponge Cities

Our cities must be adapted to better co-exist with water. We don't like wet shirts, wet pants, wet socks, and especially not wet homes. With an increase in global temperature and rising sea levels, we have greater occurrences of floods along our coasts. When we evolve our cities to act as "sponge cities", we can alleviate the damage caused by these natural events. A sponge city is a permeable system that allows for the absorption of water, rather than an impermeable "concrete jungle". The adoption of this form of green infrastructure within coastal cities would help to alleviate the damage caused by water. There are many aspects of sponge cities that allow them to achieve maximum efficiency, such as wetlands, stormwater wetlands, green roofs, and green public spaces. These integrative practices are discussed below.

Yanweizhou Park in Jinhua before and after a monsoon, eastern China. Turenscape.[4]

B. Wetlands

A green infrastructure strategy serves to help cities preserve natural floodwater barriers, improve outdoor "green" areas, and to alleviate- not totally prevent- the damage that excess rainfall and flooding entail. Although we may implement green infrastructural practices, it is important to note that the natural world has already formulated a method to retain and process water: wetlands. In cities where they are already present, this is the most economical way to reduce the likelihood of floods, as these areas naturally retain rainwater and do not require any capital to perform their natural function. The Federal Emergency Management Agency (FEMA) states that floods are the second most common and widespread form of natural disaster in the United States (U.S.).[5] Therefore, it is imperative that cities begin to develop methods to mitigate the damage associated with these events. There is some maintenance surrounding the continued existence of wetlands, mainly through stemming the introduction of pollutants from entering the area where these wetlands occur, and the prevention of any invasive species that may negatively impact the wetland ecosystem. Wetlands possess a natural component of water retention, and their purposeful adoption within cities may further enhance water retention in urban environments.

C. Stormwater Wetlands

Stormwater wetlands are manually constructed to purify urban stormwater before it is used by or diverted away from a coastal city. Though they serve the same purpose as naturally

[4] Leanna Garfield, *China is building 30 sponge cities that aim to soak up floodwater and prevent disaster*, (Nov. 10, 2017), www.businessinsider.com/china-is-building-sponge-cities-that-absorb-water-2017-11.
[5] www.epa.gov/sites/default/files/2016-02/documents/flooding.pdf.

occurring wetlands- rainwater retention- this is a secondary purpose.[6] When rain falls in an urban area, pollutants on the ground are picked up and carried with the flow of the water. This may include oil and other waste from cars, various sediments, and other unpleasant particulates

It is important to remember that although water may be destructive, it is inherent to our existence. In essence, we must learn to utilize it to its fullest extent to reduce its potential to cause damage. Elisa Palazzo, a senior lecturer in urban and landscape design at the University of New South Wales, mentions how rainwater is a resource, not a form of waste.[7] Though it is commonly treated as such. Since cities are primarily concrete, stormwater is not effectively absorbed into the ground for dispersal. All this water is then funneled into a city's storm drain. Normally, coastal cities divert excess stormwater into the nearest body of water, like the ocean. However, even with this practice, there are still instances where sewers become backed-up with excess water.[8] This may cause sewage leakage, which causes an array of human health issues. The diversion of stormwater also risks relocating various pollutants into the coastal areas, and negatively impacting the coastal environment. This can cause a population reduction of various species in the coastal area, or the growth of copious amounts of algae that impact humans' ability to swim and may even contribute to dead zones in our coastal waters.[9]

So, the diversion of pollutants to coastal waters does not serve the general wellbeing of our cities, or the Earth. A method for cities to further purify urban stormwater is through the incorporation of stormwater wetlands, where the water may be diverted to these pools and native

