CHAPTER 3

Transforming Cities and Science for Climate Change Resilience in the Anthropocene

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3.1 Introduction

Cities are where some of the most advanced climate action occurs, but they are also locations of some of the largest social and economic impacts of climate change. With climate change-driven extreme events rising in frequency and intensity, cities are on the front lines of needs for innovative climate adaptation and resilience efforts. Transforming cities to be flexible, adaptive, and resilient to a future that is unpredictable requires transformative governance capable of building, designing, and planning cities in ways that also recognize the challenges of governing complex urban systems. Cities are dynamic, with interacting and interdependent social-economic, ecological-biophysical, and technological infrastructure components that together generate behaviors and patterns that can be desirable, or,

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undesirable. Governing this complexity, now with additional pressure of climate change, requires rethinking governance and even how we approach science in the context of urban social-ecological-technological systems (SETS) (McPhearson et al. 2016a; Markolf et al. 2018). Further, transformative climate governance must now more than ever recognize that long-term futures are uncertain, subject to non-stationarity, and therefore difficult to prepare for (Elmqvist et al. 2019).

3.2 Key Climate Risks in Cities

As the toll from extreme events continues to mount, there is an urgent need for convergence of science and transformative governance in a way that can enhance the resilience of cities in the Anthropocene (Elmqvist et al. 2019; Steffen et al. 2015). Cities and urban regions are particularly at risk of climate-driven extreme events because they hold the highest concentrations of people and critical infrastructure (Bouwer 2011; Dickson et al. 2012). Rising sea levels, flooding, and heat waves, among other extreme climatic events, pose significant risks to communities and infrastructure—risks that are increasing in every part of the world.

Extreme weather is already leading to record heat waves, drought, floods, and wildfires impacting cities globally. Many cities are located in low lying coastal zones and are likely to suffer from development intensification increasing the exposure of people, infrastructure and economic activity to coastal storms, and the effects of sea level rise (Neumann et al. 2015). Of course, it is not only coastal cities that are at risk. Cities around the world are more prone to suffer from extreme heat due to the combined impacts of the urban heat island, rising temperatures, and air pollution (IPCC 2015). In fact, cities already experience more than twice as much warming as non-urban regions due to the amplificatory effect of urban heat islands. Projections indicate that some of the world's largest cities could warm by as much as 7°C by 2100 (Estrada et al. 2017).

Large cities due to a dominant twentieth-century mode of urbanization and development modify the local and regional environment, changing the microclimate (e.g., by creating urban heat islands), paving over soil and altering ecosystem processes and building up infrastructure (e.g., roads, buildings, pipes, wires), which, together with projected impacts of climate change such as sea level rise, contributes to magnifying hazard impacts in coastal inhabited areas (Pelling and Blackburn 2013; McPhearson et al. 2018). Megacities (i.e., urban areas exceeding 10 million inhabitants), for example, are highly interconnected and vibrant centers in which enormous physical and intellectual resources are concentrated. Mainly located along waterways and coastal areas, megacities tend to be more exposed to disasters and suffer higher social and economic losses (UNDESA 2016). Earthquakes, cyclones, and flooding are major threats to these urban areas (Philippi 2016; Depietri and McPhearson 2018).

Sea level rise, coupled with other environmental issues, such as urban land subsidence or coastal erosion, could trigger unprecedented environmental and social changes in many cities (Newton et al. 2012). A primary concern is how increasing frequency and intensity of extreme weather events will damage urban infrastructure and threaten urban residents (Bender et al. 2010). Estimates show that future economic and social costs could dwarf those incurred after recent major hurricanes, cyclones, and typhoons, such as those which occurred in the 2017 in the USA (Hurricanes Harvey, Irma, and Maria) that caused damage exceeding 260 billion US dollars (NOAA 2018).

It is clear that urbanization and climate change are on a collision course. Developing governance systems that can transform cities for resilience in the face of multi-hazard risk (Fig. 3.1) must take center stage to alter urban trajectories and deliver climate adapted cities. Not only will the increasing rates of urbanization expose more urban dwellers to urban heat island and extreme temperatures, but urban land expansion is also likely to increase the exposure of urban infrastructure to floods and droughts (Güneralp et al. 2015). For example, the number of urban residents facing water shortages could increase by a factor of 5, placing 160 million residents at risk driven by the collision of urbanization and climate change (McDonald et al. 2011).

