Learning from the complexities of NYC's High Line: The Urban Heat Island Effect and Green Gentrification

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ABSTRACT

The impact of climate change on cities reverberates across multiple environments: Bio-physically, the intensification urban heat islands underscores the urgency for effective mitigation strategies. Socio-politically and -economically, systemically marginalized communities are structurally positioned to experience the worst of climate injustice. How do we design climate solutions in a way that mitigate the urban heat island and the structural inequality that comes with it? Reflecting on one angle of this complexity, I highlight the importance of scientific research surrounding the biophysical formation and mitigation of the UHI mitigation. Then, through a case study of New York City's High Line, I demonstrate that urban greening and sustainable redevelopment strategies risk catalyzing green gentrification because of their embeddedness in racialized, capitalist structures. From there, this paper proposes (re)politicized climate solutions through frameworks and examples of justice-centered pedagogy and critical urban theory with an overall goal of supporting a systematic approach to just sustainable redevelopment.

INTRODUCTION

In the introduction of *Climate Futures*, a newly published anthology synthetic of work at the edge and across schools of thought and action surrounding climate change, the editors invoke the powerful words of writer and activist Naomi Klein: "Nothing is inevitable. Nothing except that climate change changes everything. And for a very brief time, that change is up to us (Bhavnani et al., 2019). Klein powerfully captures the gravity of our changing world while pushing against defeatism and nihilism. The shape of climate resilient *is up to us.* For that reason, the work of this paper is to examine the shape of climate solutions with attention to their complexities: In settler colonial landscapes, white-supremacist structures and contemporary articulations of racialized capitalism, the soils in which dominant climate solutions grow call for serious questioning of their form (Rice et al., 2021; Tuana, 2019). The specific dimension of climate solutions examined in this paper are the biophysical formation of urban heat islands (UHIs) and the political ecology of mitigation strategies. In the spirit of Klein, our strategies for adaptation and resilience are *up to us;* in acknowledgement of the inherently unequal risks associated with climate change, there is an urgency to do the work of environmental science in a way that is both scientifically effective and socially just.

At the risk of being disjointed, yet with the possibility of being uniquely synthetic across disciplines, this paper examines the particularities of UHIs and UHI climate solutions in three parts: Section I of the paper synthesizes a literature review of current scientific understanding of UHIs with attention to a) the land-atmosphere interactions underpinning UHIs, b) the anthropogenic magnification of the UHIs, and c) the public and environmental health implications of UHIs. From there, a review of prominent, scientifically-based UHI mitigation strategies is examined to build a strong

foundation of current scientific work surrounding UHI. Section II pivots to a case study of New York City's High Line to highlight the realities of environmental gentrification as a way to contextualize and complicate well intended and highly researched mitigation strategies for UHIs—which are often primarily scientifically informed. Here, the paper briefly reviews the political economy underpinning the High Line while also synthesizing indicators and implications of green gentrification. Finally, this paper returns to the question of reconciling what is scientifically effective with what is socially just in terms of mitigating the harms of UHIs. In this space of contestation, I argue for the importance of contextualizing and (re)politicizing science by using a critical urban theory and justice-centered pedagogy as well as building strong coalitions for engaging the "wicked problems" of climate change.

PART I. THE SCIENCE OF URBAN HEAT ISLANDS & MITIGATION STRATEGIES

1.1 Climatological review of urban heat island formation

The UHI is characterized by disproportionate heating of and higher temperatures within urban centers compared to surrounding suburban and rural areas by as much as 1-3 degrees Celsius (Liu & Niyogi, 2019; Zhao et al., 2017). Research surrounding UHIs has increased dramatically in the recent years (Chun & Guldmann, 2018). With more than half of the world's population currently living in cities and an expected growth of that ratio, the importance of studying the UHI effect cannot be understated (Liu & Niyogi, 2019; Zhao et al., 2018). Georgescu et al highlights the urgency of researching and mitigating the UHI, emphasizing that urban design in and of itself will act as a climate forcing and "not just at the scale of individual cities, but over large regional swathes of the country"

(Georgescu et al., 2014). The importance of studying UHI intensifies as cities continue to sprawl and further change landscapes in drastic ways. Because of the variety of factors that influence the intensity of the UHI, the following review highlights a) the land-atmosphere interactions creating conditions for the UHI, b) the anthropogenic magnification of UHIs, and c) the environmental and public health implications of the UHI.

A helpful starting point for examining the land-atmosphere interactions that underpin the UHI is the conceptual model created by Chun and Guldmann which illustrates the compounding effects of urbanization (*see* Figure 1). It specifically identifies physical factors common within cities that influence the energy exchange between urban surfaces and the surrounding atmosphere (Chun & Guldmann, 2018). Most prominently, urban albedo, radiation dynamics in the urban canopy, and urban impacts on convection shape the UHI microclimate.

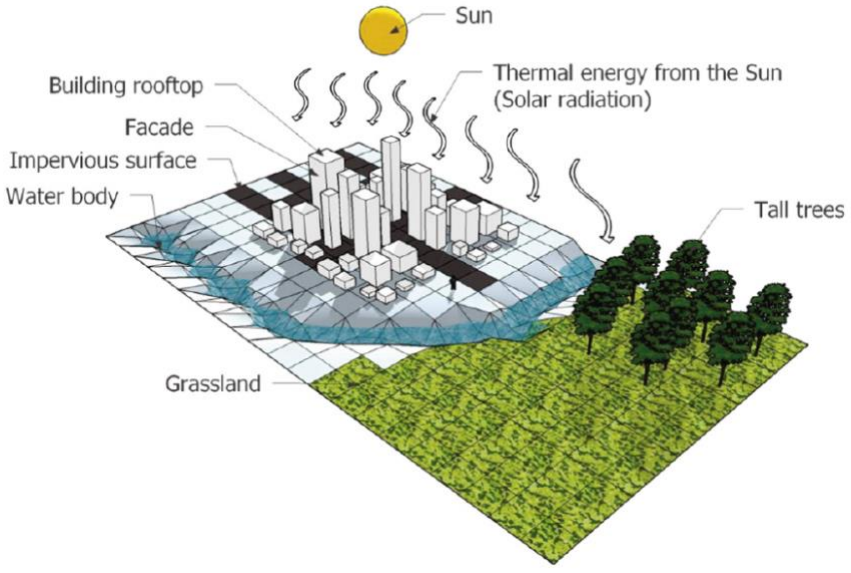

Figure 1. Chun and Guldmann's (2018) conceptual model of the UHI with clearly marked factors that influence the magnitude of the UHI (Chun & Guldmann, 2018)

The lower albedo, or reflectivity, of certain urban features like roads contributes significantly to the intensification of the UHI (Chun & Guldmann, 2018). Incoming shortwave radiation absorbs more easily into the darker surfaces and structures of cities and thus directly warms the microclimate of the urban area (Nuruzzaman, 2015). The physical factors that create UHIs are products of built changes in the environment: The proliferation of impervious surfaces, density of buildings, concentration of people and cars, as well as the removal of vegetation, all compound to create UHIs (*see* Figure 1 and Figure 2; Chun & Guldmann, 2018; Nuruzzaman, 2015; Zhao et al., 2018).