[6] David Dickson, *Stormwater Wetlands* |, CT Stormwater Quality Manual (Oct. 4, 2018), ctstormwatermanual.nemo.uconn.edu/11-design-guidance/stormwater-wetlands/.
[7] *Design For Flooding: How Cities Can Make Room For Water*, Urban Ecosystem design Lab (Dec. 20, 2021), www.urbanecodesignlab.org/18dff.
[8] *How Sewage Pollution Ends Up In Rivers*, American Rivers www.americanrivers.org/threats-solutions/clean-water/sewage-pollution/.
[9] *The Effects: Dead Zones and Harmful Algal Blooms*, US EPA (Mar. 12, 2013), www.epa.gov/nutrientpollution/effects-dead-zones-and-harmful-algal-blooms.

flora may be used to remove the pollutants from the water. The water may then be reused in the city ecosystem to water crops or feed into an underground aquifer to provide drinking water to city residents.

Qunli Stormwater Wetland Park. Haerbin, China. Turenscape.[10]

D. Green Roofs

Additionally, the incorporation of green roofs may be used by cities to reduce the instances of flooding due to increased storms and rainfall. A green roof is not its own separate design, it is merely an extension of an existing roof. It includes a high-quality waterproofing

[10] *Gallery of Qunli Stormwater Wetland Park / Turenscape 12*, www.archdaily.com/446025/qunli-stormwater-wetland-park-turenscape/52799dbfe8e44ef00400009f-qunli-stormwater-wetland-park-turenscape-image.

material, root repellant system, drainage system, filter cloth, a growing medium, and the "green" part: native plants.[11] Flooding events from rainfall are becoming more common and many cities are not adequately prepared to face the destructive nature of increased flooding events. A specific instance in which green roofs could have perhaps aided coastal cities during a severe storm was Hurricane Sandy, which devastated New York and New Jersey in 2012. New York City's subway suffered extreme flooding, to the point where one could not walk, but rather would have had to swim, through the subway system. The city was unable to process the rainfall in an adequate manner, and the water went where water flows naturally: down. This resulted in a dead-end route for the water and due to a lack of proper dispersal methods, the water remained in the subway and prevented citizens from going about their business. Green roofs can reduce the amount of rainfall that enters the street. The planting medium on these roofs, along with the native flora, captures some of the rainwater and prevents spillage onto city streets more effectively than regular roofing material. This gives city drainage systems more time to process water before it leads to flooding.

Additionally, urban greening is an effective means to beautify the constructed environments within cities. Recycled material may also be used in the roof's growing medium, which could contribute to keeping compostable material out of landfills.[12] This would reduce the amount of trash that a coastal city processes, and that its residents pay to dispose of. Through the daily dew and evaporation cycle, plants on these green roofs may help to disperse the urban heat island effect, where the light absorbed by vegetation would otherwise be converted into heat energy. The plants also capture airborne pollutants and filter out noxious gases from cities,

[11] *About Green Roofs*, Green Roofs for Healthy Cities (Mar. 12, 2005), greenroofs.org/about-green-roofs.
[12] *ScienceDirect*, www.sciencedirect.com/science/article/abs/pii/S0360132322003596.

helping to increase air quality. Public spaces, enjoyed by many city-folk, can be repurposed to not only serve recreational purposes, but also as places which can absorb and store rainwater. This may further alleviate the pressure that city storm drains face during copious rainfall and transform ordinary public spaces into beautifully defined, and practicable, green spaces.

A green roof in New York City. Mike Treglia.[13]

