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Polycentric Systems and Multiscale Climate Change Mitigation and Adaptation in the Built Environment

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Abstract

Addressing climate change requires consideration of mitigation and adaptation opportunities at multiple spatial scales. This is particularly true in the built environment, defined here to include individual buildings, neighborhoods, and the spaces between. The current U.S. political environment portends fewer resources and coordinating services for mitigation and adaptation at the federal level, however, reinforcing the relevance and necessity of actions at subnational levels. In this study, we evaluate the applicability of a polycentric model of governance to the implementation of mitigation and adaptation practices, as well as the presence of polycentric systems in the built environment. We assemble a database of practices with the potential to achieve both mitigation and adaptation objectives, as well as those that may be cross-purposed or that may achieve one but not the other. We review practices to gauge the applicability of a polycentric model of governance to mitigation and adaptation practices in the built environment, and examine the attributes of three existing adaptation and/or mitigation programs to assess the extent to which they exhibit polycentric attributes. We conclude with recommendations for a broader research agenda, including efforts to develop more in-depth examinations into individual programs and comparative analysis of performances of different governance attributes.

KEY WORDS: climate change, environment, governance, regional governance

建成环境中的多中心体系和多层次气候变化减缓及适应

应对气候变化需要将多重空间范围中的气候减缓机遇和适应机遇考虑在内。这在建成环境中尤为如此，此环境包括个别建筑、邻区和二者之间的空间范围。美国当前政治环境预示着在联邦层面上用于气候减缓和适应的资源和协调服务将变得更少。然而，次国家层面上的相关性和行动必须性有所加强。笔者评价了一种多中心治理模式对实施气候减缓和适应措施的适用性，同时评价了建成环境中多中心体系的存在。笔者收集了由一系列实践组成的数据库，这些实践中一些具备实现气候减缓和适应两个目标的潜力，一些实现的目标不一致，一些可能只能实现其中一种目标。笔者检验了这些实践，以估算多中心治理模式对建成环境中气候减缓和适应实践的适用性；笔者还检验了三种有关气候适应和/或减缓的现有案例所具备的性质，以评估其在多大程度上展现了多中心性质。本文结论建议，研究议程应更广泛，包括对个别计划开展更深入的检验和比较分析不同治理性质的表现。

关键词: 关键词: 气候变化, 环境, 治理, 区域治理

Sistemas policéntricos y mitigación y adaptación al cambio climático en múltiples escalas en el entorno construido

Abordar el cambio climático requiere considerar las oportunidades de mitigación y adaptación en múltiples escalas espaciales. Esto es particularmente cierto en el entorno construido, definido aquí para incluir edificios individuales, vecindarios y espacios entre ellos. Sin embargo, el entorno político actual de los Estados Unidos augura menos recursos y servicios de coordinación para la mitigación y adaptación a nivel federal, lo que refuerza la relevancia y la necesidad de acciones a nivel subnacional. En este documento, evaluamos la aplicabilidad de un modelo policéntrico de gobierno a la implementación de prácticas de mitigación y adaptación, así como la presencia de sistemas policéntricos en el entorno construido.

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Reunimos una base de datos de prácticas con el potencial de lograr los objetivos de mitigación y adaptación, así como aquellos que pueden tener un propósito cruzado o que pueden lograr uno pero no el otro. Revisamos las prácticas para evaluar la aplicabilidad de un modelo policéntrico de gobierno para las prácticas de mitigación y adaptación en el entorno construido, y examinamos los atributos de los tres programas de mitigación y adaptación existentes para evaluar el grado en que exhiben atributos policéntricos. Concluimos con recomendaciones para una agenda de investigación más amplia, que incluye esfuerzos para desarrollar exámenes más profundos de los programas individuales y un análisis comparativo de los resultados de los diferentes atributos de gobernabilidad.

PALABRAS CLAVE: Palabras Clave: cambio climático, medio ambiente, gobernanza, gobernanza regional

Introduction: Mitigation and Adaptation in the Built Environment

Addressing global climate change has emerged as a critical policy and social challenge (IPCC, 2014). The consequences of climate change jointly and separately affect natural and human systems at multiple spatial scales and across multiple sectors. Sea levels are projected to rise substantially (Rahmstorf, 2007). Groundwater reserves are anticipated to be at risk (Goderniaux et al., 2011). Already, climate change may be contributing to the severity and likelihood of extreme weather events, ranging from high temperatures, to dry spells, to periods of heavy precipitation (Diffenbaugh et al., 2017). Collectively, the estimated economic market and nonmarket impact in the United States from climate change could rise to approximately 1.2 percent of gross domestic product per +1°C on average (Hsiang et al., 2017).

Responding to the challenges of global climate change will entail action at multiple spatial scales and across multiple sectors (Ostrom, 2010b). Efforts are needed to both blunt the effects of climate change and to reduce the magnitude of future change itself, conceptually differentiated as adaptation and mitigation, respectively. For the purposes of this analysis, adaptation can be defined as "adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities" (IPCC, 2001a, p. 982), while mitigation refers to "anthropogenic intervention to reduce the sources or enhance the sinks of greenhouse gases" (IPCC, 2001b, p. 3). Conceptually, there is an inverse relationship between the efforts taken to mitigate and adapt and the resulting negative effects of climate change (Holdren, 2008). Though U.S. policy proposals in the latter half of the last decade tended to focus largely on mitigation efforts, a more balanced approach has emerged in recent years, echoing earlier calls for a synergy of the two to be explored and promoted (Wilcoxen & McKibbin, 2004).

The need to facilitate near-term mitigation and adaptation is particularly relevant in the built environment. From a mitigation perspective, the built environment accommodates a plurality of human activities and associated energy services (Wilkinson, Smith, Beevers, Tonne, & Oreszczyn, 2007). In 2015, residential and commercial buildings account for approximately 40 percent of the total energy consumption in the United States (U.S. Energy Information Administration, 2017) and 39 percent of carbon dioxide (CO_2) emissions (USGBC, 2015). From an adaptation perspective, estimates suggest that, as of 2010, 39% of the U.S. population lived in counties considered

to be sensitive to sea level rise and extreme weather events (National Oceanic & Atmospheric Administration [NOAA], 2017), a percentage that was only projected to increase. At the same time, the long lifetime of many built structures—Aktas and Bilec (2012) estimate that the current average lifetime of U.S. residential buildings is 61 years—complicates greenhouse gas (GHG) mitigation and adaptation efforts by creating lock-in conditions, underscoring the need to both retrofit existing structures and to better site and design new ones.