3.3 A New Urban Systems Science

Traditional disciplinary scientific approaches have failed to take into account the social-ecological-technological system complexity that can produce such risks to climate change. Cities are at risk from climate change precisely because of the dense concentration of people and infrastructure and the way they interact together within the ecological-physical world. To advance governance means also advancing our ability to understand complex urban dynamics and develop near and longer-term term scenarios to guide decision-making. Urban science itself must advance to be transdisciplinary and systems oriented (Acuto et al. 2018; McPhearson et al. 2016b).

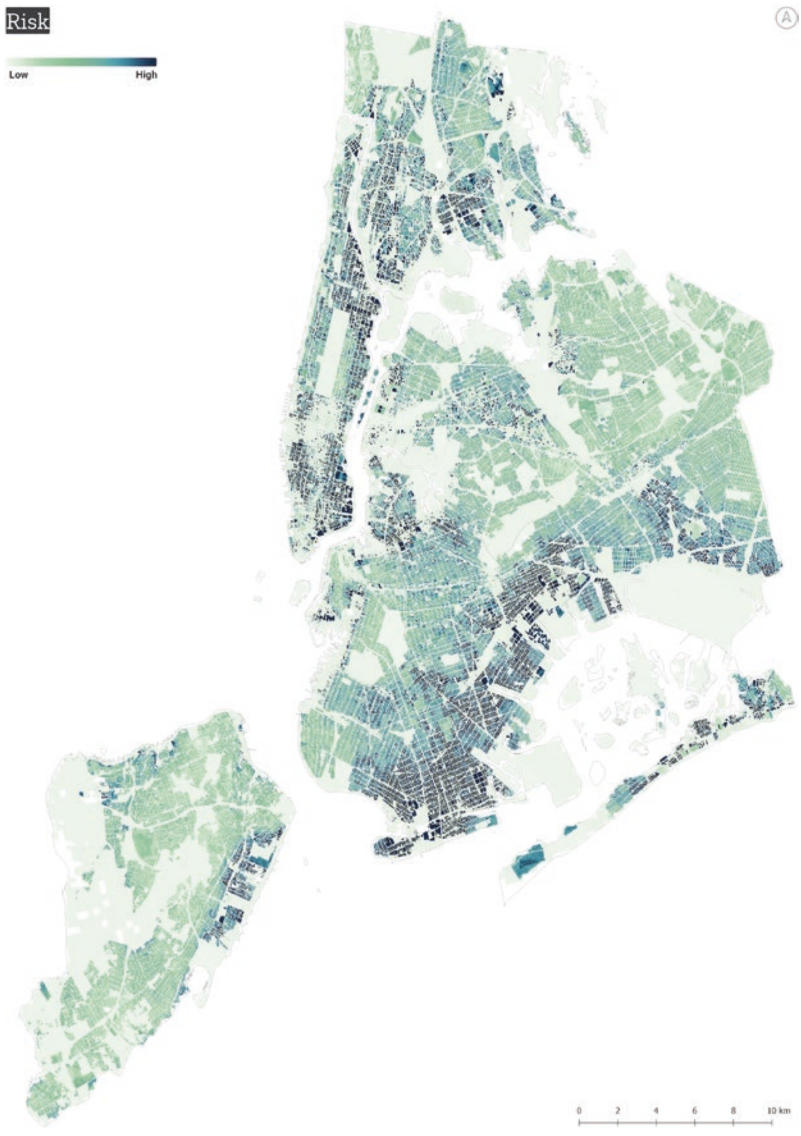

Fig. 3.1 Multi-hazard risk including from heat risk, coastal flood risk, and inland flood risk combined for New York City (Adapted from Depietri et al. 2018)

Cities need to be understood as social-ecological-technological systems (SETS) (Fig. 2.2). Without a systems approach, resilient infrastructure investments may repeat mistakes of the past. For example, increasing resilience by focusing on new infrastructure investments to harden edges in coastal cities (e.g., build sea walls) may create unintended social and ecological consequences. A key challenge facing urban infrastructure systems is that they are currently relatively inflexible, rigid, and long-lasting due to a robustness-centered approach (Markolf et al. 2018; Chester and Allenby 2018). Technological innovations are the oft-touted solutions to increase the robustness of infrastructure as a resilience strategy to climate change impacts in cities. Robustness approaches often focus on hardening and strengthening infrastructure, building bigger and stronger infrastructure to withstand more intense, frequent, or longer lasting events (Kim et al. 2019). Yet fundamental challenges and uncertainties exist with a such robustness-centered approach, including (1) limits to how much stronger you can make infrastructure, (2) the significant degree of uncertainty in extreme event forecasts, and (3) the possibility that hardening against one hazard may leave the city weakened to others. Recent extreme events such as Hurricane Harvey (2017) in Houston, Texas, Hurricane Maria (2017) in San Juan, Puerto Rico, and Hurricane Sandy (2012) in New York, New York highlight these weaknesses and exposed the fundamental interdependencies within such urban SETS. In all three cases cascading failures across the cities led to displacement, billions of US$ in economic and infrastructure damage, loss of power in some cases to homes for many months, and challenged governance systems to respond, plan, and create effective resilience policies. Rethinking resilience investments means thinking about infrastructure now as fully interactive with ecological and social domains in cities (Markolf et al. 2018).