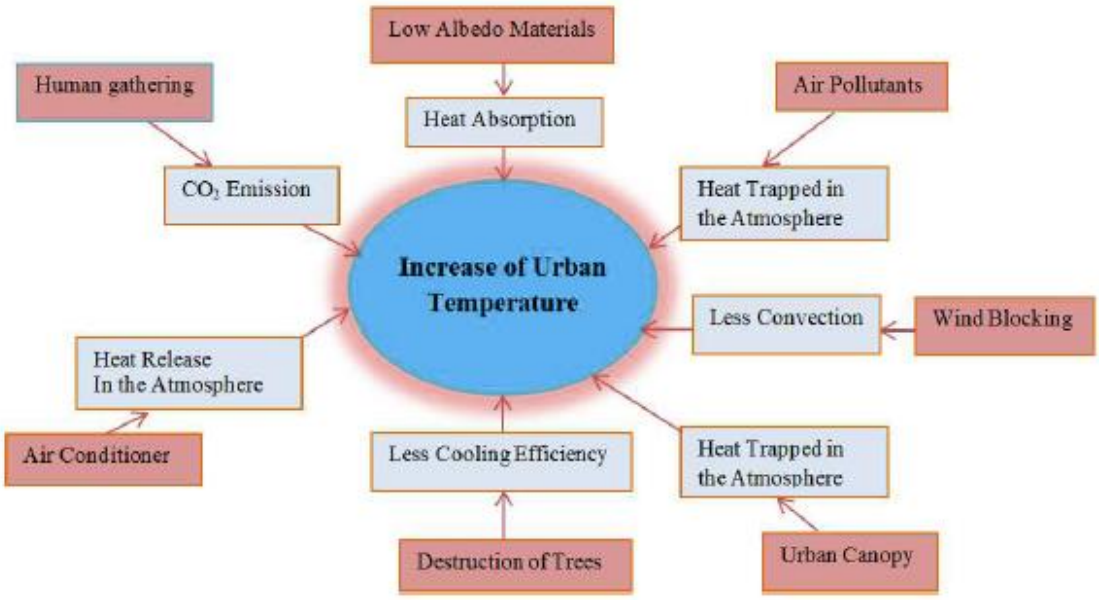

Figure 2. Nuruzzaman's (2015) diagram of factors involved in the formation of the UHI (Nuruzzaman, 2015)

In more complicated climate models, there are factors beyond surface reflectivity that influence the average albedo of a city. Urban canopy models (UCMs) take into account the impact of urban

geometry on energy and momentum exchange between urban surfaces and the atmosphere; additionally, UCMs quantify heat fluxes amongst urban surfaces (roof, wall, and road) that are modified by shadowing and reflection of incoming radiation from the built environment (Kusaka et al., 2001). The physical structuring of the built environment increases flux and absorption of shortwave radiation through reabsorption of reflected surface radiation by surrounding buildings which increases the magnitude of urban heating (Kondo et al., 2001; Nuruzzaman, 2015). In their research on urban canopies, Kondo et al conclude that a number of factors contribute to the overall dynamics of shortwave and long wave radiation flux in cities, which include solar altitude (the angle at which the sun reaches the surface), building height, road orientation, and building concentration (Kondo et al., 2001).

More specifically, the findings in Kondo et al suggest that taller buildings and increasing variety in building height contribute to an overall decrease in albedo (Kondo et al., 2001). Overall, the impact of albedo—which is characteristically low in cities—has significant yet variable impact on warming urban microclimates; the design variability of urban areas influences the extent to which shortwave and long wave radiation flux heat the area.

In addition to the warming impacts of lower albedo, the built environment of cities also play a critical role in shaping convective processes. While additional study is needed regarding urban convective dynamics and urban modification of precipitation, recent research suggests that the UHI has noticeable impact on convective processes and rainfall events (Liang et al., 2018; Liu & Niyogi, 2019). Because of spatial inconsistencies in UHI intensity and wind dynamic variability, uncertainty remains about *where* rainfall might increase through heat island feedback. However, growing evidence suggests that rainfall intensifies in urban areas with less wind and stronger UHI effects, whereas urban peripheries

and surrounding rural areas might experience more intense rainfall in regions of stronger wind and less intense UHI (Liu & Niyogi, 2019).

UHI convective modification also impacts thunderstorm formation. Related to UHI precipitation dynamics, current research suggests that strong UHIs will enhance thunderstorm formation, while weaker UHIs might actually enhance thunderstorm bifurcation causing the thunderstorms to "move around cities because of building-barrier effects" (Liang et al., 2018). Additionally, UHIs characteristically have higher concentrations of aerosols which contributes to enhanced cloud formation with increased variability of cloud condensation nuclei (Han et al., 2020; Liang et al., 2018). Energy exchange in UHIs through convective processes and thunderstorm formation demonstrate diurnal variability as well. Synthesizing a study of upwards of ninety summer thunderstorms, Niyogi et al report that "71% of the daytime storms showed urbanization impact (as compared to 42% for night)" (Niyogi et al., 2011).

Finally, anthropogenic factors other than buildings and urban design intensify UHI. Of all global environments, cities create the most aerosols and anthropogenic heat emissions (Han et al., 2020). Anthropogenic factors that influence UHIs, like energy use associated with air conditioning, are projected to increase with climate-induced intensification of UHIs (Zhao et al., 2018). The synergistic relationship between heat waves (HWs) and UHIs is a helpful entry point through which to examine the anthropogenic sources of heat beyond the human-bult city landscapes.

