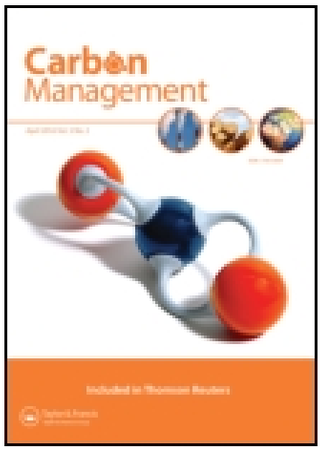

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Urban carbon governance and the transition toward low-carbon urbanism: review of a global phenomenon

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Urban carbon governance and the transition toward low-carbon urbanism: review of a global phenomenon

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This paper reviews the literature on urban carbon governance, which has become a burgeoning area of research. Since the early 1990s, the field has grown and diversified geographically, theoretically and methodologically, and now encompasses a wide range of topics, including governing techniques, limitations and challenges, central-local relations, municipal networks, network governance and grassroots initiatives. Given the increasingly global nature of low-carbon urbanism and governance, these studies have expanded our knowledge on the complexity and plurality of the role of cities in addressing climate change. This review serves as a consolidated guide for researchers, policymakers and students in this field.

Keywords: urban carbon governance ■ climate change ■ energy

Introduction

The relationship between cities and climate change significantly influences the sustainability of the global environment. Cities are vulnerable to heat waves, sea level rises, extreme weather events and other predicted impacts of climate change [1]. Urban vulnerability to climate change is likely to be greater in the cities of developing countries because of rapid population growth and deficient infrastructure, services and capacity for adaptation [2]. Cities also account for the majority of global energy consumption and greenhouse gas emissions [3,4], and consequently, many low-carbon policy responses are deployed in an urban environment. Furthermore, cities are spaces in which new ideas, new understanding and new ways of approaching problems are developed and tested [5]. A recent international survey by Broto and Bulkeley [6] has found that urban actors, rather than national or international actors, are the most active participants in carbon governance in terms of experimenting with new policy responses. Indeed, commitment toward low-carbon urbanism has grown from a regional phenomenon in the 1990s, limited to a small number of European, Australian and North American cities, to what is now a full-fledged global phenomenon. Evidence of low-carbon urbanism can be found in both the great cities that come to dominate the global economy and the impoverished and marginalized urban areas in some of the poorest countries in the world. Given the repeated failure to reach comprehensive agreements at the international levels, scholars and practitioners are increasingly turning their attention to the activity of cities for meaningful climate change action [7,8].

Corresponding to the globalization of low-carbon urbanism is the emergence of urban carbon governance as a field of study. The way urban governance meditates the relationships between cities, energy and climate, to what degree, in what area, in what form, with what effect and for whose benefit are ongoing subjects of scholarly debate that will be repeatedly visited in this review. What can be certain, however, is that this subfield of climate change governance is growing rapidly and that recent works have become more complex and differentiated geographically, theoretically and methodologically. Geographically, while earlier research mainly investigated a handful of pioneering cities, such as Toronto [9], Newcastle in Australia [10] and Chicago [11], more recent works have examined global metropolises such as Tokyo [12] and Hong Kong [13] and

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cities in developing countries such as Mexico City [14], Cape Town [15], São Paulo [16], Mumbai [17] and Abu Dhabi [18]. Theoretically, a diverse set of perspectives and frameworks has contributed to the understanding of urban carbon governance, such as the actor-network theory and governmentality [19], the implementation theory [20], the urban regime theory [21] and many more. Methodologically, the growing popularity of cross-national or global surveys and comparative research [e.g., 6,16,22,23] has advanced our understanding of the ways in which the differences in local, regional and national contexts influence the carbon governance process. Moreover, quantitative studies, by testing falsifiable hypotheses with statistical methods, have helped clarify the causal factors of urban carbon governance. Overall, this voluminous body of literature points to the multiplicity of localities, actors and relations through which carbon and energy are governed in cities. This critical review of the literature on the governance and politics of low-carbon urbanism examines four areas of work that have dominated the field:

- governing techniques
- limitations and challenges
- multilevel governance
- grassroots initiatives

Each of these themes will be addressed in detail in the following sections, which are followed by a conclusion and recommendations for future research.

Governing techniques

Turning first to the multitude of governing techniques employed by municipal governments to achieve desired changes, recent studies have documented a degree of diversity that is unprecedented in the history of urban carbon governance. The focus on municipal governments in this field reflects the fact that, among urban actors, municipal governments play a key role in shaping the energy consumption and greenhouse gases emissions of cities in various capacities (e.g., as service providers, major employers, community leaders, campaigners, regulators, planners, developers and landlords).