A new urban systems science is beginning to emerge that is key to understanding how to protect cities and urban regions from the most severe impacts of climate-driven extreme events. This science accounts for the interdependencies among social, ecological, and technological infrastructure components of urban systems as SETS (Fig. 3.2) (Grimm et al. 2016, 2017; McPhearson et al. 2016a, b; Grabowski et al. 2017). Most traditional scientific approaches to improving resilience are siloed, with analytical efforts focused on one or two domains. Yet, as recent events have shown, extreme events can cause cascading impacts across domains. For example, flooding can simultaneously cause power and transportation disruptions, damage ecosystems, impact human health,

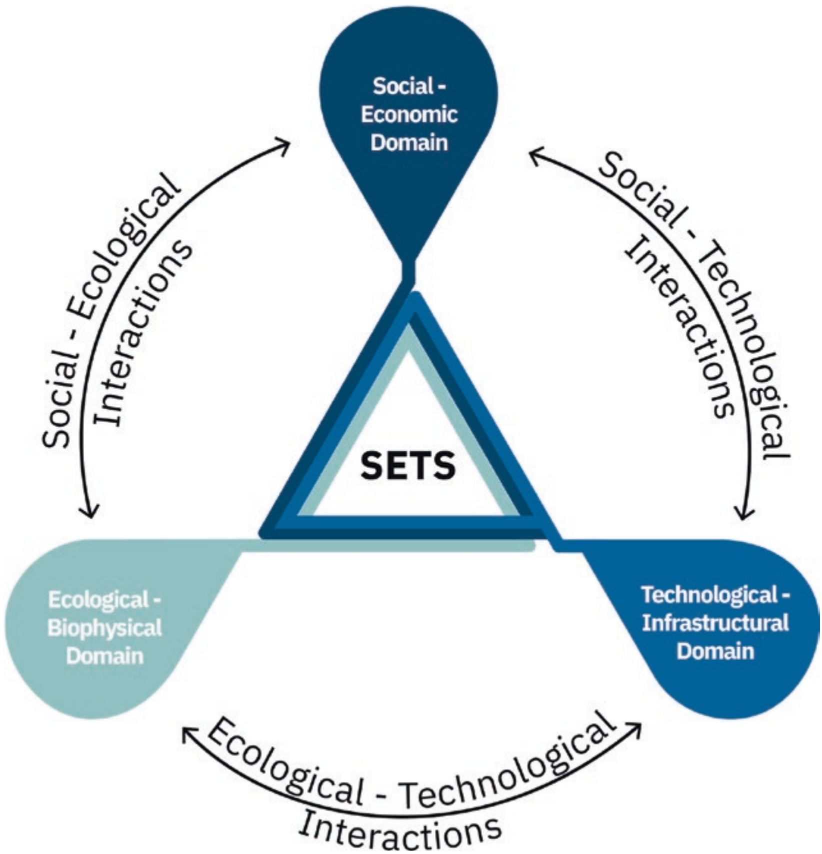

Fig. 3.2 The social-ecological-technological systems (SETS) conceptual framework emphasizes the social-economic, ecological-biophysical, and technological-infrastructural interactions that drive systems processes and patterns in an increasingly interconnected world at local and global scales (Adapted from McPhearson et al. 2016a; Depietri and McPhearson 2017)

and damage homes and critical infrastructure. Recent extreme events also demonstrated failures or inadequacies not just in the built infrastructure but also in resources, institutions, information, and governance systems—components of the urban SETS—to prepare for, and respond to, events of this magnitude (Eakin et al. 2018).