The Intergovernmental Panel on Climate Change projects that HWs will continue to occur more frequently and intensely (Zhao et al. 2018). Depending on the climate forcing of a given scenario, the UHI effect will likely intensify with an increase in HWs. The diurnal and regional

variability will likely influence these dynamics. Generally, Zhao et al (2018) calculated that "near the end of this century, the average HW exacerbation of UHI_{2m} is projected to increase to 0.2 ± 0.06 K and 0.3 ± 0.05 K under RCP 4.5 and RCP 8.5, respectively," which is a statistically significant amount of warming and 20-30% of the magnitude of global warming experienced thus far. (Zhao et al., 2018). A key anthropogenic heating factor underpinning this synergistic warming is the increased usage of air conditioning to mitigate extreme heat stress which releases heat though energy usage (Nuruzzaman, 2015; Zhao et al., 2018). Additionally, anthropogenic heat and pollution associated with high traffic densities contribute to the disproportionate warming of urban environments (Nuruzzaman, 2015).

The anthropogenic heat release associated with increased energy use in UHIs—especially during HWs—not only contributes to the overall mechanics of UHI formation but also further exacerbates the environmental and public health implications of UHIs. Strong evidence projects UHIs to be an even more deadly force as the climate warms (Zhao et al., 2017, 2018). Already, heat-related illnesses and deaths account for the number one cause of nature-related deaths in the United States (Bobb et al., 2014). In addition to the mortality associated with extreme heat, the high concentration of pollution and aerosols in cities creates high risk health conditions: from pollution-induced asthma to heart attacks and lung cancer, particulate matter concentrated in UHIs creates extremely dangerous health outcomes (Bobb et al., 2014).

In summary, the current scientific understanding of UHI formation highlights the important role that urban settings play in altering radiation flux in a way that disproportionately warms cities. Relative to rural environments, the heat storage of urban environments is greater because of the overall lower albedo of cities which creates absorption pathways for incoming shortwave radiation. Shortwave

radiation that is reflected from the ground also reabsorbs into surrounding buildings in the built urban canopy. Further, the pollution of cities and associated production of aerosols alters both radiation dynamics and weather-related convective events, while also creating public health challenges. Under different warming scenarios, UHI demonstrates spatio-temporal variability, as well as generally synergistic dynamics with HWs. Overall, the environmental and public health concerns of UHIs, which will only be exacerbated by climate change, generate urgency for better understanding UHI dynamics and mitigation strategies.

1.2 Scientifically-based UHI mitigation strategies

With a scientific foundation of UHI formation set, the following review summarizes the most common UHI mitigation strategies. It highlights current research to demonstrate *how* each strategy works climatologically, as well as each strategy's potential impact by expanding upon the pathways illuminated in Figure 3 (Hoverter, 2012).

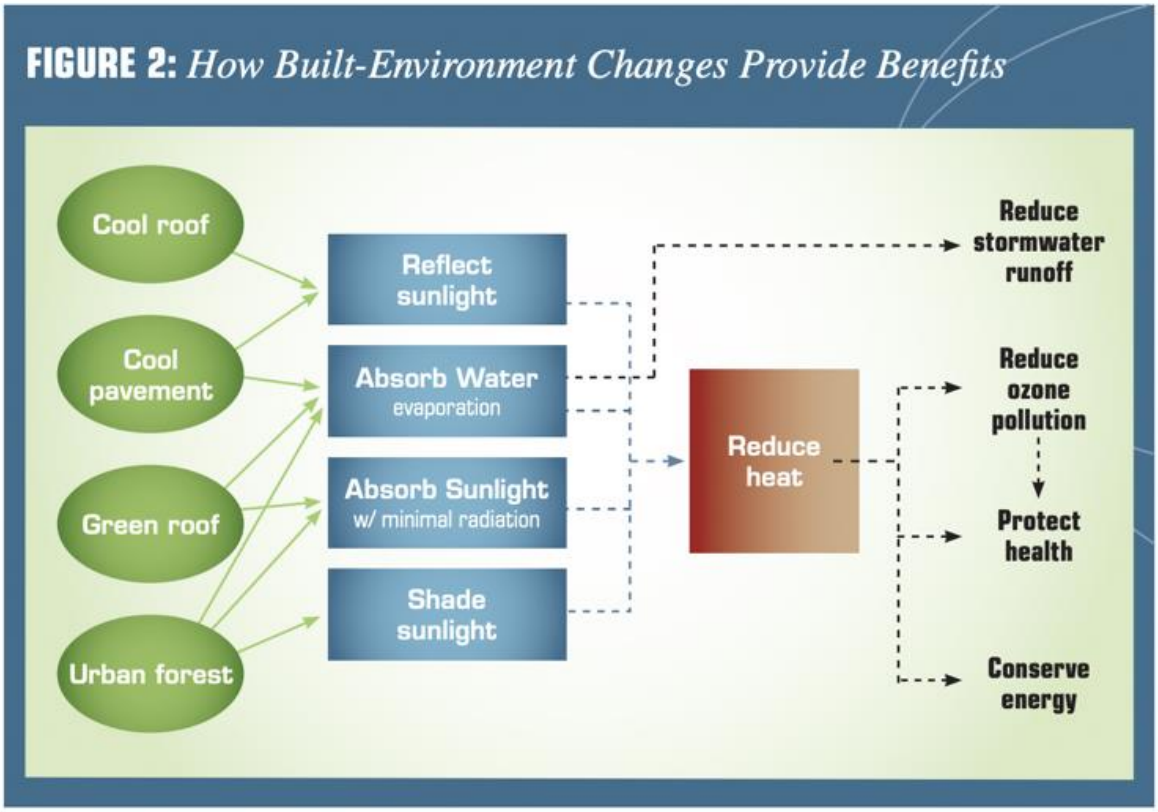

Figure 3. Hoverter's (2012) schematic of UHI Mitigation strategies (Hoverter, 2012)

Cool roofs and pavements: The central benefit of cool roofs is their potential to increase albedo (Nuruzzaman, 2015). Hoverter references a study which calculates "that cool roofs on half of the available surfaces could lower the air temperature by 0.3 degrees F" (Hoverter, 2012). While the cooling potential of this strategy is significant, wide scale cool roof adoption can create challenges for energy usage during colder seasons (Georgescu et al, 2014). The high albedo of cool roofs can increase energy demands for heating in some regions during the winter time because of its inter-seasonal cooling effect. For this reason, the use of cool roofs will need to be examined in the context of regional climates to ensure that their effect has a net decrease on energy usage for heating and cooling buildings (Hoverter, 2012).