Under the Obama administration, a series of actions were put in place attempting to deal with the changing climate in the built environment. With regard to mitigation, the American Recovery and Reinvestment Act of 2009 (ARRA) aimed to provide investments and tax incentives for a wide array of clean energy initiatives across the country, including improving energy efficiency (e.g., residential retrofits and weatherization) and expanding renewable energy generation (The White House, 2016). Subsequent analysis suggests that the ARRA was successful in several respects, in terms of not only programs created and funding distributed, but also emission reductions achieved (Lim & Bowen, 2018; Tonn et al., 2014). Other actions include, but are not limited to, the Clean Power Plan (reduce emissions at new and existing fossil fuel power plants), the Better Buildings Initiative (an effort to increase commercial and municipal building efficiency), and the establishment of new appliance efficiency standards. Regarding adaptation, the Obama administration implemented a series of measures designed to reduce vulnerability to climate change, generally, and severe weather, specifically. Notable among these are the creation of the Partnership for Resilience and Preparedness and the Climate Resilience Toolkit (platforms to aid data access and information sharing) and the establishment of new standards to ensure that new federal-funded construction meet more rigorous standards for flood risk (Executive Order 13690; January 30, 2015).

The 2016 election of Donald Trump to the U.S. presidency, however, portends a reduced emphasis by the federal government to address its causes and effects, generally (Roberts & Plumer, 2016). This reduced emphasis can be assumed to translate into fewer resources being available to facilitate climate change mitigation and adaptation in the built environment, as well as less guidance on how to coordinate the use of those resources that are available. The August 2017 rescinding of the aforementioned Obama-era executive order to improve the resilience of federally funded infrastructure to both current and future flooding (Executive Order 13807; August 21, 2017) is but one example.

The current situation creates at least two immediate governance imperatives. The first is to better inform practitioners how best to make use of scarce resources and coordinate the application of technologies and practices to achieve mitigation and adaptation in the built environment. In the absence of coordinating federal policy and the high likelihood of reduced federal incentives for climate change initiatives, there is a need to consider how climate change goals can be achieved through other mechanisms, such as voluntary alignment or harmonization, defined here as the realization of co-benefits by formulating and implementing mutually supportive adaptation and mitigation policies (Kalafatis, 2017; Moser, 2012), or "mainstreaming" approaches, the integration of environmental concerns into national and/or regional development policies (Oates, Conway, & Calow, 2011). To facilitate decision-making processes, actors will also require "serviceable knowledge" of individual practices to

achieve mitigation and adaptation objectives (Howard & Monbiot, 2009, p. 30; see also Wang, Hawkins, Lebredo, & Berman, 2012).

Such information has been compiled in the literature to some extent, but the coverage across topics and disciplines remains uneven and incomplete (Corfee-Morlot, Cochran, Hallegatte, & Teasdale, 2011). For example, a substantial amount of research has explored so-called "climate-smart" strategies to facilitate joint mitigation and adaptation objectives in agriculture and forestry (Bakkegaard, Møller, & Bakhtiari, 2016; Chia, Forbissie, & Kanninen, 2016; Duguma, Minang, & van Noordwijk, 2014; Harvey et al., 2014). Research has likewise explored the potential for joint mitigation–adaptation in the built environment, ranging from the technical potential at the individual building scale (Galik, Rupert, Starkman, Threadcraft, & Baker, 2016) to the development of typologies to evaluate trade-offs at the scale of entire urban areas (Solecki et al., 2015). Despite these contributions, there remains a need for a careful evaluation of the options to inform action at multiple scales (see, e.g., Klein, Schipper, & Dessai, 2005; Laukkonen et al., 2009; Zimmerman & Faris, 2011).

A second related imperative is the deployment of mitigation and adaptation practices in an efficient and coordinated fashion. Over the course of the last decade, numerous authors have commented on the failure of the global community to achieve binding climate policy solutions at the international level while offering alternative solutions. For example, Bulkeley and Betsill (2005), Betsill and Bulkeley (2006), and Corfee-Morlot et al. (2011) all note the relevance of urban governance in addressing climate change objectives, with an emphasis on multilevel, multiscalar processes. Levy (2011) cites the importance of private resources and capacity in dealing with this international "governance deficit," whereas Cashore (2002) and Cashore, Auld, and Newsom (2004) focus on the role of the market in providing compliance incentives in the absence of governmental requirements. But while embracing such nongovernmental solutions can be advantageous, accountability remains a potential concern (see Kramarz & Park, 2016; Balboa, 2017; Rosenberg, 2017).

In terms of implementation, Green, Sterner, and Wagner (2014) and Jordan et al. (2015) note the advantages of linking top-down solutions with local initiatives. Similarly, Bollinger et al. (2014) cite the complexities of contemporary climate change policies in their call for an increased emphasis on interconnected systems. Elsewhere, Burch (2010) notes the importance of facilitating the effective use of existing capacities and emphasizes the roles of institutional structures, organizational culture, and policy-making procedures. Anguelovski and Carmin (2011) meanwhile find that most urban-level environmental responses, in both the global North and South, are driven by their endogenous motivations and thus carried by relatively independent actions, and emphasize the roles of capacity building and institutional support. Robinson and Gore (2015), however, identify a more active role of municipal efforts and highlight the impact of internal governance structure on broader climate arrangements.

Though the above literature contributes much to our understanding of multiscaled, multiactor governance arrangements to facilitate climate action, gaps nonetheless remain, particularly at the nexus of multipurpose climate action (e.g., mitigation and adaptation practices), the need to operate simultaneously at multiple scales and across multiple sectors, and the unique issues under consideration in the built environment. It is here where an assessment of polycentric systems can be helpful. While

viewing climate change mitigation and adaptation through a polycentric lens is certainly not new (e.g., Ostrom, 2009, 2010b), we argue that it takes on new relevance and importance given the current U.S. political environment and the unique challenges associated with the built environment.

Compared to a federal system, which accommodates multilevel governance through "neatly nested jurisdictions," polycentric systems may foster increased inclusiveness by hosting crosscutting jurisdictions for a specific administrative function (e.g., a multistate water governing organization) (McGinnis & Ostrom, 2012, p. 15). By facilitating mutual learning, cooperation, and monitoring among participants, while simultaneously permitting decision makers to utilize local knowledge, polycentric arrangements may have potential advantages in yielding more "effective, equitable, and sustainable outcomes" (Ostrom, 2010b, p. 552). Knowing the extent to which programs to facilitate multipurpose climate action in the built environment are compatible or even facilitated by such governance arrangements can help researchers understand the continued relevance of polycentric systems to global governance imperatives like climate change while also helping local decision makers better prioritize specific practices to deploy in the near-term.