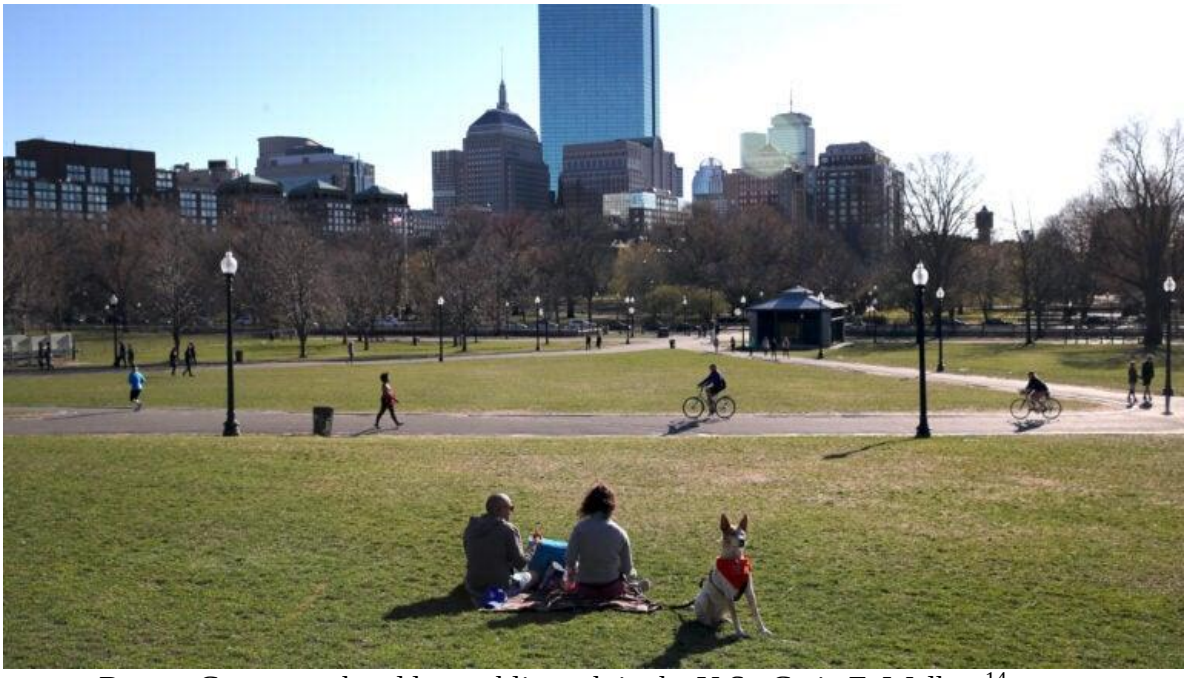
IV. Green Spaces

A. Boston

Green spaces in cities are not a new concept. The Boston Common in Massachusetts, for example, was established in 1634. In addition to being the oldest park in the U.S., it also serves to absorb rainwater during storms. Green space often provides a permeable layer for rainwater to enter. Most cities get their water from underground aquifers, so allowing water a porous path to enter back into the ground works to better provide access to water for residential purposes, such

[13] Kate Frazer, *Unlocking the Power of New York Citys Roofs*, The Nature Conservancy (Dec. 12, 2019), www.nature.org/en-us/about-us/where-we-work/united-states/new-york/stories-in-new-york/nyc-laws-green-roofs-solar-panels/.

as drinking or irrigating plants. Of course, many coastal cities do not face torrential downpours year-round. Most cities go through periods of rainy and dry seasons. This is where the true beauty of these practices come into fruition. On one hand, they provide a space for human enjoyment, and on the other hand, they provide a place for water to enter, be retained, and utilized. These are not just green-scapes, they are tools that future generations, long after we are gone, will be able to benefit from. That is where a much deeper value of these practices come into existence.



Boston Common, the oldest public park in the U.S.. Craig F. Walker.[14]