Through processes similar to cool roofs, cool and permeable pathways have the potential to mitigate the UHI by capturing runoff and creating more pathways for evaporation within the city while also lowering the albedo (Nuruzzaman, 2015). However, costliness of permeable pavement as well as effectiveness of cool pavements raise concerns for how feasible and effective this mitigation strategy is for UHIs (Hoverter, 2012).

Green roofs: The cooling mechanisms of green roofs come from their high transpiration potentials. In contrast to cool roofs, modeling studies demonstrate that green roofs do not facilitate wintertime cooling because the moisture contained in the green roofs stabilizes temperatures and prevents extreme cooling to some extent (Georgescu et al., 2014). Lastly, green roofs play a large role in shrinking the scale and speed of runoff after heavy precipitation events because of their absorptive properties. By slowing and capturing run-off, green roofs have a sustained cooling effect, created by the evaporation of captured run-off (Nuruzzaman, 2015). This cooling effect also has co-benefits with stormwater management and mitigates overloading storm water systems in cities.

Urban vegetation: Through shading, evapotranspiration, and air filtration, the potential of urban vegetation to mitigate the UHI is immense and multi-faceted. Aforementioned, typical city materials both have higher capacity to store heat and have lower albedos (Zhao et al., 2017). Increased tree coverage shields incoming radiation. In one study, the shielding and cooling effect of trees reduced "the surface temperatures of walls and buildings by 20 to 45 °F" (Bell et al., n.d.). In addition to cooling buildings, a modeling case study in Los Angeles estimates that afternoon air temperatures could drop by about 3.6 degrees Fahrenheit if the city increased their vegetated land area by only one percent (Hoverter, 2012). Beyond shading, the evapotranspiration properties of urban vegetation cool

areas as water moves from the ground to the atmosphere, releasing absorbing latent heat in the process and transferring it to the upper atmosphere (Zhao et al., 2017). Lastly, studies have found that the increase in surface roughness created by urban trees can also catalyze efficient convection, which can cool urban areas (Hoverter, 2012).

1.3 Urban greening climate solutions

Most mitigation strategies mentioned in scientific papers operate through parameters of climatological impact and feasibility. Quantifying and strategizing impact are crucial, especially because "for a very brief time, [climate] change is up to us" (Bhavnani et al., 2019). However, I argue that socio-economic impact of climate solutions is a crucial parameter that must be considered across all levels of research and implementation—from scientific studies to city councils voting on sustainable redevelopment projects. All mitigation strategies reviewed in this paper have socio-economic impacts on cities. However, a specific focus on urban greening climate solutions illuminates the complexities of implementation though its relationship to environmental gentrification.

Already, cities have implemented urban forestry and greening initiatives for both environmental, health, and aesthetic reasons (Sisson, 2020). Incorporating vegetation into cities has the aforementioned environmental benefits of cooling, while also contributing to overall wellbeing and health of city communities (Bell et al., n.d.; Hoverter, 2012; Sisson, 2020). Because of the embeddeness of urban greening in racialized capitalism, urban greening can also force green gentrification. This reality should not lead us to believe that cities should not incorporate urban vegetation, or worse, not invest in urban greening in areas most vulnerable to green gentrification. Rather, my goal is to highlight that

redevelopment projects can reproduce harm that is a product of their embeddedness in racialized and capitalist structures.

In a departure from the scientific literature review, the next part of this paper closely analyzes a particular sustainable redevelopment project in NYC. The High Line's incorporation of urban greening solutions pulls through scientific knowledge described in Section I and threads in political context in Section II. The value of situating scientific analysis next to socio-economic and political analysis is the possibility of building multi-faceted knowledge of urban space to support complex, contextualized and critiqued articulations of climate solutions.

PART II. CONTEXTUALIZING STRATEGIES: THE HIGH LINE

2.1 The High Line: A Case Study

The well-established and growing body of scientific research that tracks both the climatological and biophysical factors of UHIs today is an important way to understand the built, urban environment. For good reason, mitigation strategies rooted in science strongly focus on and quantify cooling effects of urban greening solutions. These modes of scientific knowledge production and implementation help inform a growing field of sustainable infrastructure. The perceived objectiveness of scientifically-developed climate solutions enable the framing of redevelopment projects in public discourse as apolitical, or win-win solutions (Anguelovski et al., 2018). Because of the way that scientific discourse[1]

[1] For the purposes of this paper, when I describe "science" or "scientific discourse," my focus is on Western science.

can be used to legitimize sustainable redevelopment, if scientifically based solutions for climate change silo knowledge and decontextualize solutions, existing environmental injustices that fall along racial and class lines will be reproduced and exacerbated (Anguelovski et al., 2019). The focus on scientific discourse and sustainable redevelopment is not to falsely ascribe blame to the field of science and urban planning, or scientific actors and urban planners. Doing so would risk an individualistic approach to a political and economic structural problem. Rather, the focus of scientific discourse and scientifically informed UHI mitigation strategies for sustainable redevelopment is to highlight the way that science and redevelopment are not immune to reproducing the structural injustice inherent in racialized capitalism. The impact of New York City's High Line convincingly demonstrates this logic.

To demonstrate this, first, I discuss how the High Line fits into sustainable redevelopment frameworks while also describing the potential climatological impact of the High Line. Inherent in this analysis will be the threading in and threading through of scientific knowledge that underpins and supports the shape/form of mitigation strategies. Then, I uncover the political economy enabling the High Line's creation. Finally, I round out the discussion by analyzing the political ecology of the High Line across socio-economic environments. From this conversation, I will enter into a broader conversation about environmental gentrification and invoke the question asked by Anguelovski et al. (2019): *For whom are we building resilient cities and by what means?*

2.2 Sustainable Redevelopment and climatological impact of the High Line

The High Line's website proudly highlights that "environmental sustainability is a core value of [the park]" (*High Line*, n.d.). Sustainability comes in a number of forms at the High Line. First and

foremost, the High Line repurposes an existing railroad structure which significantly cuts down on the energy and materials required for ground up development (Lindner & Rosa, 2017). While the environmental effects of the Highline have yet to be well quantified, biophysical and microclimatological cooling potential certainly abound. The increase in greenery, trees, and soils atop the High Line creates both shading potential and evapotranspiration cooling potential. Additionally, the High Line increases the biodiversity across a substantial region of the city though its linear form (Heijn, n.d.). On an ecological scale, the incorporation of native and climate resilient plants also strengthens regional biodiversity and has the potential for supporting pollinators (*High Line*, n.d.).