Polycentric Systems and Climate Mitigation and Adaptation in the Built Environment

Polycentric systems are institutional arrangements with a multitude of governing units at diverse scales making decisions within a specific domain and with a certain degree of formal independence (Carlisle & Gruby, 2017; Cole, 2011; Ostrom, 2010b; Ostrom, Tiebout, & Warren, 1961). Participants in polycentric systems include mutually overlapping organizations from public, private, and nonprofit sectors embedded in a crisscrossed political system, for example, a collaborative planning process among national, regional, and local actors from both public and private sectors to reduce GHG emissions (Matrak, 2009; McGinnis & Ostrom, 2012; Ostrom, 2010b). Since its introduction by Ostrom et al. (1961) in an investigation of the potential effectiveness of delivering public services by nested public and private organizations in a metropolitan area, the concept of polycentricity as an alternative to a pure-market or nested government model has been bolstered by substantial empirical evidence (Baldwin, Washington-Ottombre, Dell'Angelo, Cole, & Evans, 2016; Ostrom, 2010a, 2010b; Pahl-Wostl & Knieper, 2014; Paterson, Hoffmann, Betsill, & Bernstein, 2013; Zia, Meek, & Schulz, 2015). Research of polycentric models of governance has also contributed to a broader understanding of public good provision and service delivery, as well as collective decision making in an increasingly nested social setting with more flexibility and adaptability (Ostrom, 2001, 2010b; Pahl-Wostl & Knieper, 2014).

In light of repeated failures by the global community to reach a binding international climate agreement, polycentric models of governance gained attention over the last decade as a potential path to achieve GHG reductions in the interim (Merino, Protocol, & Ostrom, 2012; Ostrom, 2009, 2012). These calls supplemented previous work on the applicability of polycentric systems to climate governance, generally (e.g., Sovacool, 2011); analysis of the potential advantages of a polycentric approach to

establishment of sustainable energy systems (Goldthau, 2014); and the potential limits to polycentric governance and the related need for top-down policy drivers in the development of climate change programs in forestry and land use sectors (Sunderlin et al., 2015). The present analysis seeks to extend this literature by considering the extent to which a polycentric model of governance is compatible with and can be identified within mitigation and adaptation objectives in the built environment at multiple spatial scales.

The Polycentric System Attributes of Climate Mitigation and Adaptation

We argue here that mitigation and adaptation responses to climate change in the built environment fit well within a polycentric model of governance. The literature generally supports the notion that many aspects of climate change mitigation and adaptation are conducive to a polycentric model of governance. As noted by Cole (2011), those policies and programs that emerged to address climate change have attributes that are, in his words, at least weakly polycentric, largely owing to the multiple scales at which they operate. What supporting evidence there is in the literature is generally theoretical in nature (Ostrom, 2009), anecdotal (Cole, 2011), or suggestive in manner (Ostrom, 2012), necessitating analysis and confirmation of the applicability of a polycentric approach to a wider array of both individual practices and the broader programs designed to encourage their use.

A necessary first research question is the extent to which the implementation of individual mitigation or adaptation practices is compatible with polycentric models of governance. In the context of our analysis, a "practice" can be broadly understood as a technology, process, or approach through which actors intervene to affect a change in either the mitigation or adaptation performance of the built environment. A program can be thought of as the organizational or policy context that seeks to implement or deliver a particular practice.

At first blush, the development and operation of structures and spaces in the built environment would seem to share multiple attributes with polycentric systems in that decision making occurs at multiple spatial scales and falls under the purview of multiple separate and interrelated institutions with varying degrees of autonomy (e.g., Carlisle & Gruby, 2017; Laukkonen et al., 2009; Ostrom, 2014). A diverse range of monitoring and enforcement practices likewise govern decision making in the built environment, ranging from simple information provision campaigns to formal regulation and legal sanctioning (e.g., Ostrom, 2014).

For instance, buildings and structures in the United States are governed by building codes, the sets of regulations providing minimum requirements for their design, construction, alteration, and maintenance. Instead of developing their own codes, all 50 states and the District of Columbia adopt the model building codes maintained by the International Code Council (ICC) (FEMA, 2018; ICC, n.d.). State adoption is processed through either legislative or regulatory actions, where in some states, codes are adopted by local jurisdictions. The responsibility of code enforcement is usually delegated from state to local governments to adjust for regional variations (Oster & Quigley, 1977). Voluntary actions by the private and nonprofit sectors simultaneously contribute to the governance of the built environment as well. The Leadership in Energy and Environmental Design (LEED) program developed by the U.S. Green

Building Council is an independent market-driven sustainable building assessment rating system seeking to improve the energy performance of buildings and communities. As a third-party certification system, the LEED program works across jurisdictions at multiple spatial scales to help achieve energy efficiency goals by holding contractors and project teams accountable for incorporating high-performance standards and requirements (Howard, 2015).

Our second research question is the extent to which deployment of mitigation and adaptation practices in the built environment follows a polycentric model of governance. The theoretical advantages offered by polycentric systems in terms of efficiency, and innovation in program delivery (e.g., Cole, 2011) entails the exploration of the presence of polycentric systems functioning in mitigation and adaptation practices. While Homsy and Warner (2014) fail to find support for polycentric models of implementation of a broad suite of environmental sustainability practices, they assess polycentricity by way of a series of attributes that have been associated with or have the potential to facilitate polycentric systems (e.g., population growth, homeownership rate, metro status). This is a very different approach than undertaken here, in which we empirically assess the presence or absence of polycentric attributes in a selection of existing mitigation and adaptation programs using a recently developed model (Carlisle & Gruby, 2017).

An advantage of the Carlisle and Gruby model is that it seeks to clarify the institutional properties that necessitates or facilitates the achievement of the functionality of a polycentric governance system with two definitional attributes and seven enabling conditions. While thus providing a tractable approach for assessing the degree of polycentricity in a given system, the complexity and multiformity of polycentricity as a concept suggests that systems unable to meet one or a few of the criteria listed in the model could still be considered being polycentric, at least to a moderate level, as long as they possess multiple overlapping semiautonomous decision-making units interacting with each other in a competitive and cooperative manner with resources to resolve potential conflicts by Carlisle and Gruby (2017).

Methods

Our analysis undertakes a two-step approach. First, we assemble a database of mitigation and adaptation practices in the built environment from governmental documents, the peer-reviewed literature, and professional reports. Next, we evaluate three short cases to explore the compatibility of a polycentric model of governance with existing efforts to address climate change mitigation and adaptation in the built environment.