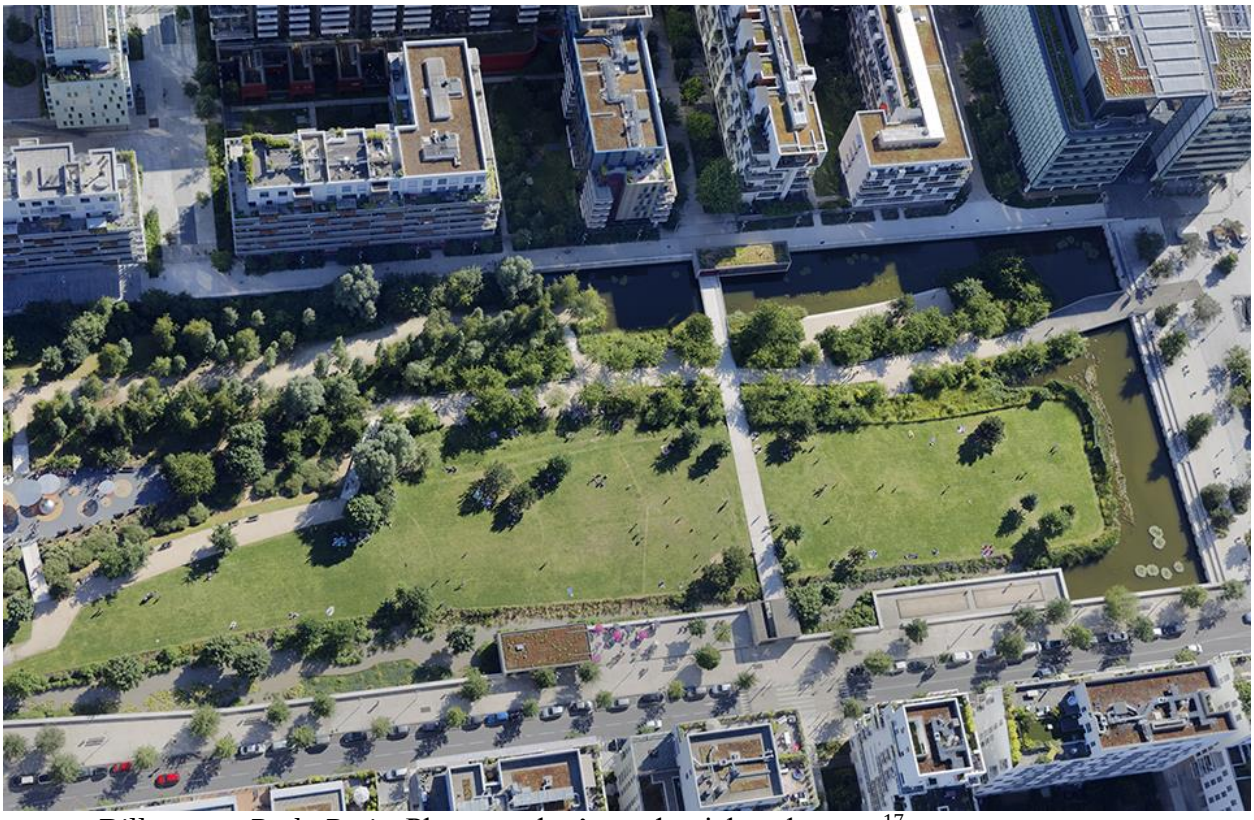
B. Billancourt Park

Billancourt Park, located in Paris, was designed to handle drastic changes in water levels.[15] Storing water in these spaces lessens the strain on the city's sewer and pump systems, and allows for native vegetation and wildlife to flourish in this city. Water defines the changing

[14] Kristi Palma, *A guide to Boston's parks and green spaces*, (Sept. 16, 2021), www.boston.com/travel/travel/2021/09/16/guide-boston-parks-and-green-spaces/.
[15] *Design For Flooding: How Cities Can Make Room For Water*, Urban Ecosystem design Lab (Dec. 20, 2021), www.urbanecodesignlab.org/18dff.

space of the park. This prominent design allows humans to use the green space, whilst at the same time promoting the storage of water within its boundaries. The Park covers an area of over 15 acres that once housed a massive Renault car manufacturing plant that halted production in 1992. Now, this ground has been designed to allow the Seine River to overflow into its area. The water flows into the park and forms ponds and marshes around "islands" with various elements: a flower-covered prairie, peat bog, and orchard which will shrink or grow depending on the level of the water table.[16] The design helps to mitigate the damages these flood waters would cause and allows citizens to enjoy the naturalized usage of this water in the form of a public park. Rather than using a powered drainage system to remove the water elsewhere, the park utilizes the water to irrigate the various flora that in turn beautify the area. Designs such as this showcase how with thoughtful environmental planning, we can create green spaces that contribute beauty and practical benefits to the surrounding area.