Given the threat of the UHI effect, post-industrial, sustainable urban redevelopment with attention to sustainability is critical both for the importance of cooling effects and for the ways that green spaces improve overall wellbeing by filtering pollutants and stimulating outdoor activity for residents (Wolch et al., 2014). On a purely environmental level, the High Line certainly checks the climate-mitigation infrastructure. Yet, the High Line does not exist in a vacuum; the political contexts into which the impacts of green infrastructure reverberate spark tension and contestation.

2.3 Political Economy of the High Line

Beyond environmental impact, the High Line is a globally recognized linear, sky park and flagship example of a post-industrial, sustainable redevelopment project (Lindner & Rosa, 2017; List, 2016). The High Line formerly operated as West High Line Railroad. Now the railroad's skeleton elevates the 1.5 mile green park. Lofted in NYC's urban canopy, the High Line brings in almost 8 million tourists every year as a celebrated, worldwide attraction (Matthews, 2019). In the shadows of its wide

celebration, real-estate values surrounding the High Line have skyrocketed, increasing by more than 100% since its reconstruction (Patrick, 2017). With abrupt increase in property values, long-time residents face increasingly heightened displacement with the trickling in of high-wealth individuals. Following racial and class lines, the gentrification and displacement occurring around the High Line call for serious consideration of the *form* sustainable redevelopment takes, especially with clear evidence that projects like the High Line are exacerbating structural inequalities, similar to the unjust distribution of climate harms (Anguelovski et al., 2018; Patrick, 2017).

To understand the political economy enabling the High Line, an important force to track is the way in which the High Line's historical transformations appeal to socio-economic hegemony. Along gradients of high urban production of goods, the original High Line pulsed from places like NYC's meatpacking district to surrounding markets in the height of the industrial era (Lindner & Rosa, 2017). With deindustrialization, the High Line abandoned its railroad identity and fell into disrepair and abandonment. In the late 20th century, redevelopment pressures came in two forms: 1) to demolish the High Line and develop the real estate for business and residential aims or 2) repurpose the High Line (Lindner & Rosa, 2017). A group of wealthy patrons collectivized under a nonprofit called Friends of the High Line (FHL) and "were able to catalyze interest among the economic and cultural elite of the city" (Lindner & Rosa, 2017). Through this conglomerate of social capital and wealth, FHL was able to "influence the mayoral debate, eliciting the support of all six mayoral candidates for the viaduct's reuse," paving the way for the High Line's repurpose to a cutting edge linear park and greenway (Lindner & Rosa, 2017).

In the process of constructing the High Line, a number of competing interests arose. In their introductory chapter of *Deconstructing the High Line,* authors Rosa and Lindner elevate sentiments from Joshua David, one of the co-founders of the High Line, with regard to the structuring of the High Line Space:

> "You had a group fighting to keep buildings as low as possible, and a group pushing for more affordable housing. There was a smaller group pushing for retention of manufacturing space, not just for the galleries, but also to support a continued manufacturing sector. . . . The reality was [that] moving the development rights away from the High Line sites was going to mean that some buildings were going to be taller. And in order for the economics of the development right transfers to work, there had to be a major chunk of market- rate housing in the formula, which was not what the affordable housing group wanted to hear" (Lindner & Rosa, 2017).

What David's words capture is the tension inherent in the question "*For whom are we building resilient cities and by what means?*" Through rezoning, market-rate housing accompanied the construction of the High Line. In addition to high end residences, the incorporation of upscale restaurants and art galleries resulted in an estimated 2 billion dollars of real estate reinvestment and more than 100% increase in real-estate values in close proximity to the High Line (Patrick, 2017). As evidenced by these statistics, the High Line demonstrates a privatized and market based approach to post-industrial urbanism—one that "promote[s] environmental sustainability within a market logic, emphasize[s] urban entrepreneurialism, align[s] with the property and banking sectors, and brand[s] New York as a world- leading city of luxury" (Lindner & Rosa, 2017). On a macro scale, the High Line's

redevelopment embodies a systemic political and economic issue, yet a magnified focus on the politics of environmental sustainability offer an interesting entry point through which to examine larger forces at play.

Analyzing the political economy enabling the High Line is of particular importance because the High Line has served as a point of *global* inspiration for what "success" can look like for a sustainable and redeveloped space (McGinn, 2014). Yet clearly there seems to be tension around success *for whom* and *by what means.* This tension is visible in the words of Jeremiah Moss, a long time New Yorker, write and activist. He penned a powerful critique of the High Line in its early stages: "Moss lamented that [the High Line] had become 'a tourist-clogged catwalk and a catalyst for some of the most rapid gentrification in the city's history,' and that it was part of 'the Bloomberg administration's creation of a new, upscale, corporatized stretch along the West Side...Gone entirely will be regular New Yorkers, the people who used to call the neighborhood home. But then again the High Line was never really about them" (Lindner & Rosa, 2017).

2.4 Political Ecology and Green Gentrification

What are the implications of the High Line "never really [being] about [regular New Yorkers]?" Moss's grievances illuminate a crucial impact of sustainable urban redevelopment: green gentrification. Examining green gentrification offers an important entry point into analyzing the impact of post-industrial, sustainable urbanism that operates through capitalist structures. Broadly, green gentrification is the process by which urban greening-- which can entail anything from planting trees to mitigate the UHI to the creation of new parks-- sharply increases property values and displaces current

residents who can no longer afford the rent with an influx of new upper income residents (Haffner, 2020; Rigolon et al., 2020). Notably, green gentrification forces movement along racial and class lines, with primarily low-income and residents of color being pushed out by higher-income white residents (Anguelovski et al., 2019; Rigolon et al., 2020). To help quantify the magnitude of green gentrification forcings, some studies have estimated that just the addition of trees to a space can raise property values by as much as 10 percent ; additionally a study in "Chicago estimated that its trees are collectively worth $2.32 billion" (Hoverter, 2012).