Identification of Practices

Online research methods (ORMs) have been long aiding research practice in social science as well as in other major disciplines (Benfield & Szlemko, 2006). The primary function of ORMs is collecting and analyzing data through digital tools and processes (Borgman, 2010) due to its advantages of "lowered cost, ease of data entry, and flexibility in format" (Granello & Wheaton, 2004, p. 387). For the purpose of

this analysis, we assembled our database of mitigation and/or adaptation practices in the built environment using documents and information contained on individual websites returned through targeted Internet searches between April and May 2017. The keywords of the search process include "built environment," "practice," "design," "technology," "green buildings (neighborhoods)," "climate change," "mitigation," "adaptation (adaptive)," "sustainability," "smart growth," "GHGs," "climate(eco)-friendly," "innovation," and their combinations. Searches were halted at practice saturation, or when review of additional sources yielded no new practices. To ensure completeness, results were compared against previous analyses of sustainability and climate change efforts in cities and municipalities, as well as the datasets consulted therein (Kalafatis, 2017; Wang et al., 2012).

In all, our search yielded a total of 154 practices (Appendix A in supporting information). Once a practice was identified, it was placed into one or more categories related to the spatial extent of the activity: building, neighborhood, city, region, state, and federal. Practices were then coded for Aggregated Practice Category, Lead Administrative Entity, Lowest Level Decision Maker, Direct Mitigation Effect, and Direct Adaptation Effect. Definitions of the different categories used to code, as well as relevant examples, are included in Table 1. An initial code book was developed and assessed against a subset of practices to gauge its effectiveness. Revisions were made to address inconsistencies, redundancies, and gaps in coverage. Practices were then coded separately by the study authors and then compared to identify any differences in coding selection. In all categories, inter-rater reliability was found to exceed commonly accepted thresholds for satisfactory agreement (Table 1). In those few instances where there was a divergence between coders, the practice was discussed and agreement reached on the most appropriate response.

Identification of Cases

The literature and other sources consulted in this analysis contain multiple examples of programs to encourage climate mitigation, adaptation, or both in the built environment. We explore our third and final research question through a brief review of three programs to achieve mitigation and/or adaptation in the United States. The selection of cases is guided by three criteria. First, we sought variation among the cases so as to increase the relative strength of the evidence provided (see, e.g., Sovacool, Axsen, & Sorrell, 2018). We deliberately chose three programs designed for different purposes, with one for mitigation (AllianceNRG), one for adaptation (South Carolina Safe Home), and one for both (Rebuild by Design), so that we are able to investigate the presence of polycentric attributes across programs for different purposes. Second is program operational level. The multiscaled nature of a polycentric governance arrangement necessitates the consideration of the role of operational scale or scope. Here, South Carolina Safe Home operates at the state level; AllianceNRG operates at the subnational, regional interstate level; Rebuild by Design operates across the country. Such a mix enables us to gauge the presence of polycentric attributes across different operational scales. The third criterion is the general approach or business model, ranging from financing (AllianceNRG), to grant (South Carolina Safe Home), to research-based, design-driven problem-solving (Rebuild by Design). Though such selection may not capture the full spectrum

Table 1. Overview of Practice Coding Options

Category	Practice Coding Options	Kappa
Aggregated Practice Category: The generalized mode of effect by which a given practice operates	• Appliance/fixture selection • Financial support • HVAC design/operation • Information provision • Infrastructure development/management • Material selection/installation • Performance management • Planning • Research and development • Site design/maintenance • Site selection • Standard setting • Structure design/maintenance • Utility design/operation	0.861
Lead Administrative Entity: Organization with authority over what an activity is, what it includes, or how it can be implemented	• Agriculture/interior dept. • Codes/inspections • Commerce dept. • Emergency management • Energy dept. • Environmental protection • Housing/urban development • Labor dept. • NGO/community organization • NOAA/climate dept. • Occupational safety/health • Planning dept. • Private sector • Public works • Transportation dept. • Utility	0.778
Lowest Level Decision Maker: Most disaggregated entity possessing authority to institute a practice	• Administrative staff • Builder/owner/occupant • Community group • Elected leadership • Independent business • NGO staff • QUANGO staff	0.741
Direct Effect—Mitigation: The mechanism by which a given practice achieves mitigation objectives	• Distributed generation • Energy efficiency • Reduced GHGs • Reduced energy load	0.923
Direct Effect—Adaptation: The mechanism by which a given practice achieves adaptation objectives	• Resilience—drought • Resilience—flood • Resilience—pest/disease • Resilience—temperature • Resilience—wildfire • Resilience—wind	0.858

Note. Also indicated is inter-rater reliability measure (Cohen's kappa) for each category.

of services provided, they are nevertheless indicative of the multitude of efforts in the built environment, providing insight into the attributes of different governance arrangements.

Following presentation of the cases, we employ a model developed by Carlisle and Gruby (2017) to examine the presence or absence of key enabling conditions in each program reviewed. The Carlisle and Gruby (2017) model consists of two basic definitional attributes with seven additional enabling conditions to specify the characteristics of a functional polycentric governance system. An advantage of the model is that

Table 2. Application of a Functional Polycentric Governance System Model to Climate Change Mitigation and Adaptation Practices in the Built Environment

Attribute	Enabling Condition	Compatibility with Mitigation and Adaptation Activities	Observed Practice Evidence
Multiple, overlapping decision-making centers with some degree of autonomy	Decision-making centers employ diverse institutions	√	Representation across aggregated practice categories
	Decision-making centers exist across political jurisdictions	√	Co-occurrence of specific lead administrative entities and specific practices at multiple spatial scales
	Scope of authority is coterminous with boundaries of problem	√	Variation within list of lead administrative entities at different spatial scales
Actions take into account others through processes of cooperation, competition, conflict, and conflict resolution	Generally applicable rules and norms structure behavior	√	Presence of regulatory provisions, regulatory bodies, and elected leadership across lead administrative entities and aggregated practice categories
	Cross-scale linkages or other mechanisms for deliberation and learning	√	Co-occurrence of specific lead administrative entities and specific practices at multiple spatial scales
	Mechanisms for accountability exist within system	√	Presence of elected leadership, administrative staff, and nongovernmental lead administrative entities at multiple spatial scales
	Formal and informal mechanisms for conflict resolution exist within system	√	Presence of elected leadership, administrative staff, and nongovernmental lead administrative entities at multiple spatial scales; presence of regulatory provisions at multiple spatial scales

Source: Adapted from Carlisle and Gruby (2017).

it simplifies many of the complex concepts implicit in polycentric system scholarship into a tractable approach for the empirical evaluation of the presence or absence of polycentric attributes in a given system.