[16] Heidi Ellison, *Parc de Billancourt & Jardin de lIle Seguin*, Paris Update (June 16, 2010), www.parisupdate.com/parc-de-billancourt-a-jardin-de-lile-seguin/.



Billancourt Park, Paris. Photographer's credentials unknown.[17]

C. Enghaveparken

Enghaveparken, a park in the Danish capital of Copenhagen, showcases a design which reflects the variability and periodic change in flood levels.[18] During times where heavy rainfall is unlikely, the park serves as a space for residents to enjoy.

[17] *Id.*
[18] *OPINION Design for flooding: How cities can make room for water*, (Dec. 10, 2018), www.unsw.edu.au/news/2018/12/opinion-design-for-flooding--how-cities-can-make-room-for-water.

Enghaveparken, Copenhagen. Flemming Rafn.[19]

Studies have linked green spaces in cities to an increase in human health, both physically and mentally.[20] The promotion of happiness and health through these spaces is yet another incentive for their introduction and upkeep in cities. When rain levels increase, the landscape of the park changes, and it becomes "pond-like". This changes- but does not limit- how people interact with the space, which remains a constant reminder of how human ingenuity can be utilized to design spaces which better mitigate the environmental impacts of a changing climate. Spaces such as this have become a prominent topic in the U.S., especially as U.S. coastal cities continue to deal with the realities of a changing climate.

[19] Fotograf: Flemming Rafn, *Enghaveparken er klar til fremtidens skybrud*, Magasinet KBH (June 5, 2021), www.magasinetkbh.dk/indhold/ny-enghaveparken.
[20] Michelle C Kondo, *Urban Green Space and Its Impact on Human Health*, (Mar. 1, 2018), www.ncbi.nlm.nih.gov/pmc/articles/PMC5876990/.

There are many benefits to the inclusion of these "green" practices in city plans to reduce the potentially devastating effects of climate change. When cities utilize rainfall as a resource, and not as waste, positive changes take shape in the form of flood and trash reduction, temperature regulation, prevention of sewage overflow, improved air quality and access to water, and the reduction of coastal pollution, as seen in cities like New York and Boston.

Environmental Urban Planning in Practice

A. New York

New York City faces many factors that exacerbate flooding, such as rainstorms and impaired infrastructure. However, with over 500 miles of coastline, coastal storms present the most significant flood risk in terms of compromising human safety, property damage, and business disruption.[21] One of the goals within New York's Stormwater Resiliency Plan is to advance policies that reduce urban flooding and research that informs future risks. An initiative implemented to bring about this change includes the incorporation of green roofs in priority areas- areas that experience the highest risk of coastal flooding.[22] Green roofs will act to offset the amount of rainwater cities are tasked with processing during coastal storms. In 2019, the New York State legislature renewed the Green Roof Property Tax Abatement available for property owners installing green roofs. It reauthorized the reimbursement of $5.23 per square foot of installed green roofs and allowed the City to designate community districts that would receive an enhanced abatement of $15 per square foot.[23] In the advancement of environmental justice, the City could afford this abatement to communities that face a higher risk of coastal

[21] www1.nyc.gov/assets/planning/download/pdf/plans-studies/flood-resiliency-update/project-description.pdf. (2).
[22] www1.nyc.gov/assets/orr/pdf/publications/stormwater-resiliency-plan.pdf, (13).

[23] *Id.*

flooding, ensuring that these protective measures, along with their incentives, may be given to those who need them most.