Across all levels, the High Line is an archetypal example of green gentrification. At its inception and through its implementation, the '*for whom*' and '*by what means*' have been contested. The skyrocketing real estate prices, influx of white wealthy residents, and tourist sensation of the High Line demonstrates a reproduction of structural inequality. Importantly, green gentrification embodied in the High Line and beyond reveals the overall danger of decontextualized climate mitigation strategies. This danger is summarized well by Birge-Liberman who quotes Heynen et al. in *Deconstructing the High Line:* "By examining these processes we can see that 'environmental transformations are not independent of class, gender, ethnicity, or other power struggles,' but instead these transformations 'produce socio-environmental conditions that are both enabling, for powerful individuals and groups, and disabling, for marginalized individuals and groups" (Birge-Liberman, 2017; Heynen et al., 2006).

Urban spaces capture collisions of socioeconomic, political and environmental realities that shape the lives of so many people. The High Line holds multiple truths: The formation of climate-resilient infrastructures is important as the UHI intensifies. Of equal importance is affordable housing and anti-gentrification development. The final section of this paper imagines alternative restructuring

of urban space through (re)politicization of climate solutions, equitable policy, and collation building amongst residents and scientists.

PART III: CRITICAL CLIMATE SOLUTIONS

I am deeply interested in how to resist and reinterpret scientifically-based policies that (in)advertently reproduce climate injustice. The tension between sustainable urban development, the scientific research underpinning it, and the impact of environmental gentrification is one of many entry points through which to examine generative, alternative frameworks that can address these sorts of tension. For the final section of this paper, I propose a set of frameworks through which to analyze climate solutions. Before exploring these frameworks, I identify depoliticized characteristics of the High Line development, which helps to underscore the importance of alternative methods of climate solutions. Then, I analyze the importance of (re)politicizing climate solutions through justice-centered pedagogy and critical urban theory. After establishing these conceptual frameworks, I explore political and material embodiments of them through examples of community land trusts (CLTs), eco-district affordable housing policy, and coalitional politics among local organizations, residents and scientists to design for socially just climate solutions.

3.1 Dangers of depoliticized climate solutions

Moving towards an analysis of (re)politicized climate solutions is possible only after clarifying the characteristics and impact of depoliticized science. Doing so creates the foundation for generating alternative frameworks. On a broader scale, apolitical climate solutions center ostensibly "win-win"

outcomes of proposed urban greening projects (Anguelovski et al., 2019). Apolitical climate solutions highlight the potential for a market-based return on investment, as well as the overall environmental benefits of urban greening (Anguelovski et al., 2019). This garnering of political approval through emphasis on collective and wide-spread benefits is a post-political strategy that obscures reality. The emphasis on widespread benefits erases the particularities of struggle within communities that fall along racial and class lines and that are rooted in racialized, capitalist structures. Articulated with more nuance, political scholars Jonas Anshelm and Simon Haikola emphasize that post-politics, or depoliticization, operate under a "hegemonically enforced assumption of a fundamental and universal consensus around certain principles, such as (neo)liberalism, capitalism, free movement of capital and the need for techno-managerial solutions to socio-environmental problems" (Anshelm & Haikola, 2018). To emphasize universal benefit of urban redevelopment projects is a move towards decontextualization. In reality, city spaces have long been sites of segregation and racialized displacement, and "decontextualized projects underpin large shifts in socio ecological realities" (Haffner, 2020).

Within the context of both scientific discourse surrounding UHIs and the construction of the High Line, two modes of depoliticization are worth analyzing: (1) scientific strategies largely fail to account for the political climate of the location where they are being implemented and (2) emphasis on the widespread benefits of the High Line obscure the reality of green gentrification. First, in the scientific literature synthesis, the mitigation strategies articulated through scientific discourse in almost all cases do not acknowledge the social and political contexts into which climate solutions might be implemented. For example, in their analysis of UHI mitigation strategies, Hoverter (2012) creates a decision making matrix to access the different strategies. Among the criteria are: Heat reduction,

economic benefit, public health outcomes, and environmental outcomes (Hoverter, 2012). Without attention to the socio-political impact of climate solutions, criteria like these are not fully contextualized and run the risk of triggering climate injustices like environmental gentrification.

Secondly—and in a similar manner—the criteria for construction of the High Line also decontextualized the benefits. Through appeals to market-based return on investment and sustainable urban design, the debate around the High Line did not take into account the particularities of contemporary struggle with regard to affordable housing rights. The resulting proliferation of green gentrification occurring around the High Line demonstrates the material impact of a depoliticized[2] sustainable redevelopment process and all that is wrapped up in that process, including but not limited to the scientific discourse informing part of its design and the political economy enabling its market-based redevelopment.

3.2 Imagining (re)politicized climate solutions

Without critical analysis of the histories and contexts into which climate mitigation strategies are implemented, urban redevelopment projects risk reproducing existing structural harms which are exacerbated by climate change. For this reason, climate solutions must be (re)politicized. "(Re)politicized" captures the incongruent political realities of marginalized communities most impacted by environmentally racist and classist distribution of climate harms and institutions that structure climate injustice. The parenthetical formatting of (re)politicized acknowledges the reality that

[2] As I will describe in the following section, "depoliticized" does not suggest that a project like the High Line is *not* political. In fact, the creation of the High Line was *very* political. Rather, "depoliticized" points to the strategic obscuring of politicized projects to garner widespread support.

science has always been political[3]; however, in hegemonic public discourse-- evident in the city's and redeveloper's support for the High Line-- climate solutions must be (*re*)politicized. (Re)politicization challenges climates solutions branded technocratically and packaged apolitically to avoid contestation. I propose that the "re" suggests a political becoming of scientific discourse.

(Re)politicization is critical in the process of disentangling the scientific and socio economic underpinnings and impacts of UHI, especially with its intensification from climate change. Often, the urgency of climate change is used as a justification for urban greening projects (Anguelovski et al., 2019). Inherently, scientific foundations for urban greening and resilience projects are deeply important. The biophysical and climatological knowledge captured briefly in the first part of this paper speaks to the value of knowledge produced to broaden understanding of climate risk and impact. However, the formation of mitigation strategies rightly based in science should be contextualized through a critical understanding of socio-political economies that also shape environments that highlights political and economic power hierarchies.