Achieving Mitigation and Adaptation in Practice

We assess our practice-based dataset against our first question that mitigation and adaptation practices are compatible with a polycentric model of governance. To do so, we adopt the Carlisle and Gruby (2017) model to explore the contextual applicability of a polycentric model to the implementation of climate change mitigation and adaptation practices at multiple scales in the built environment (Table 2). The first attribute of polycentric systems identified by Carlisle and Gruby (2017) is the presence of multiple decision-making units with some degree of independent authority and overlap. This attribute is itself achieved through the presence of multiple enabling conditions. The first is that decision-making centers employ diverse institutions. In our analysis, this condition is met by the presence of multiple and varied aggregated practice categories, ranging from regulatory, command-and-control approaches, to approaches that employ incentives or information provision to achieve some practice outcome (Figure 1). Institutions, consisting of formal and informal rules, norms, and shared strategies, can be defined as a set of constraints collectively adopted by a group of individuals or organizations to structure their political, economic, and social interactions (Hall & Taylor, 1996; North, 1991; Ostrom, 2005). Individual policy instruments can be considered to be derived from such formal rules and are therefore representative of broader institutional context. In addition, the different entities implementing such policy instruments are again indicative of institutional diversity in the built environment.

The requirement that decision-making centers extend beyond political jurisdictions is satisfied in our analysis through the existence of specific lead administrative entities (e.g., public works, state or federal transportation department, state or federal environmental protection agency) and mitigation and adaptation practices (e.g.,

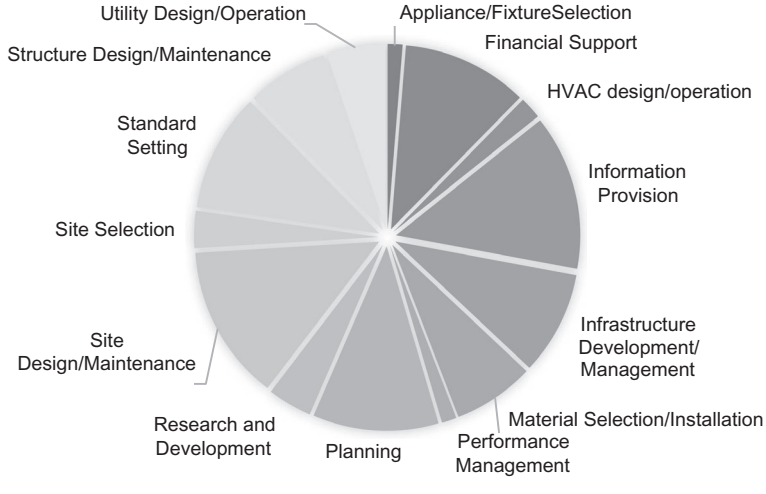

Figure 1. Allocation of Practices by Aggregated Practice Category ($n = 154$)

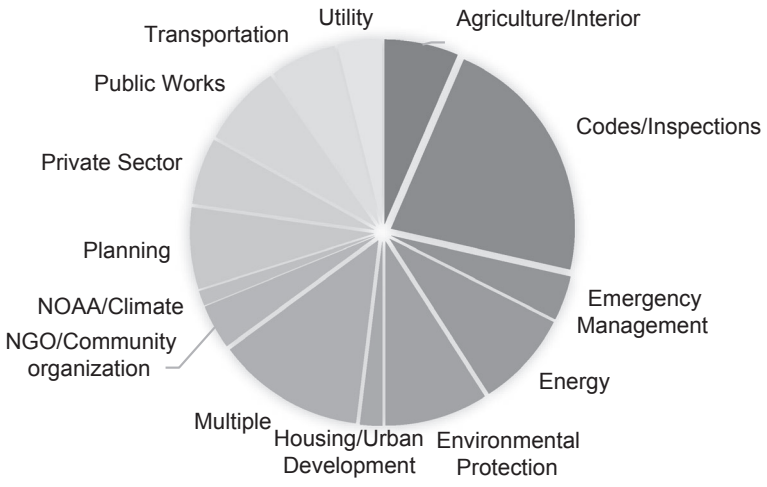

Figure 2. Allocation of Practices by Lead Administrative Entity ($n = 154$)

weatherization programs, transportation planning, practice certification) at multiple scales (Figures 2 and 3). Finally, the scope of authority must align with the spatial scale of the problem the practice is trying to address. In our analysis, this is implicitly supported by variation in lead administrative entities identified at each spatial scale (Figure 3). Though, as above, there is some overlap across spatial scales, there is also substantial variation; codes and inspections play a more prominent role at the building and neighborhood scale, while mission-oriented agencies (e.g., environmental protection, agriculture, energy) play a larger role at the state and federal levels.

A second attribute of polycentric systems is the presence of multiple actors functioning as a system, taking into account the actions of others in making decisions or working on tasks (Carlisle & Gruby, 2017). Again, this attribute is a function of several

