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Green infrastructure, stormwater, and the financialization of municipal environmental governance

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ABSTRACT

Municipalities large and small are grappling with how to address enduring water quality challenges stemming from the impermeability of much of the built environment and how to address shifting precipitation patterns due to climate change. Finding ways to fund and finance the redesign, retrofit, and adaptation of the built environment, however, presents a major obstacle in an environment of municipal fiscal austerity. In this paper, we examine how municipalities are adopting different fee structures and financial tools to pay for stormwater abatement through green and gray infrastructure and improve their capacity to deal with the impacts of climate change. Drawing on a survey of 233 municipalities and interviews with municipal leaders, we show that transitioning towards green infrastructure in municipal stormwater and climate change planning is a broad goal among most respondents, but stormwater fee systems are typically not sufficient for meeting regulatory mandates as well as the operation and maintenance costs needed to replace or repair urban water infrastructure. This shortfall has led many municipalities to use a host of other financial tools, such as credit and mitigation banking and social impact and green bonds. We suggest this shift has important implications for achieving sustainability and ensuring just transitions.

KEYWORDS
Green infrastructure; financialization; stormwater; climate change adaptation; environmental governance

Introduction

The climate crisis is a water crisis with direct and indirect impacts on livelihoods and human health, property and infrastructure, and a range of ecosystem services. The United Nations indicates that 90% of all natural disasters are water related (UNISDR, 2015). This brings issues of stormwater governance into sharp focus as a central concern in municipal climate action planning. From floods to droughts, how a municipality's stormwater infrastructure is designed and planned can either exacerbate or alleviate the impacts of extreme events on humans and the biophysical world. Municipalities face considerable constraints in adapting and upgrading their infrastructures, including uncertain climate and weather patterns, deep-seated racism in the built environment and access to services, austerity measures, fiscal conservatism, and competing planning priorities.

While extreme storms cause significant damage to life and property and expose the vulnerabilities and inequalities in infrastructural services, sewage overflows are often overlooked. When Hurricane Sandy hit the northeast United States, 11 billion gallons of raw and partially treated sewage flowed into city streets and nearby waterways as the region's stormwater infrastructure was overwhelmed (Kenward et al., 2013). Similarly, in 2017 when Hurricane Harvey hit southeastern Texas, around 31.6 million gallons of raw sewage flooded into communities and local waterways, in addition to the more than 100 spills of hazardous pollutants

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across Houston's sprawling network of petrochemical plants and refineries (Griggs et al., 2017; Metzger & Cook-Schultz, 2017). These events demonstrate a clear need to address sewage and stormwater infrastructures alongside a host of other adaptation and mitigation strategies to address climate change impacts.

Most storms are much less extreme than Hurricanes Sandy and Harvey, but pollution stemming from stormwater runoff, including sanitary sewer overflows (SSOs) and combined sewer overflows (CSOs), present a major environmental challenge across the United States. In the Great Lakes Basin alone, 1482 CSO events occurred among 184 communities in 2014, discharging an estimated 22 billion gallons of untreated water (ASCE, 2017). Environmental governance and decision-making efforts to address these challenges are complex, situated and distributed among national, state, regional, and municipal agencies and utilities. The National Pollutant Discharge Elimination System (NPDES) program under the Clean Water Act (CWA) serves as the primary regulatory mechanism influencing how local and state governments seek to address water quality problems stemming from stormwater runoff. The initial focus of the NPDES program centered on industrial point sources of pollution, but the diffuse character of nonpoint sources of pollution and stormwater runoff impeded efforts to improve water quality (Karvonen, 2011; Melosi, 2000). Phases I and II of the NPDES program sought to resolve this issue by creating a permitting system focused on stormwater pollution. A key aspect of Phase II was the requirement to implement a number of best management practices (BMPs) and minimum control measures (MCMs).

At this intersection of climate change impacts and stormwater runoff pollution, green infrastructure emerges as a nature-based solution for a range of municipalities. Efforts to come into compliance with municipal NPDES permits, for example, have driven many communities to experiment with different types of infrastructural and policy interventions that tie together stormwater management and green infrastructure planning (Cousins, 2017b; Fitzgerald & Laufer, 2017). In some cases, these interventions are driven by consent decrees issued by United States Environmental Protection Agency (EPA) to enforce requirements under the CWA. Green infrastructure programs in Philadelphia, Pittsburgh, Washington DC, Chicago, Los Angeles, and Boston are all examples of consent decrees driving green infrastructure development as a means to address stormwater pollution problems (Christophers, 2018; Cousins, 2017b; Finewood, 2016). Often, as these cases suggest, stormwater governance and management are also green infrastructure planning.

While green infrastructure offers a multi-benefit approach, it is typically associated with stormwater management in research and practice (Cousins, 2017b; Finewood et al., 2019; Meerow & Newell, 2017). Using green infrastructure's ability to capture, store, and cleanse stormwater runoff brings it to the fore of planning and governance decisions to come into compliance with regulatory drivers. Green stormwater infrastructure, however, can come at considerable costs to municipalities. For example, when Washington DC went into its consent decree, they embarked on a $2.7 billion program labeled the DC Clean Rivers Project, which incorporated various green infrastructure and gray infrastructure approaches to improve water quality and reduce CSOs (DC Water, 2015). These policy and planning measures bind stormwater problems with green infrastructural interventions. The high costs of retrofitting the existing infrastructure to come into compliance with federal and state regulations, however, present considerable challenges and barriers for municipalities.

The lack of financial resources and funding streams to implement green infrastructure and to update existing stormwater and flood control systems has driven municipalities to experiment with a range of financial tools. Stormwater utility fees have emerged as an important alternative revenue stream, despite often facing legal challenges. At least 1600 municipalities and local governments utilize stormwater fees across the United States. Their appeal rests on generating dedicated revenue sources to upgrade, maintain, and retrofit stormwater infrastructure. A range of different fee systems exist, but the most common rationale for calculating stormwater fees is based on the equivalent residential unit (ERU) model. In this model, fees are typically calculated based on the average impervious area of a residential parcel within a jurisdiction (Campbell et al., 2016). Fees, however, often do not provide adequate revenues to implement and maintain all of the projects needed or desired. To make up for gaps in funding, market mechanisms to control stormwater runoff through green infrastructural upgrades are gaining traction. These approaches seek to place an economic value on stormwater runoff, and the ecosystem services accrued through green infrastructure, to establish financial incentives to implement and adopt new control measures with green infrastructure (Cousins, 2018; Parikh et al., 2005).