An urban systems science is emerging that aims to create better understanding about urban SETS and is solution-oriented to find and assess solutions that converge across urban SETS including human-cultural-economic-governance systems (social), biophysical-ecological systems (ecological), and technological-engineered-infrastructural systems (technological). Further, co-production of knowledge is critical to both frame research questions and methods for bringing transdisciplinary science into a co-design process with stakeholders at multiple levels. Co-production and co-design are not only needed in science, but governance too: Governance and technological solutions that address only one system domain are unlikely to be resilient for urban systems in the future. Decision-makers, designers, engineers, and managers need solutions that converge across disciplines and knowledge systems.

3.4 Transforming Urban Climate Governance

Addressing climate risks in cities is a critical governance challenge: Governance approaches must themselves transform to take into account the complexity of SETS and feedbacks between urban SETS and climate change impacts in cities. Addressing risks to climate change will require many levels of investment, innovation, and transformation and urban climate governance will be a key component of transforming cities for resilience. Only recently has climate change planning and policymaking in cities become formally recognized as part of the global response to climate change (Amundsen et al. 2018; van der Heijden 2018). However, cities are where the majority of climate action exists and climate governance in cities is poised to lead climate action globally (Bai et al. 2018; Elmqvist et al. 2018). Still, while urban climate governance is advancing (Hölscher et al. 2019), it is uneven with some cities leading the way and others struggling due to lack of resources, knowledge, or political will.

Local governments have primarily framed climate mitigation and adaptation as opportunities for improving human wellbeing in cities (Shaw et al. 2014; Aylett 2015; den Exter et al. 2014). Even in cities that are leading with ambitious climate agendas, climate policy and planning initiatives often remain add-on priorities to short-term existing practices. While local governments have taken a leading role in urban climate governance, a plethora of other actors from local communities, regional and national governments, to businesses and research institutes are generating and integrating knowledge and experimenting with actions at local scales (Bulkeley 2010; Burch et al. 2016; Moloney and Horne 2015; Hughes et al. 2017; Hölscher et al. 2019). These actors are key to bringing more inclusive transformative urban climate governance approaches forward.

Perhaps the most pressing challenge for urban climate governance is to fundamentally shift the dominant divisional model that plagues efforts for transformative governance in order to upend traditional approaches and create new governance models and frameworks. A systems approach in urban governance is thwarted by the siloed structure of city government agencies, where departments that focus on public health, operate independently of parks, transportation, sustainability, and other departments. The majority of urban governance systems are still characterized by administrative and jurisdictional divisions across sectors and scales and short-sighted political cycles, resulting in policies, plans, and solutions that prioritize short-term needs over long-term resilience goals (Friend et al. 2014; Torabi et al. 2018; Wamsler 2015). This type of decision-making and planning continues to exacerbate existing path-dependencies keeping cities on trajectories that challenge efforts to fundamental adapt to the current and coming climate impacts (Torabi et al., 2018; Ürge-Vorsatz et al., 2018).

Further, inclusive and integrated climate governance approaches are rare and most cities trend toward actions that are subordinate to business-as-usual interests and policy and planning approaches, which favor isolated, incremental, and short-term responses (Hölscher et al. 2019). While the emerging learning-based and collaborative approaches open-up new avenues for organizing urban governance for transformations, it is unclear what mechanisms will be most effective and that can allow for the emergence of alternatives to existing urban governance approaches (Elmqvist et al. 2019; Romero-Lankao et al. 2018). To accommodate the system perspective on cities and urban areas, new governance approaches are needed that link climate change to other goals, consider the interdependent nature of urban SETS, and take more collaborative and co-production approaches.

3.5 Conclusion

Building resilience to climate change in cities is complicated by the need to enhance social, ecological, and infrastructure resilience simultaneously, requiring novel systemic and transdisciplinary approaches in science and governance that match local needs and risks and that recognize and are able to work with urban SETS complexity. This is a challenge for both science and policy, which often work in disciplinary and departmental siloes, respectively. Cities can be global leaders in building societies capable of adapting to a new climate reality, but this will lean heavily on transforming both urban science and governance approaches to facilitate systemic solutions. The challenge for strengthening urban systems science and transformative climate governance approaches that cross policy siloes will be to develop rigorous institutional and organizational conditions that make more systemic connections across disciplines, sectors, scales, and societal spheres in ways that can fundamentally build systemic resilience for cities in the face of climate-driven extreme events. The challenge is clear, but to meet it requires rethinking governance, rethinking urban science, and creating a co-creative and adaptive process where science and governance approaches can learn while experimenting.

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