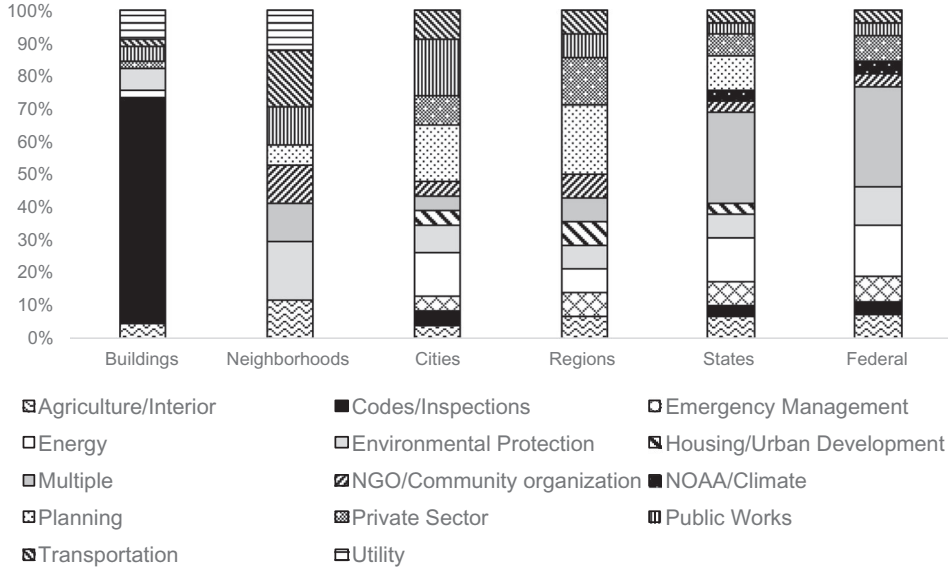

Figure 3. Practice Lead Administrative Entities Allocated by Spatial Scale

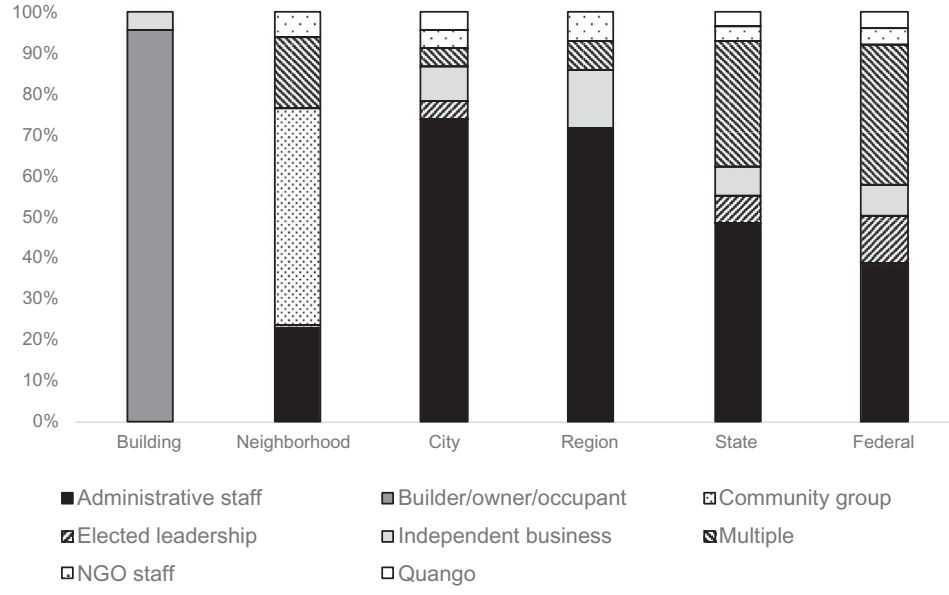

Figure 4. Practice Lowest Level Decision Maker Allocated by Spatial Scale

underlying enabling conditions. The first is that the system is bounded by generally applicable rules and norms. This is identifiable in the presence of multiple regulatory bodies (e.g., codes and inspections) and provisions (e.g., water use restrictions, density requirements) throughout our list of practices (Figures 1 and 2). Also required are cross-scale linkages, which we suggest is supported in the co-occurrence of specific entities and practices at multiple spatial scales (Figures 3 and 4). In many ways, this is similar to (and implicit in) the existence of cross-jurisdictional decision-making bodies discussed immediately above.

Another enabling condition is the presence of mechanisms to ensure accountability. For this condition, we use the presence of elected leadership (e.g., mayors, city council, Assembly, or Congressional representatives), agency administrative staff, and nongovernmental organization staff to indicate the presence of either direct (i.e., elections) or indirect (i.e., public information campaigns) means to achieve political accountability (Figure 5). The wide array of administrative entities identified in our practice database can also contribute to accountability, as the participation of a multitude of players within a given sector can reduce the probability of abuse as each actor has limited power (e.g., Ostrom, 1999). In addition, the dispersal of decision-making units, instead of confusing citizens with multiple lines of authority, may actually enhance the system's accountability as it creates more venues for citizens and officials to correct misconduct (Ostrom, 2010a). It likewise makes it more difficult for parochial interests to control multiple levels of governmental authority than just one (Carlisle & Gruby, 2017; Sovacool, 2011). Finally, there must be mechanisms for conflict resolution. Again, we rely on the presence of regulatory provisions, administrative staff, and elected political leadership at multiple spatial scales (Figure 4). Though the simple presence of these attributes does not guarantee the availability of mechanisms for conflict resolution, such mechanisms are oftentimes implicit in provisions guiding

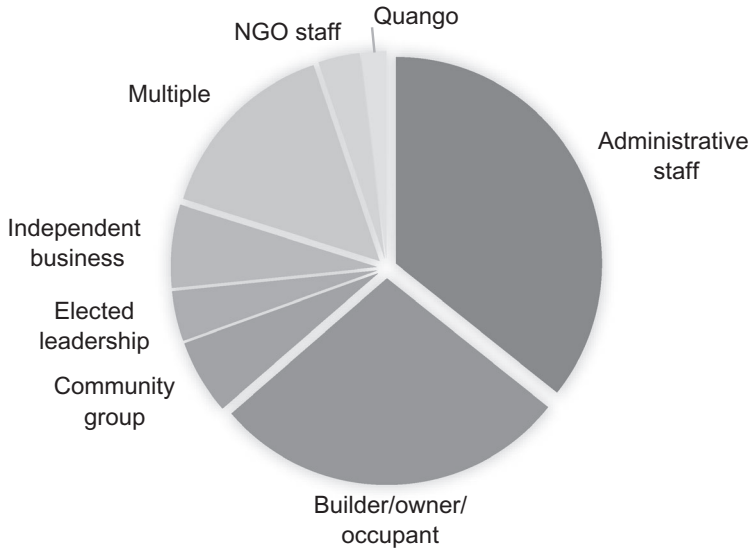

Figure 5. Allocation of Practices by Lowest Level Decision Maker (n = 154)

the content and process of regulatory proceedings and the behavior of public staff and their leadership.

The Polycentric Attributes of Individual Programs

In the following section, we assess the polycentric attributes of three separate programs targeted to achieve mitigation and/or adaptation in the built environment. We first provide a detailed introduction of each program, providing information on their origins; administrative entities in charge of implementing, program design, operational scales, services provided, and operational processes; as well as their achievements. We then evaluate their performances with respect to polycentric governance arrangements. Following presentation of the cases, we return to the model developed by Carlisle and Gruby (2017) to examine the presence or absence of key enabling conditions in each program reviewed. We note that the selected programs are by design operating at different scales. Maintaining a consistent scope of analysis in our review of polycentric attributes is thus challenging. The programs reviewed nonetheless provide a sense of the variety of conditions present and the possible directions for future research.

AllianceNRG Program—The AllianceNRG Program is a national Property Assessed Clean Energy (PACE) financing program launched in 2015 for mitigation and adaptation practices in both residential and commercial properties (Association of Bay Area Governments, 2015; PACENation, 2016). It is currently under the joint administration of Leidos Engineering and CounterPointe Energy Solutions. It runs as a national funding platform for up to 100% financing in energy efficiency, structural reinforcement, and renewable energy products and is now available in Florida, California, Louisiana, New Jersey, and Connecticut (PACENation, 2016).