Municipalities are experimenting with a range of financial instruments, including tax increment financing (TIF), green bonds, in-lieu fees, mitigation banking and offsets, as well as credit trading, to inject capital into a mix of green and gray infrastructural upgrades for stormwater management and climate change adaptation. In 2016, for example, the San Francisco Public Utilities Commission issued a certified green water bond to fund a series of sustainable stormwater management and wastewater projects. San Francisco is not alone in their embrace of green bonds to finance water infrastructure upgrades. Washington D.C. looked to green bonds to finance green infrastructure projects to resolve CSO problems. Their environmental impact bond is modelled after pay for success contracts, which, in this case, rewards investors for the performance of green infrastructure in reducing runoff. Similar schemes have been utilized in Columbia, South Carolina, Atlanta, Georgia, and other municipalities across the United States.

The goal of this paper is twofold. The first is to understand how stormwater infrastructure planning and governance is accomplished through different fee and financial systems. In particular, we focus on how different fee and financial systems for stormwater abatement are used to support green infrastructure planning and how that might connect to climate change adaptation efforts. As cities and municipalities look to utilize different economic mechanisms to implement a mix of gray and green infrastructure to make adjustments to their stormwater systems, how might they also leverage those funds toward climate change adaptation measures? The question is about how cities are mainstreaming climate change adaptation into existing stormwater plans and funds.

The second is to explore how regulatory and environmental risks coalesce with financial risks under contemporary neoliberal urban governance. In other words, how do financial innovations to fund retrofits of the built environment and upgrade stormwater systems as a means to address regulatory and environmental risk introduce new forms of financial risk? As we show, many municipalities are moving beyond stormwater utilities and fees towards alternative financial instruments, such as green bonds, credit trading, and mitigation banking. We suggest that this shift materializes environmental (e.g. water pollution, floods, etc.), regulatory (e.g. changes in government, rules and requirements, etc.), and financial (e.g. unanticipated costs, loss of property, future financial loss, etc.) risks in ways that have the potential to magnify one another and reproduce inequality in the built environment, especially in fiscally constrained and austere municipalities. In doing so, we contribute to literatures exploring how these risks can interact and intensify one another to undermine more transformative and just pathways (Collins, 2010; Leichenko, 2012; Tellman et al., 2018). The challenge is how municipalities can deliver large-scale transformations in the built environment to address climate impacts and environmental hazards while also doing so in ways that boost social justice and equity.

In the following section, we review the literature around the financialization of stormwater infrastructure. While definitions of financialization vary, we conceptualize financialization in this manuscript as the broad set of market and financial tools, practices, discourses, and measurements that influence how municipalities translate physical and material assets into financial assets that can be traded or used to capitalize on future income streams generated through infrastructural investments. We then outline our method, which draws on a large-scale survey of US municipalities utilizing fees to address challenges in municipal stormwater management and green infrastructure planning. The results reveal an uneven landscape of fee and financial tools to simultaneously address changes in stormwater flows and climate change through green infrastructure. We conclude by elaborating on the risks associated with challenges in retrofitting the urban built environment.

Financialization

Climate change adaptation planning requires significant financial, technological, political, and social support to identify and mobilize resources to respond to and prepare for climate shocks and stressors. In the case of addressing the impacts of climate change on municipal stormwater systems, a suite of traditional gray infrastructural approaches emerges alongside green infrastructural approaches to redirect and capture stormwater flows. While the drivers of green stormwater infrastructure planning typically stem from regulatory and legal ordinances, such as the Clean Water Act in the United States, a primary goal of green infrastructure is to achieve co-benefits of climate adaptation (Gill et al., 1998; Matthews et al., 2015; Meerow & Newell, 2017). The lack of financial resources, however, is often cited as a primary impediment to adapt and retrofit municipal infrastructure to address the spectrum of regulatory, political, and climatic drivers of changes in urban environmental governance and decision-making (Hughes et al., 2013; Shi et al., 2015). To understand how municipalities are currently utilizing and looking to expand fee and financial structures to implement green infrastructure this manuscript builds on work around the financialization of green urban infrastructure (Bigger & Millington, 2020; Christophers, 2017) and the politics of urban stormwater governance (Finewood et al., 2019; Karvonen, 2011).

The emergence of stormwater fees and experimentation with new financial tools to fund improvements in stormwater infrastructure through green infrastructure needs to be understood within the contexts of austerity and neoliberal policy and planning (Bigger & Millington, 2020). Adaptation planning and adjustments to the built environment require financing, which is particularly challenging when faced with stretched municipal budgets. A number of planning pressures and impacts associated with austerity constrain infrastructural development and maintenance and influence how municipalities might embrace alternative financial mechanisms (Mell, 2020).

The most common strategies municipalities use to fund local stormwater infrastructure, include general funds, bonds, and stormwater fees. Fee systems can vary considerably from place to place, but the most common fee structure is the equivalent residential unit (ERU). This fee structure is calculated based on the average impervious surface area on a single-family residential parcel. Financial pressure is a key driver influencing the adoption of municipal stormwater fees, as well as developing and carrying out experiments in urban environmental governance and planning that can fund and adapt infrastructures to meet regulatory and climatic realities (Castán Broto & Bulkeley, 2013). Municipalities, however, have limited options in acquiring the capital needed to upgrade infrastructure, which has led many municipalities to experiment with different financial tools without increasing rates or taxes on their constituencies. These austere fiscal environments, which often overlook the service provisioning of stormwater infrastructure and leave them as 'fiscal orphans', push municipalities to explore innovative funding mechanisms to overcome barriers to the build out of green and gray infrastructure (Hanak et al., 2014; Mell, 2020).