An additional initiative implemented by New York City to combat the effects of coastal flooding is the amendment of chapters within Title 15 of the Rules of the City of New York (RCNY) to incorporate a Unified Stormwater Rule.[24] These changes will update and align Chapter 31 (Stormwater Quantity and Flow Rate Requirements), with Chapter 19.1 (Industrial, Commercial, Construction and post-Construction Stormwater Sources). This will increase the amount of stormwater required to be managed on-site and further restricts the release rates for all new and redevelopment projects that require a House or Site Connection Proposal from the New York Department of Environmental Protection (DEP).[25] Sites that disturb more than 20,000 square feet of soil, or increase impervious surfaces by 5,000 square feet or more in the city will have to manage the water quality volume- currently defined as 1.5 inches- using stormwater management practices by the DEP.[26] This initiative serves to promote the incorporation of environmental awareness within building practices, and the additional environmental planning scope also reshapes how construction projects are undertaken in the city. This will serve to lessen the impact of flooding and contribute positively to the livelihood of the current and future generations of the City.

B. Boston

[24] *Unified Stormwater Rule*, NYC DEP www1.nyc.gov/site/dep/water/unified-stormwater-rule.page.
[25] www1.nyc.gov/assets/orr/pdf/publications/stormwater-resiliency-plan.pdf, (13).
[26] *Id.*

Boston has also implemented various changes to lessen the impact of coastal flooding. Climate Ready Boston is an initiative which was established to prepare the city of Boston for the long-term impacts of climate change and its related effects.[27]

Waterfront parks along Boston's coastline maybe used to alleviate the impacts of coastal flooding and provide recreational spaces for residents. A distinct advantage of preserving open space along the waterfront is that space provides flexibility to further adapt and elevate waterfront areas if climate projections worsen in the future.[28] These areas may employ vegetation, like wetlands, to lessen the impact of flooding- and they may be designed to enhance neighborhoods and the waterfront by providing access and connection to an open space for passive and active recreation, natural landscapes, carbon mitigation, heat island reduction, and stormwater flood mitigation.[29] With community participation, the implementation of these waterfront parks may reduce the likelihood of the flooding of homes and businesses along the coastline. Additionally, due to the availability of space to set the design flood elevation further back from the shoreline, the impact upon waterfront views is minimized; an aspect that coastal business and homeowners have an obvious interest in maintaining.[30]

The Boston Harborwalk, a 43-mile linear park along Boston's coastline, can be adapted to serve as a more efficient flood barrier. Raising the top of the walking path onto compacted fill or adding additional height to the associated shoreline protection structures- such as seawalls, bulkheads, and revetments- would serve to keep Boston's neighborhoods connected to each other and to Boston Harbor by reducing the impact flooding may have on the area.[31] These proposed

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[27] *Preparing for climate change*, Boston.gov (July 17, 2016), www.boston.gov/departments/environment/preparing-climate-change.
[28] www.bostonplans.org/getattachment/d1114318-1b95-487c-bc36-682f8594e8b2, (54)
[29] *Id.*
[30] *Id.*
[31] *Id.*

changes would greatly benefit the homes and businesses along Boston's coastline. The question that remains, however, is how to pay for these changes.

It is worth noting that the longer things stay as they are, the higher the cost of inaction will be. The increasing frequency of severe storms, abnormally high tides, and flooding pose a threat to the stability of life and business in Boston. There is no simple financial solution to combating climate change, but the Sustainable Solutions Lab of the University of Massachusetts Boston suggests that funding could come in the form of a statewide carbon tax, a tightened Regional Greenhouse Gas Initiative (RGGI) cap, or a 5-cent gasoline tax increase.[32] The Lab estimates that the latter item alone could generate more than $156 million a year.[33] Complex issues such as climate change mitigation require adept and thoughtful solutions, which will challenge the people of Boston and others who face increases in climate-related disasters to develop methods to mitigate these damages.