Different from loans, which usually finance hard costs of construction, the AllianceNRG Program also covers soft costs (e.g., permits, inspections, service

contracts) with fixed interest rates for up to 30 years. It functions through a tax assessment levied by the local government with self-amortizing terms that match the lifetime of the upgrades (no down payment required) (AllianceNRG, 2017). As a PACE program, the AllianceNRG serves as a public–private partnership in improving communities' resilience against climate change-induced pressures, incorporating efforts from local governments, code and inspections, private business, independent contractors, and property owners. Due to its direct impact on the local environmental advancement, its potential positive impact on the local economy by creating more jobs and demands for construction projects, and its sharing of local governments' liability in service delivery (AllianceNRG, 2017), the program is gaining increased popularity from local governments (CounterpointeSRE, 2018).

In the specific instance of the AllianceNRG program, cooperation among multiple actors at different scales and potential competition from other actors due to the presence of similar programs (e.g., subsidies for energy efficiency from public and private entities) are both conducive to a polycentric governance system, yet the multiplicity of actors may not necessarily guarantee the institutional diversity of this system, given the program's reliance on a single approach (financing) and its private entity-based management. In this situation, the condition of Decision-Making Centers Employ Diverse Institutions may not be satisfied, which may further curtail its adaptive capacity. The relevance of, and mechanism by which, conflict resolution mechanisms are developed is also uncertain. For instance, the Federal Housing Finance Agency (FHFA) alerts that the program should be positioned secondary to the first-lien status of Fannie Mae and Freddie Mac mortgages (Brinkmann, 2017; FHFA, 2014). Finally, cross-scale linkages or other mechanisms for deliberation and learning are unclear, as we are unable to assess whether structured and effective communication among actors involved are developed within this system, which is again important for the system's adaptive capacity (Carlisle & Gruby, 2017). The AllianceNRG Program thus possesses many, but not all the conditions of a polycentric governance arrangement. The lack of the three conditions necessary for the development and enhancement of a governance system's adaptive capacity may hamper achievement of the theoretical advantage of a polycentric governance arrangement in effectively adjusting its responses to the complex and changing environment.

South Carolina Safe Home—The South Carolina Safe Home program was established to finance low- and middle-income homeowners in coastal counties with grant money to fortify their properties and to provide discounts or credits on insurance policies for retrofitting projects (Domingo, 2011). The program was initiated and administrated by the South Carolina Department of Insurance from 2007 and was ended in the fall of 2014 due to the redesign of the application process. In 2017, the SC Department of Insurance announced that they expected to reopen the program in the fall of that year. Currently, the program remains closed due to the overwhelming number of applications. As a state-funded grant program, it was fueled by 1% of the state's annual tax collections on insurance premiums, plus 1% on Wind Pool policies, which together add up to approximately $2 million each year (Slade, 2017). During

its operation, more than $17 million in grants were awarded to 3,700 homeowners across all eleven coastal counties (FEMA, 2015).

The qualification process requires homeowners' active insurance policies, guaranteeing a certain level of financial resilience against damaging effects. The South Carolina Safe Home program was also credited for developing community-level resilience by offering educational outreach, which could benefit the community in the long run as participants would continue to improve their household resilience even after the retrofit projects were finished, and those who were not eligible for the program might be encouraged by their neighbors to upgrade their homes on their own (FEMA, 2015).

In the instance of the South Carolina Safe Home program, a multitude of decision-making centers, including the state legislature, the South Carolina Department of Insurance, insurance companies, and applicants (homeowners) are collaboratively developing community resilience in South Carolina's coastal counties. The presence of elected officials, administrative agencies, and private entities, as well as the co-provision of financial incentives and educational supports, ensure the institutional diversity, the availability of generally accepted rules and norms, and the mechanisms for accountability of its governance arrangement. The condition of possessing cross-jurisdictional decision-making units, however, is uncertain in our analysis as the program follows a relatively hierarchical arrangement where the state-level agencies dominate its governance with the cooperation of county-level efforts. Whether there is a special arrangement designed for the eleven coastal counties is also unclear, requiring further analysis.

The presence of cross-jurisdictional decision-making centers is important for dealing with environmental challenges, as such challenges oftentimes extend beyond jurisdictional boundaries. Cross-jurisdictional decision-making centers alone may not be able to guarantee the expected institutional fit, however, which also requires the compatibility between the decision-making centers' jurisdictional scope and the spatial boundaries of the challenge of concern ("scope of authority is coterminous with boundaries of problem"). As the South Carolina Safe Home program was designed to enhance resilience against severe weather in South Carolina's coastal counties, the institutional arrangement of this program may be assumed to accomplish the desired outcomes. The uncertain presence of cross-jurisdictional decision-making centers and the relative homogeneity of the target groups (coastal counties) may still pose challenges on the development of cross-scale linkages and/or other mechanisms for deliberation and learning. Further, the dependence on state administration for processing applications, as well as on grant money as a funding source, may challenge the program's capability in handling the high demands from the public. As such, programs specifically designed to operate at certain jurisdictional levels may need further deliberation and careful crafting to ensure institutional fit and preservation of internal adaptive capacity.

Rebuild by Design—Hurricane Sandy called for a rethinking on and redefinition of the community resilience development from all sectors, especially policy makers. To improve future response, preparedness, and resilience, the U.S. Department of Housing and Urban Development (HUD), as well as a number of nonprofit, academic, and philanthropic organizations, jointly launched the Rebuild by Design

program in 2013 as a multistage planning and design competition (HUD, 2014; Rebuild by Design, n.d.). Specifically, the competition sought to find local, flexible solutions for regional adjustment to reduce the vulnerabilities to future challenges (HUD, 2014). As a policy innovation, the competition is now a model for public service providers to develop collaborative systems based on research in rebuilding community resilience (Rebuild by Design, n.d.).

The Rebuild by Design program begins by pairing selected experts with those who have the best knowledge of a community to develop regionally specific building projects to enhance resilience. Next, a series of collective efforts are made through site visits, conversations, and research projects—including discussions, symposiums, and workshops—to identify potential challenges. This process helps uncover vulnerabilities and interdependencies within and among communities. After problem recognition, a collaborative design seeks to ensure that final deliverables are feasible, knowledgeable, and innovative.

Thus far, the program has built a partnership with one hundred cities worldwide to prepare the globe for future challenges (Rebuild by Design, n.d.). In this program, the cooperative nature of a polycentric governance system is represented by the collective efforts from a multitude of participants. Specifically, the collaboration of governmental, private, and nonprofit actors under the overlapping purview of multiple (independent) governing units at diverse scales and the diversity of program deliverables together satisfy the condition of decision-making centers employing diverse institutions, which may further imply the presence of generally applicable rules and norms as well as the establishment of mechanisms for accountability. The flexibility of the program design in fitting different special scales and contexts, the competition among different projects with shared knowledge and inputs, and the participation of governmental agencies may also facilitate the development of cross-scale learning and deliberation as well as the mechanisms for conflict resolution. The fulfillment of the aforementioned conditions ensures the adaptive capacity of the governance system of the Rebuild by Design program in dealing with changes in its operating environment. Furthermore, the pairing of selected experts with those who specialize in local knowledge and the involvement of governmental and academic actors for a specific concern at a given yet flexible spatial extent ensures institutional fit so that desired outcome can be effectively accomplished (Carlisle & Gruby, 2017). As such, the Rebuild by Design program appears to align with the features of a polycentric governance system.