Within the political-economic context of austerity, municipalities utilize a range of financial tools to address stormwater and climate change, including, but not limited to, credits, rebates and discounts, co-funding, tax increment financing (TIF), green bonds, in-lieu fees, and mitigation banking and credit trading. Among these, green bonds, TIF, and mitigation banking have received the most attention within literature around stormwater governance (BenDor et al., 2009; Christophers, 2018; Cousins, 2018; Dhakal & Chevalier, 2017). Green bonds and municipal bonds are increasingly prominent but are not simple funding solutions for addressing stormwater and budget deficits. Green bonds are not direct revenues, instead, green bonds are mechanisms to borrow money. In the case of Washington D.C., the move to green bonds interlinked environmental and financial risks. As Christophers (2018) notes, the merging of environmental and financial risks created through green bonds can create lasting consequences for local residents, who bear environmental risks through exposure but also financial risk through the payment of DC Water fees. While proponents of green bonds generally frame them as financial innovations to facilitate environmentally beneficial investments, very little distinguishes them from conventional municipal bonds. The issuance of bonds may also impact the ability for a municipality to issue debt for other purposes and create risks to credit ratings if debts are not repaid (Hammer & Valderrama, 2018). Furthermore, as scholars have noted, the issuance of municipal debt through green bonds can leave many communities more at risk and shift environmental and financial risk onto vulnerable communities (Bigger & Millington, 2020; Christophers, 2017). The logic of finance capital in issuing green bonds for green infrastructural investments is an alignment toward projecting the creation of future values. This can be seen in other financial strategies municipalities utilize to support green transitions.

Tax increment financing (TIF) operates as another financial tool to secure funds for green infrastructure, stormwater retrofits, and environmentally related projects. As Rachel Weber (2010, p. 251) notes, 'TIF allows municipalities to bundle and sell off the rights to future property tax revenues from designated parts of the city.' TIF operates by designating certain sections of the city as blighted or in need of redevelopment. Special tax districts are then created around these targeted areas. The expected increase in property taxes, or future tax revenues, from the redevelopment go on to finance ongoing infrastructural improvements, maintenance, land acquisitions, and other expenditures that might be associated with the redevelopment project. This is one of the most popular incentive tools for economic development in the United States and municipalities are leveraging it towards improvement in stormwater infrastructures. In Chicago, for example, TIF has supported the development of a mix of green and gray approaches, including green roof programs, green alleys, and stormwater diversion tunnels. Approaches, such as TIF, fit within molds of urban entrepreneurialism (Harvey, 1989; Lauermann, 2018) that also include the diffusion of municipal bond markets (Hackworth, 2007), social impact investing to engender positive social change or goods (Rosenman, 2019a), and the speculative redevelopment of public lands (Beswick & Penny, 2018; Weber, 2010). Strategies such as TIF have been critiqued on a number of fronts, from debt-machine dynamics (Peck & Whiteside, 2016) to their failure to produce the intended economic development in real estate benefits that would have occurred without TIF (Lester, 2014).

Mitigation banking represents another type of market-based approach municipalities adopt in their stormwater infrastructure programs. The approach centers on developing private markets to encourage investments in green infrastructure through credit banking schemes. The buying and selling of credits are considered by advocates as a cost-effective solution to achieve stormwater goals and improve water quality (Valderrama et al., 2013). The flexibility embedded within banking schemes allows developers to offset their on-site impacts on water quality through the buying and selling of credits associated with stream, wetland, or ecosystem restoration (Robertson, 2004). Credit banking schemes, however, are often criticized for allowing some developers to avoid on-site mitigation measures through their ability to purchase credits that satisfy their low impact development requirements in their stormwater permits (Cousins, 2017c). Maintaining ecological equivalency between altered and restored ecosystems also present challenges about how to resolve on-site versus off-site mitigation measures (Lave, 2012) and highlight the difficulties of coordinating action across different levels of governance and the private sector (Robertson, 2012, 2018).

Resolving environmental problems through market logics that promote economic growth alongside reduced environmental impacts is fraught with challenges and limitations (Bakker, 2005). Within municipal planning, the attribution of economic value to ecological and landscape resources is not a simple matter (Mell et al., 2013). Some of these barriers stem from accounting practices that do not report the multiple values of ecological and landscape resources or the multiple values green infrastructure provides through ecosystem services (BenDor et al., 2018). A range of models have been developed to allow planners to establish economic evaluation methodologies and toolkits to direct green investments across municipal or regional scales (Cousins, 2018; Schilling & Logan, 2008). Additional challenges rest in financial asset management standards used by municipalities. As Marissa Matsler (2019) notes, financial asset management standards developed for gray infrastructure are incommensurable with the biophysical components of green infrastructure. As she goes on to explain, the incongruences between financial accounting systems and ecological knowledge systems impede broader aims of green infrastructure serving as a nature-based solution for restoring ecosystems and improving human well-being. Translating ecosystem services into standard municipal accounting practices has proved challenging in seeking to achieve many on the ground goals of environmental sustainability (Ernstson et al., 2010; Marissa Matsler, 2019; Norgaard, 2010; Robertson, 2012).

The dissonance between 'green' and 'gray' approaches to valuing and assessing urban infrastructural systems speak to broader challenges that reside in competing knowledge systems, the politics of participation, and in achieving just outcomes in urban greening initiatives. Comprehensive planning to remake the urban built environment in greener forms depends on financial innovation to generate new forms of capital for infrastructural adjustments that generate value, either through future based value projections, such as through TIF, or through different fee earning opportunities. As many forms of contemporary urban infrastructures – either in their gray or green forms – target privileged groups of people at the expense of the public good (Graham & Marvin, 2001) or utilize market-oriented approaches that attempt to resolve environmental problems through profitable ventures, clear social justice elements emerge around who benefits from urban greening initiatives (Dooling, 2009; Wolch et al., 2014). Increasingly, scholars are noting how urban greening reflects, and is undergirded by, gray and traditional planning and engineering practices and ongoing challenges of uneven and inequitable participation and outcomes in urban greenspace planning (Cousins, 2018; Finewood et al., 2019; Wachsmuth & Angelo, 2018). Many of the challenges exist in how nature is framed, valued, and defined in urban environmental governance and decision-making.

Methods

The aim of the study is to understand the relationship between different fee and finance structures to address stormwater and climate change adaptation actions through green infrastructure. A survey was created between January and May 2018 and was pre-tested and administered through Qualtrics at Dartmouth College. The first section of the survey was organized to identify the type of fee and finance instruments municipalities are using and what type of activities are funded through them. This included open-ended questions to collect qualitative data on perceived preferences and barriers to utilizing different fee and finance systems to address stormwater-related issues and climate change. The second section of the survey focused on climate change adaptation planning. Questions looked to examine if and how fee and finance structures utilized for stormwater management are used to implement green infrastructure for climate change adaptation. The final section of the survey asked questions about the type of information used in their planning.