This solidifies the fact that when cities begin to implement practices that reduce the impacts of climate-related events, homes and livelihoods can continue without disastrous consequences. So, it is submitted that environmental urban planning within cities such as Boston may aid in the reduction of climate induced migration.

V. Climate Induced Migration

Climate migrants, or "environmental refugees", defined as people who can no longer gain a secure livelihood in their homeland because of marked environmental disruptions, are regularly presented as one of the most severe consequences of climate change and natural disasters.[34]

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[32] *UMass Bostons Sustainable Solutions Lab provides recommendations on financing climate resilience*, PreventionWeb (Apr. 14, 2018), www.preventionweb.net/news/umass-bostons-sustainable-solutions-lab-provides-recommendations-financing-climate-resilience.
[33] *Id.*
[34] *Climate induced migrations*, (Nov. 3, 2017), en.unesco.org/events/climate-induced-migrations.

Through the use of environmental urban planning, we may establish practices that can mitigate the occurrences of climate induced migration.

When cities are equipped with the tools to combat the effects of climate change and reduce the chance of people being unable to conduct their daily lives in a safe, efficient manner, this has the potential to reduce the rate at which people are forcefully uprooted from their homes and forced to move elsewhere. This can go some way to ensure that people may remain in areas they call their home and are able to carry on with their daily lives safely and effectively. This lessens the effect of stressful factors placed upon the areas that these groups migrate towards, such as issues of overcrowding, disease, crime, and sanitation issues.

VI. Potential Negative Impacts of Environmental Urban Planning

Along with the positive notes that environmental urban planning carries, there are also certain detriments that may occur as a result of these practices. The need to identify with a group is so deeply imbedded in the human psyche, it may even be considered biological. Festinger's social comparison theory explains how we compare ourselves to those around us to see how we fit into the world.[35] Our realities are subjective, and we constantly search for frameworks to better understand ourselves and those around us. Social comparison provides us with the information to build those frameworks.[36] We instinctively use other people through comparison to protect ourselves from actions that may harm ourselves or our group. With this clannish nature in mind, we can draw a logical link between the implementation of environmental urban planning in a city, and the exclusion of "outsiders" from a coastal city if climate change becomes so disastrous that living becomes nearly impossible outside of cities.

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[35] *Module 8: Group Influence Principles of Social Psychology*, opentext.wsu.edu/social-psychology/chapter/module-8-group-influence/.
[36] *Id.*

Left to their own discretion as to how best to change their cityscape to better suit a changing climate, some cities may become more hospitable than others. Certain cities would inevitably become bastions of human survival amidst catastrophic climate change, pitting populations against one another for a placement in these cities. If some cities were to act more swiftly than others, this would cause an imbalanced shift between cities better suited to sustain human life, and cities from which people would undergo a mass exodus. This would lead to its own set of detrimental issues such as disease, human trafficking, famine, and displacement. This is the delicate scale between the implementation of environmental urban planning and ensuring that all people can benefit from these practices. However, without adequate adaptation at all urban levels, it is difficult to distinguish the exact scale of negative drawbacks these practices would ensue. Though these negative events could occur due to the uneven distribution of these practices, it must also be considered, once more, that humans are adaptable and proficient builders. This trait has led us to survive thus far, and will continue to shape the way we adapt in the future.

VII. Conclusion

Human ingenuity, paired with our ability to manipulate our landscape will be the defining factors as to how we adapt our environment to a growing human population amidst a changing climate.

The use of environmental urban planning presents an exciting prospect for how we may better shape our cities to harbor human life, whilst at the same time reducing the negative effects of climate change.

Climate change is an intimidating prospect, but humanity has overcome detrimental odds in the past. It is not unreasonable to assume that we can once more achieve great results in these

unsure times through appropriately allocated funding, amendment to local statutes, the prioritization of resources, and the creativity to ensure these initiatives may result in multiple benefits for citizens now, and in the future.