As with individual practices, the individual cases reviewed above can be mapped to the attributes and enabling conditions identified by Carlisle and Gruby (2017) (Table 3). For example, the AllianceNRG program possesses multiple and varied cross-jurisdictional decision-making centers, as well as the general applicable rules and the mechanisms for accountability. The South Carolina Safe Home program demonstrates an involvement of diverse institutions as decision-making centers and a variation in those institutions at different levels. Also, the collaboration among state-level regulations, local efforts, and private companies signals the presence of general applicable rules and the mechanisms for accountability. The Rebuild by Design program, with its relatively larger scope of operation and flexibility in the program design, appears to possess all the features of a polycentric governance system. In this

Table 3. Application of a Functional Polycentric Governance System Model to Reviewed Climate Change Mitigation and/or Adaptation Programs affecting the Built Environment

Attribute	Enabling Condition	Program		
		AllianceNRG	South Carolina Safe Home	Rebuild By Design
Multiple, overlapping decision-making centers with some degree of autonomy	Decision-making centers employ diverse institutions	–	+	+
	Decision-making centers exist across political jurisdictions	+	O	+
	Scope of authority is coterminous with boundaries of problem	+	+	+
Actions take into account others through processes of cooperation, competition, conflict, and conflict resolution	Generally applicable rules and norms structure behavior	+	+	+
	Cross-scale linkages or other mechanisms for deliberation and learning	o	–	+
	Mechanisms for accountability exist within system	+	+	+
	Formal and informal mechanisms for conflict resolution exist within system	–	–	+

Notes A "+" indicates that a given program possesses a given condition, "o" indicates the qualified or uncertain presence of a given condition, and "–" indicates the absence of a given condition. Attributes and Enabling Conditions adapted from Carlisle and Gruby (2017) .

situation, we may see that all three programs convey the fulfillment of the conditions of the match between the scope of decision-making centers' authority and the boundaries of problems of concern, the availability of generally applicable rules and norms, and the presence of mechanisms for accountability. At least a certain level of institutional fit can be expected from these three programs, even though the presence of cross-jurisdictional decision-making centers is uncertain in the South Carolina Safe Home program. The lack of evidence in demonstrating the institutional diversity in the AllianceNRG program, and of mechanisms for cross-scale learning and deliberation and conflict resolution in both the AllianceNRG program and the South Carolina Safe Home program, may impede achievement of the adaptive capacity that might otherwise be found in polycentric governance systems. Compared to programs operating at relative larger scopes (e.g., interstate, national, and global), programs designed to function within a certain jurisdictional level (e.g., state and municipal) may have difficulties in possessing cross-jurisdictional decision-making centers and/or cross-scale arrangements for deliberation and learning.

Of the three programs reviewed, the only one to exhibit all seven enabling conditions is Rebuild by Design. This is not completely surprising owing to the nature of our selected cases. Programs specifically designed to operate at a particular scale (e.g., South Carolina Safe Home) or to operate through a particular mechanism (e.g., AllianceNRG) may face challenges to conforming with all seven conditions identified by Carlisle and Gruby (2017), however, chiefly through a lack of cross-scale linkages and multiple mechanisms for conflict resolution. Further research could assess whether such challenges hold beyond the few cases assessed here.

Failure to meet one or a few enabling conditions may not strictly disqualify a governance arrangement from being polycentric. Furthermore, the relative importance of any particular enabling condition may vary across different contexts. Also unclear in the context of our analysis is the extent to which the programs allow for operation at all relevant scales; each is necessarily geographically focused, and the relationships with entities and programs at larger spatial scales (e.g., federal) are unclear. AllianceNRG appears to allow for at least the potential for cross-scale linkages, but again is lacking in diverse conflict resolution mechanisms and is largely driven by a single model of operation (i.e., finance). Gauging the relative importance of different polycentric attributes, though of great importance and relevance, is difficult here given our limited initial scope. This, however, suggests directions for future research, so that a more comprehensive understanding of polycentric governance systems in the built environment can be pursued.

Conclusions

Addressing climate change at multiple spatial scales is of great importance, especially in the built environment, which accommodates a plurality of human activities and energy consumptions, as well as presents growing vulnerabilities against risks posed by a warming planet. In doing so, it is essential to evaluate the applicability of a polycentric model of governance to the implementation of mitigation and adaptation practices, as well as to identify the extent to which programs designed to deliver such practices exhibit polycentric attributes in the built environment. Relying on a

theoretical model of polycentric governance as operationalized by Carlisle and Gruby (2017), we did find that such an arrangement of governance is compatible with, and indeed present within, the implementation of climate change mitigation and adaptation practices in the built environment.

Though our focus is on the built environment, or more specifically on the U.S. built environment, our hope is to identify areas for broader research in examining the applicability and functionality of a polycentric governance arrangement outside the U.S. and/or across multiple sectors. Despite their applicability and presence in our reviewed cases, polycentric governance systems are neither the default nor the only solution in dealing with climate change in the absence of a comprehensive international arrangement. More comparative research is thus necessary to justify the relative strengths and limitations of different approaches, signaling a growing need for research that examines specific types and combinations of different practices, as well as the governance arrangements facilitating their implementation.

In reviewing a selection of existing programs for facilitating mitigation and/or adaptation in the built environment, the scope of our analysis prevented a more complete articulation of the relationships between entities and programs at larger spatial scales. A more in-depth investigation into the programs selected could better contribute to the examination of the role of polycentric systems in dealing with the climate change. Greater attention is likewise warranted on outcomes, in terms of success in facilitating both climate change mitigation and adaptation solutions, as well as the relative performance of practices themselves. A promising area of study is to gauge the relative potential of polycentric governance systems in facilitating mitigation and adaptation practices. For example, are systems which exhibit a greater number of polycentric attributes more conducive to facilitating mitigation practices or adaptation approaches, or are they more useful in facilitating joint solutions instead of promoting a particular type? Further, of the seven enabling conditions against which polycentric systems are assessed, which is more important in improving its effectiveness (relative strengths and limitations) at different special scales? Though the present analysis represents an exploratory attempt to shed light on questions such as these, further theoretical and empirical work is necessary.

About the Authors

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