The survey sample drew from Western Kentucky's 2016 Stormwater Utility Survey, which is the largest known database of stormwater utilities in the United States. The research team compiled contact information for all 1583 municipalities included in the 2016 survey and in July 2018 distributed an online survey to the individual directly in charge of stormwater management or green infrastructure planning in each municipality. In some cases, the survey was sent to other individuals in the department more directly involved in the development, maintenance, and financing of stormwater and green infrastructure projects in the municipality. In cases where the research team could not identify a specific municipal department, or person, in charge of stormwater management in the municipality, the survey went to city council clerks because they are typically responsible for documenting municipal activities and could direct the survey to the most appropriate person (Kalafatis, 2018; Schneider et al., 1995). The survey remained open for 8 weeks, and in total, we received 233 responses with a 14.7% response rate. This is an average response rate for external surveys, which typically range from 10% to 15% (Fryrear, 2015).

Multiple response categorical variable analysis

Survey questions included in the current study were multiple response categorical variables (MRCVs) which are a common 'pick any' or 'check all that apply' question in which the respondent may choose more than one response. The possibility that a respondent chooses more than one reply to one question creates interdependence of responses and makes use of traditional Pearson chi-square tests for association between different questions and different responses a poor option because the test would violate the assumption of independence between the responses (Bilder & Loughin, 2004). Alternatives exist, including a test for approximated chi-square statistic, which we use because the chi-square distribution is widely used in other studies with similar data (Pelenur & Cruickshank, 2012). The exact statistic in the current study is a second-order corrected Rao-Scott chi-square statistic, χ^2_S, which was established by Agresti and Liu (1999) and Thomas and Decady (2004).

The test statistic χ^2_S is calculated for $n \times c$ data tables where n is the number of responses for question one and c is the number of responses for question two. Each response for n is paired with each response for c creating n marginal $c \times 2$ tables. By summing the Pearson chi-square statistics for each table, the final Rao-Scott chi-square is determined with degrees of freedom (df) = $c(n - 1)$ (Agresti & Liu, 1999). The test statistic resulting from this process has been found to be numerically akin to other statistics (Agresti & Liu, 1999; Thomas & Decady, 2004; and Bilder & Loughin, 2002). Thus, in our study we can compare both single response questions with MRCVs, and two or more MRCVs with confidence that the findings indicate an actual association and not a spurious connection (Bilder & Loughin, 2002, 2004).

A hypothesis test is conducted for each set of response pairings and takes the following form:

H0: all response pairings are equal

H1: At least one pairing is not equal.

The alternative hypothesis is tested for question pairings in the current study to establish whether associations exist between responses and determine if responses are significantly correlated with one another. The hypothesis test is evaluated using a modified p-value tested against a significance level of $\alpha = 0.05$.

The modified p-value is a Bonferroni adjusted value which multiplies the p-values for the chi-square approximation together and reports the minimum of the adjusted p-values in addition to reporting individual pairwise p-values for each response. Individual category comparisons can also be extracted to identify which response categories are most significant and which are less or not significantly different for response comparisons (Ochodek & Kopczyńska, 2018). The extraction of individual responses is useful for determining if there are associations between variables within an MRCV where some responses are significantly associated while others are not. MRCV test results will indicate a significant association between two sets of question responses, but some individual pairings within the question sets might not be significant (Koziol & Bilder, 2014). Our results highlight both question comparisons and their associated statistical significance as well as individual response pairings of significance for $\alpha = 0.05$. We also report some marginally significant results ($\alpha = 0.1$) and some insignificant individual response pairings for comparative purposes. We analyzed the data in R Studio version 3.4.3 using the 'MRCV' R package (Koziol & Bilder, 2014).

Results

A range of local economic forces converge with climatic, environmental, regulatory, and political contexts to shape municipal adaptation and stormwater planning activities. 212 of the surveyed municipalities fall within US Census defined urban areas. While it is unclear how political affiliation influences the adoption of stormwater utilities (Campbell et al., 2016), our survey shows that municipalities residing in Democratic congressional districts are more likely to have climate change adaption plans alongside stormwater planning activities. Clear obstacles exist around regulatory structures, such as California's Proposition 218, which notoriously inhibits the flexibility of water utilities and public agencies to raise funds to address funding gaps around issues like water resource planning (Cousins, 2017a; Hanak & Lund, 2012). Within these varied contexts, different fee and financial structures serve as a means to implement a host of adaptation measures to address flood risk and water supply as well to create new solutions to resolve water quality issues.

The fee and financial systems at the nexus of stormwater management, green infrastructure planning, and climate change adaptation converge to create an uneven mix of approaches. Only 168 of the surveyed municipalities indicated that they have a stormwater management plan and only 32 stated that they have a climate change adaptation plan.

When asked if their municipality uses stormwater fees for projects included in climate change adaptation, 71% of the respondents indicated no. While the majority of the municipalities do not include stormwater in their climate change adaptation plans, it does not mean they are ignoring rainfall and precipitation in their climate change planning. When asked to describe how stormwater is incorporated into their municipal climate change planning, for example, a respondent noted:

> Stormwater is not included in the municipality's climate change plan. We do recognize that more frequent intense rain events are occurring, and this may be the result of climate change. Regardless of cause, it is a real impact and has resulted in a higher level of flow reduction (detention) in some cases for new development. (Respondent 67, July 2018)

Such responses were typical for municipalities not including stormwater in their climate change planning, but some respondents were unable to draw a link between stormwater and climate change. Others noted, as above, that impacts of climate change on precipitation are modeled into their stormwater planning, but citywide climate change planning tends to be focused on carbon footprints and municipal operations. Results do indicate, however, that municipalities using climate change scenario models in their stormwater management planning are more likely to be undertaking several climate change adaptation activities, including capacity building, management and planning, policy development, and physical infrastructure upgrades.

In terms of how natural hazards, such as floods and droughts, might impact stormwater management and infrastructural development, the results presented mixed responses. While 38.2% of responses rated their municipality as 'good' and 7.3% as 'excellent' at addressing flood and drought hazards in their stormwater management planning, this attention does not necessarily mean it translates into projects financed to address stormwater issues and climate change adaptation. Multiple respondents noted that their municipality is typically reactive and not proactive in addressing hazards that arise from stormwater and changing precipitation patterns. This typically takes the form of flood control infrastructure, where floods or hurricanes brought local attention to the need to address stormwater flows in their municipality. Scaling-up green infrastructure for flood risk reduction, however, is impeded by regional fragmentation and jurisdictionally bounded decision-making (Shi, 2020). Many respondents noted this and indicated a desire for regional and ecosystem scale strategies to address both the flood control and water quality aspects of stormwater management.