[3] Science has always been political: From the violence of eugenics, which is intimately tied to UVA (the academic institution through which I write), to the technocratic employment of science for projects of resource extraction, and the scientific subtleties embedded in green gentrification projects. This does not expunge other institutions and structures also imbedded and entangled in these harms. However, the material, structural, and ideological implications of scientifically-based harm cannot be erased. Activists and scholars LaToya Strong and Atasi Das have produced a compelling podcast which explores both the harms of Western modes of science, as well as the generative possibilities of science and math through abolitionist thought and praxis. They coined the term "Abolition Science" in their podcast series *Abolition Science Radio,* which is well worth listening to for a much more nuanced discussion of and broad imagination for just science futures (Strong & Das, n.d.).

3.3 Justice-centered pedagogy and critical urban theory

On a broader scale, (re)politicizing climate solutions can assume a variety of frameworks. This paper explores justice-centered pedagogy and critical urban theory as modes of (re)politicizing science. Educator and activist Daniel Morales-Doyle proposes justice-centered pedagogy for scientific teaching, which can be extended to scientific-based policy and science knowledge production. The basic goal of Morales-Doyle's work around justice-centered pedagogy is to "support alternate pathways for social transformations through science education" (Morales-Doyle, 2017). Justice-centered pedagogy builds upon "culturally relevant pedagogy" and "critical pedagogy." Both of these frameworks emphasize historical and political conditions that shape structural inequality to build a critical consciousness. Through heightened critical consciousness, justice-centered pedagogy supports transformative action that is community-based (Morales-Doyle, 2017).

Central to justice-centered pedagogy is the role students have as "transformative intellectuals" (Morales-Doyle, 2017). At their core, transformative intellectuals are fluid in their understanding of "sanctioned forms of scientific knowledge," yet can also build critique and operate imaginatively to build up anti-oppressive infrastructures (Morales-Doyle, 2017). For example, Morales-Doyle recounts an example within his classroom of students engaging in justice-centered pedagogy. Students became equipped through scientific study to investigate toxin levels in their community's soils stemming from an environmentally racist siting of a coal fire plant (Morales-Doyle, 2017). Using chemistry skills to interpret and quantify the danger of these toxins, the students were able to speak from a place of experience and trust given their resident status. The students' identification of the coal fire power plant's

relationship to and embeddedness in larger structures of systematic marginalization demonstrates the importance of solutions that are deeply informed by local experience.

In the context of the High Line, justice-centered pedagogy focuses largely on (in)equities in science education and imagines alternative modes of engaging with the physical environment through local experience and investment in students as transformative intellectuals. The emphasis that justice-centered pedagogy places on power dynamics, structural oppression and the capacity for locally informed knowledge production and solutions offers a framework through which to analyze the translation of climate solutions into particular communities. Justice-centered pedagogy calls for an extension and complication of UHI analysis and sustainable redevelopment through lenses of political economy and structural inequality. What would it mean if city planners operated with transformative intellectualism in designing the High Line?

Revisiting Moss's lamentations about the Highline, that "gone entirely will be regular New Yorkers, the people who used to call the neighborhood home," justice-centered pedagogy is a framework that could ease this sort of frustration because of its grassroots and critical approach to scientifically-based projects. With regard to grassroots, the case of the High Line is a bit complicated. Most of the impetus behind its creation came from a group called Friends of the High Line, which consisted of a few residents with a lot of social capital (Brash, 2017; Larson, 2017). Applying a justice-centered approach calls for both a grassroots and *critical* approach to build up transformative and community-relevant climate solutions. In contrast, the powerful stakeholders in the construction of the High Line demonstrated an depoliticized approach, without comprehensively acknowledging the gentrifying force of the High Line. As mentioned above, Joshua David, one of the High Line confounders, highlighted

the "necessity" of market-rate development for success of the High Line (Lindner & Rosa, 2017). The incorporation of the word "necessity" seemingly highlights one aspect "success" is in capitalist landscapes: increased private ownership of housing.

In addition to a justice-centered pedagogical approach for developing sustainable projects, another helpful framework to use for (re)politicizing scientifically based work is critical urban theory. Urban theorist Neil Brenner calls for a complication and critique of inherited urban knowledge and urban space—including socio-scientific ways of knowing and forming. Brenner underscores the importance of not accepting the status quo of built environments:

> "Rather than affirming the current conditions of cities as the expression of transhistorical laws of social organization, bureaucratic rationality, or economic efficiency, critical urban theory emphasizes the politically and ideologically mediated, socially contested and therefore malleable character of urban space – that is, its continual (re)construction as a site, medium and outcome of historically specific relations of social power" (Brenner, 2012).

Constructively, critical urban theory "insists that another, more democratic, socially just, and sustainable form of urbanization is possible, even if such possibilities are currently being suppressed through dominant institutional arrangements, practices and ideologies" (Brenner, 2012). The final section of this paper leans into critical urban theory and justice-centered pedagogy to highlight contemporary examples of communities working across, through and in contestation with socio-scientific ideology to critically design for more sustainable and resilient cities.

3.4 From frameworks to reality: Community Land Trusts

While the spectrum of policy and action is immense, this paper highlights three structures with the framework of critical urban theory and its insistence on just and democratic urbanization. As highlighted in pervious sections of the paper, the reproduction of climate injustice through certain modes of sustainable redevelopment is one articulation of the broader and harmful system of capitalism. Because of the *structural* nature of these issues, structural solutions and a reimagining of our current system is needed. The following policies highlighted in this section exist on a complex continuum of solutions: Community Land Trusts (CLTs) and other forms of collective ownership, affordable housing policy and civic science frameworks all have the potential to shape climate solutions in ways that reject the reproduction of climate injustice in its various forms (green gentrification being the mode discussed most prominently in this paper).