For those municipalities making direct connections between stormwater management and climate change adaptation planning, a variety of activities receive funding and implementation (Figure 1). While municipalities without a climate change adaptation plan still take part in green infrastructure programs, information development, and other forms of gray infrastructural development, municipalities with a climate change adaptation plan are more likely be doing capacity building work, focusing on practices and behaviors, addressing policy issues, and applying alternative financing instruments, such as green bonds or TIF to fund adaptation activities. Many of the strategies influenced by these alternative financing instruments seek to achieve multiple benefits. For example, when asked how stormwater is incorporated into their municipal climate change planning a respondent noted that it centers on the

> recognition of co-benefits provided by elements of [our climate action plan] such as a goal to increase the city's tree canopy to 40% by 2036, or the development of a sustainable zoning process that encourages green space on new development or redevelopment projects. (Respondent 147, July 2018)

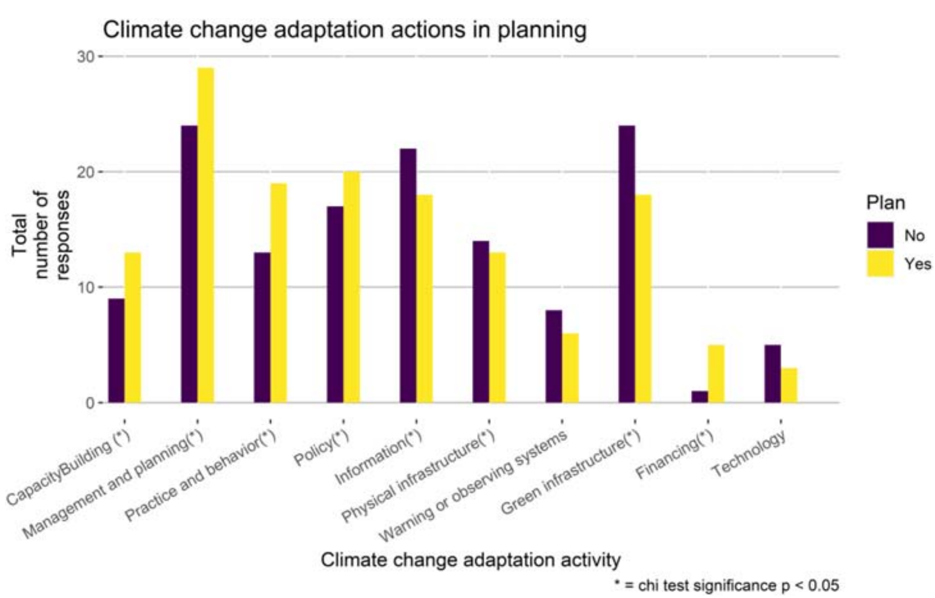

Figure 1. Climate change adaption actions within municipal planning. The existence of a municipal climate change plan is correlated with some activities including capacity building, management and planning, practice and behavior, and policy. A climate change plan was not necessary for a municipality to be more likely to be working on information, physical infrastructure, or green infrastructure. $X_S^2 = 267.883$, $p < .001$.

Overall, a mix of green and gray infrastructural interventions get prioritized, including the enhancement and expansion of stormwater infrastructure systems, increase of permeable surfaces, stream and floodplain restoration, regional flood planning, and drought management.

Stormwater user fees are the primary funding mechanism connecting stormwater and climate change activities (Figure 2). This is especially the case for activities driven at changing and adapting the physical infrastructure of the municipality (Figure 3). Different financial instruments, however, tend to focus on different policy aims or infrastructure investment strategies. Credits, rebates, and discounts, for example, tend to focus on capacity building activities and information development that incentivizes solutions at the household level and on private parcels. The use of rebates helps municipalities spread their green infrastructure matrix across the municipality by incentivizing private property or business owners to install green infrastructure. Rebates reduce initial capital costs, and property owners have the potential to realize the benefits of the added infrastructure, such as reduced flooding or increased property value. Municipalities using credits, rebates, or discounts for financing are much more likely to support the maintenance and development of green infrastructure activities and be more concerned about the overall mix of green and gray infrastructure to handle stormwater flows. These efforts are often tied to community goals and programs, such as the New York City Green Infrastructure Grant Program, which has the goal of reducing combined sewer overflows by incentivizing private property owners to install and maintain green infrastructure on their property. Other financing instruments, such as mitigation banking, credit trading, and in lieu fees support activities driven towards stormwater quality management and infrastructural services and maintenance, such as drains and street sweeping. Different financial instruments are used to address various strategies to achieve community goals and provide infrastructural services.

Climate change policy was also more likely to be occurring in a municipality if ecosystem services framed municipal stormwater management planning (Figure 4). Projects financed through ecosystem services frameworks primarily include development and maintenance of green infrastructure, commercial and industrial regulation, and household rebates and incentives. While many municipalities without ecosystem services frameworks in their stormwater management planning focus on the development and maintenance of green infrastructure, municipalities that did include them were more likely to be taking proactive climate change adaptation planning through the development and maintenance of green infrastructure and the use of household rebates and incentives. In terms of the latter, a major challenge for stormwater planning is incentivizing actions on private parcels of land and fostering behavioral change to address collective action problems. A

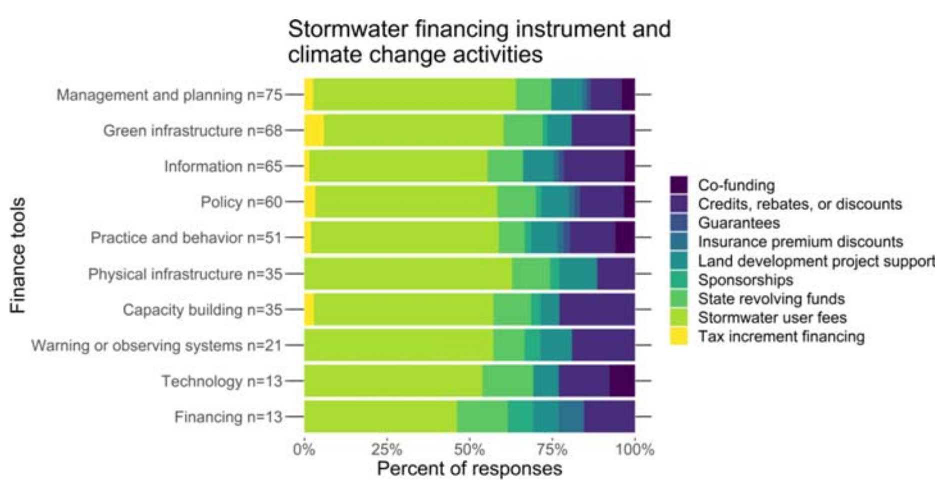

Figure 2. This figure shows the total number of responses for different climate change activities and the funding instruments used for them. $\chi^2_5 = 123.286$, $p = .011$.

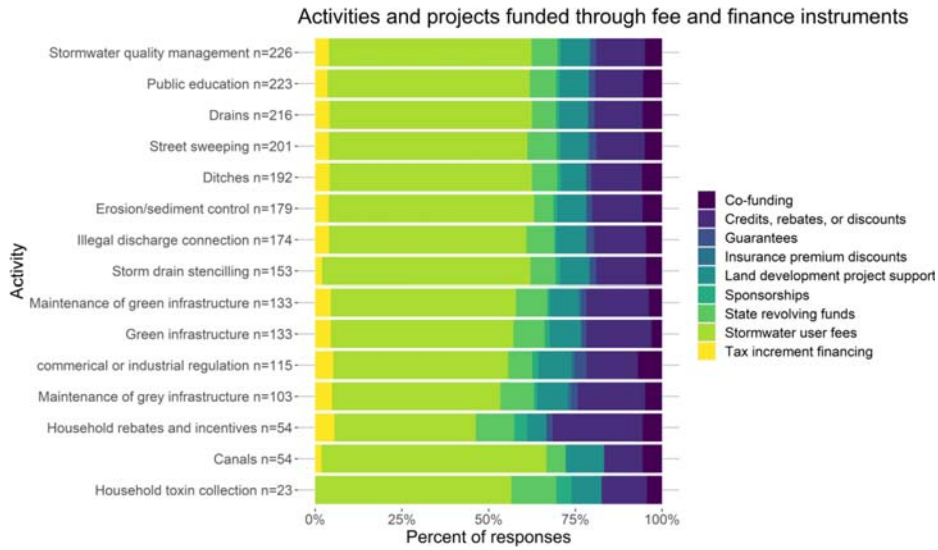

Figure 3. The number of municipalities that use specific fee and finance instruments and the activities and projects they fund. $\chi^2_S = 234.892$, $p < .001$.

common sentiment among respondents was that 'public education and citizen commitment are the two largest impediments to financing stormwater improvements' (Respondent 7, July 2018). Among the municipalities drawing on ecosystem services in their planning, household incentives and education provides the cultural services while green infrastructure supports varying provisioning, regulating, and supporting services. The

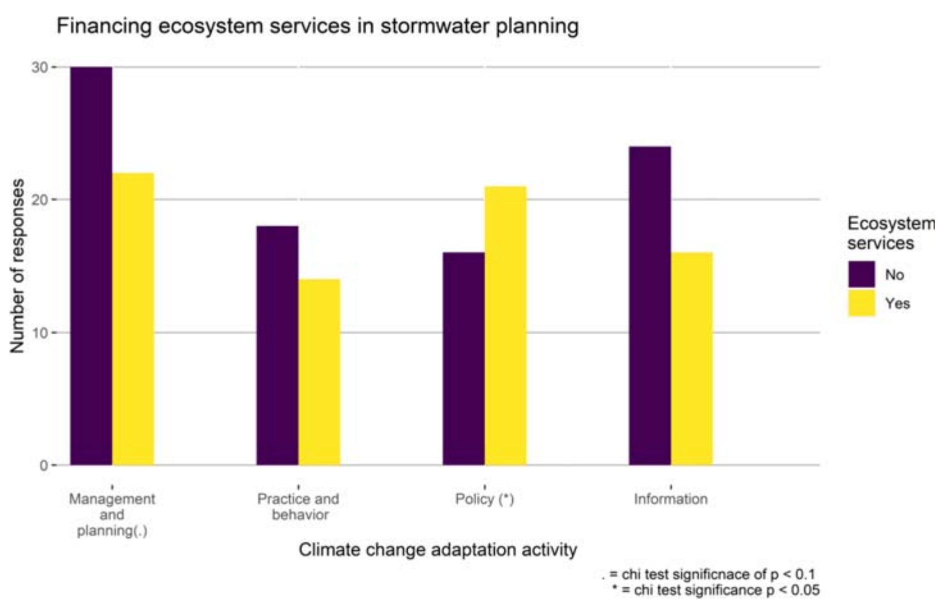

Figure 4. Ecosystem services within climate change and stormwater management and policy. Most focus on non-structural – institutional, policy, education, site planning, and management – rather than structural – engineered and constructed systems – best management practices. $\chi^2_S = 62.522$, $p < .001$.

challenge, however, was around finding 'successful and proven models for increasing resident behavior change due to increased public involvement in stormwater activities' (Respondent 67, July 2018).

Many barriers indicated by respondents are not surprising. Budget constraints, maintenance, and replacing or extending old infrastructure are the primary barriers municipalities identified in addressing stormwater problems. Lack of useful information, conflicting mandates, or the siloed nature of municipal planning present barriers for some municipalities, but overall, they were not identified as significant barriers across all municipalities in the survey. Other work has shown how departmental silos may not entirely explain different approaches in how to resolve stormwater planning in cities, but many limitations exist in terms of how stakeholders view financial mechanisms for valuing and managing stormwater and urban drainage systems (Cousins, 2017b). In an environment of fiscal austerity, where siloed funding impedes coordination, planners frame decisions with a clearly definable and justified business case scenario (Matthews et al., 2015; Shi, 2020). These strategies rely on assigning a monetary value to the volume of stormwater captured based on different program types, which is characteristic of market environmentalism in the water sector (Bakker, 2014; Cousins, 2017a).