CLTs have grown in prevalence and popularity both across the US and internationally as an alternative mode of land ownership. With their origin in the Civil Rights era, CLTs embody a rich history in the United States of rejecting the landlord/tenant binary and hierarchy. CLTs also engage in a politic of the commons through collective ownership, mutual aid and additional solidarity practices (Davis, 2014; Thompson, 2015). A key component of CLTs is their emphasis on community ownership as a way to reclaim public space, challenge disinvestment, and stabilize an area through long time land ownership. Community ownership also directly challenges market-based rates for housing. CLTs are an antidote to legal frameworks of ownership and property in the United States that allow and legitimize the exploitation of tenants and the commodification of housing with redevelopment projects

(Thompson, 2015). Alternatively, CLTs occupy a third option in a predominantly dualistic legal landscape for housing. Thompson writes:

> "Mutual housing models provide a third option to the familiar dualist categories of public/private, state/market provision – as non-profit, voluntary, community-led, place-based membership associations. The key function of mutual models...is their capacity to 'lock in' the value of land and assets, to protect the commonwealth from private expropriation" (Thompson, 2015).

In his theoretical analysis of CLTs, Thompson draws out the ways in which CLTs act to disrupt the private capitalist enclosures of place and land through mutual housing models that demonstrate a stewardship ethic (Thompson, 2015). The impact of CLT models is to disrupt displacing and gentrifying forces. Therefore, CLTs are an important model to consider when thinking more broadly about (re)politicized climate solutions. In fact, a CLT in Granby, Liverpool demonstrates the capacity of this type of mutual ownership to protect against green gentrification. Following deindustrialization, Granby, which is also a historically disinvested area, essentially fell into ruins (Thompson, 2015). Through processes of guerilla gardening and space reclamation, remaining residents created what is known as the Green Triangle—a thriving community space with a number of common green amenities. The establishment of a CLT has prevented an influx of wealthier residents who might have been attracted to the grassroots redevelopment and greening of Granby.

In the context of the High Line, there are clear indicators—in fact, almost a predetermination and acceptance—of the coming green gentrification. The residential rezoning and simultaneous neoliberal shifts in NYC policy supported private redevelopment of surrounding areas around the High Line. The resulting green gentrification is evidenced by the skyrocketing of rent prices by more than 100%. Had CLTs been established before the construction of the High Line, longtime residents in the Chelsea area and former meatpacking district would likely experience a different housing reality. Perhaps Moss's grievances would dissipate. Additionally, a coalitional approach to a project like the High Line would center residents and key stakeholders from *within* the community in ways that acknowledge power dynamics and hierarchy as well as historical disinvestment in areas like the meat-packing district.

3.5 From frameworks to reality: Affordable housing policy & coalition-building

On a less structural level, a coalitional organizing practice amongst scientists, residents and planners also has the potential to critically shape urban space and climate solutions. An example of such coalitional organizing is evident in Malmo, Sweden's sustainable redevelopment (Sandberg, 2014). Following sharp deindustrialization, Malmo made a name for itself through its uniquely democratic and holistic approach to redeveloping. Sustainability marks a major tenet of Malmo's redevelopment (Fitzgerald & Lenhart, 2015). The creation of eco-districts is central to the plan. With attention to creating channels for community input, Malmo's sustainable redevelopment features the incorporation of affordable housing in all ecodistricts. While this policy has certainly been successful in preventing green gentrification, all urban development holds complexity: Subsequent neoliberal policy shifts in

Malmo's redevelopment plans created an inequal split between market-based and affordable housing units with the former much outweighing the latter (70-30%). Policy shifts like this have enhanced green gentrification (Fitzgerald & Lenhart, 2015; Sandberg, 2014).

For this reason, other forms of contestation are crucial to engage critically with the construction of urban space and climate solutions. Beyond the development of ecodistricts, another Malmo-specific example is the formation of resident-scientist coalitional power which developed in opposition to postindustrial redevelopment of a quarry (Sandberg, 2014). Scientists' keen attention to post-industrial ecologies springing forth in the quarry created a foundation for local scientists and residents to petition planners to instate the quarry as a protected natural area. Through the identification of species particular to the region and studies demonstrating their regrowth, ecologists were able to ensure that the space remained public and accessible (Sandberg, 2014). This feature directly challenges green gentrifying forces by creating a public space that might otherwise have become a high-end green amenity through more traditional redevelopment. The coalition built between scientists and residents illuminates a critical approach to doing environmental science—one that acknowledges the power and impact of scientific discourse for transforming space.

However, troublesome realities persist: the nature reserve in Malmo is highly policed (Sandberg, 2014). A policing presence demands consideration of for whom is this space built and by what means is that obtained? Despite wins like the incorporation of affordable housing in ecodistricts and the publicly accessible nature reserve spearheaded through coalitional work of resident-scientists, urban constructions of space will always exhibit complexity. Understanding, unwinding and moving through such complexity requires continual critique, reconstruction and imagination.

CONCLUSION

The first major take away of this paper is that climate change has caused and will continue to exacerbate precarious conditions for urban residents through both the UHI effect and its intensification with heat waves. For this reason, UHI mitigation strategies must be a priority. While a variety of UHI mitigation strategies exist, urban greening offers the most potential because of its multiple climatological and socioeconomic benefits. On an aesthetic and well-being level, urban vegetation as a climate solution also supports healthy communities through recreation and green spaces. Overall, science plays an invaluable role in sparking discovery and imagination of climate solutions.

Secondly, because of the structural complexity of our political and economic systems, the implementation of scientifically-based climate solutions risk articulating some of the injustices associated with racialized capitalism. This is demonstrated through certain modes of sustainable redevelopment that have catalyzed green gentrification and displacement, as evidenced by the High Line's effect. However, the complexity of implementation should not be interpreted as a call to halt urban greening projects. In fact, given the immense environmental and socio-economic benefit of urban greening, a priority should be widescale greening. Rather, examining green gentrification as a symptom of broader structural injustice strengthens the importance of designing sustainable redevelopment to be paired with or foundations for systems-based change.

Thirdly, climate solutions should challenge the economic and political structures that have created climate injustice through a systematic approach. I argue that that this can take the form of (re)politicized climate solutions that disrupt power dynamics and socioeconomic hierarchy created by racialized capitalism. (Re)politicized climate solutions work well with justice-centered

pedagogy and critical urban theory. In the context of urban greening and environmental gentrification, (re)politicized climate solutions can take on the form of: CLTs, affordable housing policies paired with green amenities, and coalitional power between scientists and residents – among other solutions. Overall, climate solutions must operate on a continuum that builds towards systematic change.

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