Budget constraints, however, trickle down to the type of projects financed and advocated for in municipalities. When asked what type of stormwater-related projects a municipality would like to start, build, or construct but cannot fund or finance, responses focused on the repair, replacement, retrofitting, and upgrading of existing gray infrastructure to create a broader matrix of green and gray infrastructures. The green redevelopment of gray infrastructure is a broad goal among many of the respondents as a means to protect surface and groundwater resources. As one respondent noted, it is also about the 'pro-active grey infrastructure replacement and flood mitigation projects' and how most of their municipalities funding and financing is 'focused on water quality improvement projects (including green infrastructure) to comply with MS4 permits' (Respondent 148, August 2018). For a range of municipalities, the struggle is the end-of-life replacement of gray infrastructure and creating better control measures for surface water flow. Revenues from fees are typically too low to fund all of the projects needed to enhance stormwater control. This lack in revenue drives municipalities to experiment with different financial instruments to make up deficits.

Regional stormwater infrastructure and best management practices also emerged as a needed response to changes in urban run-off, but many municipalities lack the financial and political resources to implement them. As one respondent noted, 'flooding in 2013 spurred political drive to raise stormwater rates high enough to finance large CIP stormwater projects and we are focusing more on regional detention' (Respondent 160, August 2018). Regional planning presents unique challenges to funding across municipalities, but regional stormwater utilities have emerged in the United States to pool resources together to implement infrastructural improvements capable of addressing stormwater problems and remaining in compliance with stormwater permit requirements.

While most municipalities look to fund stormwater-related projects through stormwater user fees or a utility, many municipalities are drawing on a range of other financial instruments, including TIF, credit trading and mitigation banking, as well as social impact and green bonds to fill in gaps in funding. This is particularly acute in cities impacted by restrictive tax and expenditure limits, which drive municipalities to seek out alternative revenue sources and incur more debt (Wen et al., 2020). Not only are laws that limit the growth of government taxes and or expenditures leading cities to diversify their revenue streams, but also declining tax bases and sources of income. As one respondent noted,

> economic constraints have reduced available funds due to a declining population and resultant tax base. Combined with a reduction in grant funding sources the available money to plan, study and construct improvements along with necessary maintenance efforts limits the type and number of efforts the City can fund. (Respondent 11, July 2018)

These fiscal constraints are further amplified by push back against fees as 'rain taxes', which a respondent described as 'not acceptable to rate payers … and generally under attack from legislators annually' (Respondent 33, July 2018).

The turn towards fees to fund public services and operate municipal budgets like businesses is part of the neoliberal shift from publicly planned and coordinated solutions towards market-based solutions (Peck, 2012;

Sager, 2011). Within stormwater management, this trend emerged in the 1970s and emblematically took off after the passing of Proposition 13 in California, which restricted local property taxes (Cousins, 2017a; Pincetl & Gearin, 2005). These moves significantly reduced important sources of municipal funding. As respondents noted, the main limitation to funding green or gray stormwater infrastructure first comes down to the overall costs of addressing and managing stormwater in an urban environment, and secondly, the competing costs and priorities. These fiscal constraints are especially austere in disadvantaged communities, whether or not they are rural or urban.

In the midst of constrained municipal finance, these different funding and financial tools offer a range of options for decision-makers and planners to implement green infrastructure and other forms of stormwater infrastructure, such as sewer upgrades. The move towards alternative financial methods such as bonds, TIF, and mitigation banking matter in terms of how municipalities structure municipal finance. In terms of bonds, few respondents indicated that their municipality was using them but when asked their preferred method, bonds were pronounced and heavily present. Projects funded through green bonds have a designated purpose, such as climate change adaptation or environmental remediation, and need to support 'greening' efforts. This specified use restricts funds but allows municipalities, such as Washington D.C., to hedge the performance risk of green infrastructure projects. In the case of Washington D.C., green bonds pushed infrastructural investment strategies and policy design towards meeting requirements within their consent decree with the EPA. Project funding through TIF make use of public investments to attract private capital to special districts, usually economically depressed areas with potential for growth, and use the anticipated property tax increases to fund projects. Chicago, for example, used TIF schemes to fund their green roof program and other green infrastructure projects throughout the city. Other strategies, such as mitigation banking, set up private markets to encourage investments in green infrastructure, but rather than being focused on on-site retention or treatments for stormwater control, they allow for the development of off-site controls in situations where on-site implementation is cost-prohibitive or not feasible. Overall, survey respondents note that they desire a mix of fees and alternative financial mechanisms, such as green bonds, mitigation banking, and grants though state revolving funds, as needed to adequately address their stormwater challenges and build out a mix of green and gray infrastructure programs for stormwater management and climate adaptation.

The issue as one respondent noted, however, is that 'financing of large projects through loans, bonds, etc. may occasionally be necessary. However, debt servicing of those financing methods hamstrings stormwater utilities from dealing with future or current higher projects which aren't the project du jour' (Respondent 124, July 2018). A range of new fee and financial structures may be able to aid planners in funding new projects but a number of perceived limitations to standard economic models for valuing and managing stormwater and urban drainage systems exist among the respondents. Fees are typically not sufficient for addressing all of the required unfunded regulatory mandates and operational fees to maintain and replace urban water infrastructure.

Limitations arise around the overall cost of addressing and managing stormwater in urban environments and competing costs and priorities. Respondents indicated that fees are typically used for reactive repairs instead of anticipatory projects. This leaves shortfalls in funding activities that can help achieve co-benefits. Respondents note that increasing public awareness could increase the political appeal of raising stormwater fees, but all of the utilities – water, sewer, and stormwater – are facing similar challenges of aging infrastructure, climate change impacts, and increasing regulations. These challenges come together to increase the need for funding across a range of infrastructural services and finding alternative financial mechanisms to pay for infrastructural needs. The challenge, for many of the respondents, centers on how to retrofit the entire built environment with green infrastructure but do so in ways that work around the financial risk of projects not satisfying regulatory obligations or achieving environmental outcomes.

Conclusion and discussion

The need to redesign and retrofit infrastructure is not only turning the attention of planners, designers, and engineers to questions of what a greener, more resilient, and sustainable urban form might look like, but also to questions of how to fund and finance infrastructural transitions. While this study addressed how new fee and financial tools to address environmental and regulatory risk stemming from stormwater runoff might coincide with adaptation efforts to reduce risks from climate change, we found that fees are typically not sufficient for meeting regulatory mandates as well as the operation and maintenance costs needed to replace or repair urban water infrastructure. This shortfall has led many municipalities to use a host of other financial tools, such as credit and mitigation banking and social impact and green bonds. Few municipalities indicate a move towards full financialization of their stormwater infrastructure, but results suggest a broad desire to move towards deeper financial market integration in urban environmental governance. This move is most evident with municipalities planning for climate change adaptation and moving beyond fees to finance stormwater infrastructure projects. In light of this shift, we conclude on what a move towards green financing might mean in terms of introducing new forms of risk and its impact on retrofitting urban infrastructure and environmental justice.

First, a movement towards green finance to advance urban sustainability goals is occurring through the use of municipal debt markets, similar to those used for poverty management, housing, taxation, austerity, and urban redevelopment policy broadly (Peck, 2012; Rosenman, 2019b; Tapp & Kay, 2019; Weber, 2010). Risk is a fundamental part of this shift in urban environmental governance. Notably, Washington DC adopted green bonds to build green infrastructure to meet regulatory requirements to address urban stormwater runoff. As Christophers (2018, p. 146) notes of their program, the greening of both finance and infrastructure in Washington D.C. knits financial and environmental risk into the socio-ecological fabric of the city, where 'local residents, who are the ultimate social bearers of those risks both as inhabitants of the environment and, through the payment of DC Water's fees and charges'. Risk is certainly double edged, where new financial and infrastructural configurations can mitigate and exacerbate uncertainty, but the use of debt to upgrade urban infrastructural services can also heighten risk for vulnerable populations and deepen entrenched racial and social divisions in cities (Bigger & Millington, 2020). Green infrastructure may enhance well-being for some, but it may also be another's burden in situations where financial risk intersects with environmental risk. Urban greening and climate policy initiatives speculate on the value of urban nature with consequences for its equitable implementation (Knuth, 2016; Long & Rice, 2019).

Risk takes many forms when finance, environment, and climate are interwoven in urban planning and policy making. On the one hand, municipalities face a set of liability, legal and policy risks arising from lawsuits or fines if they violate water quality regulations embedded within the Clean Water Act. This is fundamentally one of the key drivers of stormwater fee and finance adoption, where financial pressure arises from legal and regulatory controls as well as gaps in infrastructure spending. In Los Angeles County, for example, Measure W – a parcel tax to fund stormwater projects – passed in 2018 to avoid costly fines and lawsuits and fund backlogged stormwater projects that can address water quality and boost water supplies (Agrawal, 2018).

On the other hand, financial and environmental risks are coproduced, where environmental risks (water pollution, floods, droughts) shape financial risks (loss of property, future financial loss) and vice-versa. A broad sweep of different risks permeates social, ecological, technological, and financial stability in addressing social-ecological challenges. The use of bonds, if poorly planned, can commit cities to continued development in at risk areas to pay back bonds, which should draw researchers' attention to how, where, and for whom green interventions and nature-based solutions occur (Anguelovski et al., 2020, Cousins, 2021). The insertion of green bonds, and other market-based approaches, into urban greening initiatives, such as green infrastructure for stormwater management, centers debt finance at the nexus of environmental and financial risk and exposes limits to addressing just forms of urban sustainability.

Second, alongside fee and finance systems in urban climate and environmental governance comes a move towards retrofitting the urban environment to manage externalities of urban development – pollution and impermeability. The solution to these externalities rests on transforming the urban built environment into a permeable city where water quality and quantity dilemmas are resolved through a process of greening municipal infrastructure. With few sources of capital for maintenance and retrofits, however, fees and green finance bond visions of maintaining and sustaining a modern and resilient city with green innovation and entrepreneurialism (Cousins, 2019). Vast sums of money are required to retrofit the built environment into a system of green and gray infrastructures (Shi et al., 2016) and as Knuth (2019, p. 490) notes, 'retrofitting requires not just potentially profitable urban repair today but large-scale urban maintenance into the future'. The transition towards green infrastructure, nature-based solutions, and water sensitive urban design comes not only with a reworked meaning, structure, and function of the urban ecosystem but also a complete transformation of urban stormwater runoff into a resource.

Retrofitting situates green infrastructure and technological change alongside legal and financial systems to transform stormwater from a hazard into a resource within municipal planning. The logic rests on properly valuing biophysical functions as ecosystem services as a means to account for the benefits of a 'green' approach over a 'gray' one and develop multi-benefit approaches that provide alternative water supply sources alongside water purification, aesthetics, and improved ecosystem function. This process of converting stormwater into a 'new' resource, however, comes with an extended resource frontier that opens up new urban geographies for extraction. As Hodson and Marvin (2016, p. 270) summarize, 'retrofitting at city scale is a heterogeneous endeavour' and ecological disparities arise around who bears the costs and benefits of municipal retrofits in stormwater infrastructure and green interventions (Dooling, 2009; Finewood, 2016; Rice et al., 2020). Gentrification, in its green and ecological guises, excludes socioeconomically vulnerable populations and creates a host of interactional and procedural justice issues (Anguelovski et al., 2019). Retrofitting the urban environment to capture and cleanse stormwater shifts how it is utilized – from a hazard to a resource – and this practice of revaluation through urban stormwater retrofits turns water quality and flood control problems into new underutilized resource frontiers. Retrofitting the urban built environment into a water sensitive system, requires not only technological innovation in the form of green infrastructure and other controls but also financial innovation in developing ways to finance and fund projects.

Finally, with an estimated $298 billion in capital investments needed to improve the United States' wastewater and stormwater infrastructure over the next 20 years, much is at stake in terms of how, for whom, and where these improvements will take place. Finding ways to improve human and ecological well-being through a retrofit of the urban built environment is about more than getting the fees right or developing the proper financial tools to implement green infrastructure and other best management practices, but it is about fostering a just transition. Bioswales, greenroofs, ecological corridors, and other forms of infrastructure that seek to mimic the biophysical world provide a host of human and ecological benefits from reductions in urban runoff, urban heat island mitigation, and psychological well-being, but the extent to which green interventions address existing socio-spatial inequities in the provision of ecosystem services remains uneven. Refashioning urban ecologies creates spaces to imagine and create sustainable and just futures, but they can also be exclusionary. Understanding how and to what purpose new fee and financial structures are being used to address socio-environmental risks of stormwater flows and changing precipitation patterns is a starting point in understanding for whom transitions in the built environment are taking place for. With evidence mounting that green finance can further embed socio-spatial inequities in the built environment and transfer environmental and financial risk onto vulnerable populations (Bigger & Millington, 2020; Christophers, 2018; Ranganathan, 2015), a just transition needs to address and confront the fee and financial systems directing how value and capital flows and to whom it flows to. Addressing contestations and inequalities through greening initiatives will be central for developing and achieving just sustainabilities.

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