Ruminating on her survey results of local governments in the Pacific Northwest, Rice noted that:

> local action on climate change favors public targets and private choice – that is, cities are more likely to make policy changes that affect public infrastructures and buildings, while providing incentives and educational campaigns for individual residents and businesses to change their own behaviors. [24, p. 9]

Rice's research and many studies before hers [e.g., 5,25,26–29] agree that municipal governments around the world tend to rely mainly on two governance techniques to achieve their low-carbon objectives. The first technique is self-governing, that is, the control of direct carbon emissions from government facilities and operations. Common examples include installing light-emitting diode (LED) lights in street lamps and traffic lights, enhancing building energy efficiency, deploying renewable energies and procuring green vehicles such as electric and biofuel cars [30]. Local governments may also engage in voluntary carbon offset markets, purchasing credits from emissions reduction projects to further reduce their net emissions. For example, the City of Melbourne achieved carbon neutrality for the financial year of 2011–2012 after purchasing 44,220 t CO_2-e of offset at an average cost of AUD $5.07/t CO_2-e. The self-governing approach to carbon control is relatively simple to implement and provides the benefits of good financial return and publicity. However, given that municipal operations only account for a very small proportion of total emissions, self-governance must be accompanied by other governing techniques that are oriented toward the wider society [26].

The second governing technique is governing through enabling, defined as the provision of financial, technical and educational assistance to businesses and individual citizens to voluntarily act on climate change [26]. Again using Melbourne as an example, the municipal government provides funding and legal information for low-carbon projects such as renewable energy and energy efficiency retrofits. This neoliberal approach to urban carbon governance is, however, not only about capacity-building and empowerment, but is also a strategy employed by governments to manage the conduct of their citizens (i.e., to encourage particular forms of behavior) [19]. At the same time, this governing technique imposes a particular worldview that serves to sideline alternative approaches to low-carbon urbanism. Therefore, governing through enabling not only enables but also constrains local action on climate change [19].

While self-governing and governing through enabling are the most common governing techniques used by municipalities to achieve low-carbon urbanism, local governments have at their disposal two more governing techniques: governing by provision, referring to "*the shaping of practice through the delivery of particular forms of service and resource*," and governing by authority, meaning "*the use of traditional forms of authority such as regulation and direction*" [26, p. 2242]. Focusing first on the relationship between governing through enabling and the transport sector, municipal governments can influence transportation energy consumption and emissions by improving the provision of public transport.

Many cities, especially in developing countries, are rapidly developing their urban rail systems. In China, for example, 10 cities already have metro systems, and an additional 23 cities have formulated plans under the support of the 4-trillion-RMB stimulus package designed to combat the 2008 financial crisis [31]. For the less financially endowed cities, bus rapid transits, which give exclusive rights-of-way and signalization priority to buses, have emerged as a cost-effective option. Bus rapid transits have become a central component of transit systems in many cities, including Bogota [32], Istanbul [33], Addis Ababa [34], Seoul [35] and Guangzhou [36]. Another measure to decarbonize urban transport is the promotion of cycling. A recent survey of 13 cities in Europe, Australia and America found that all cities have taken significant steps towards promoting cycling by investing in cycling infrastructure [37]. Furthermore, public bicycle programs (also known as bike-sharing) are rapidly gaining popularity [38]. By 2009, there were approximately 120 programs globally, with the demand for bike-sharing the greatest in Europe [39]. However, the environmental and economic sustainability of bike-sharing is unclear, mainly because of the redistribution problem: bike-sharing systems are often dominated by asymmetric flows which mean that operators must regularly move bicycles from highly loaded stations to empty ones – a process that is both expensive and polluting [39,40].

In addition to mobile sources of emissions, local governments also wield significant influence over emissions from urban infrastructure and buildings. One possible approach is the provision of clean energy locally. Decentralized technologies and "*post-networked urbanism*" are viewed by many activists, experts and policymakers to be more sustainable and climate friendly than large-scale centralized infrastructure [41]. An example is Woking, a commuter town southwest of London. In the late 1990s, the council established its own energy company, Thamewey Energy, to build and operate a number of highly efficient combined heat and power units, each equipped with its own private wire and heating network. The project was an economic and environmental success, and it inspired London to support the deployment of decentralized energy with a target to supply 25% of the city's energy from local sources by 2025 [41].

Municipal governments may also use governing by authority measures to control local transport emissions. A number of German cities, including Berlin, Munich, Frankfurt and Stuttgart, have introduced emission-based control zones of various sizes [42]. Vehicles that do not satisfy certain emissions standards are prohibited from entering these zones. Road pricing has been adopted to reduce car use in Singapore [43], London [44], Stockholm [45] and Milan [46]. However, road pricing is primarily used to tackle congestion rather than climate change. Consequently, its application is often limited to urban areas that experience serious congestion problems, and thus it has a limited effect on car use at the metropolitan level. Incidentally, some of the toughest car control measures are being implemented in Shanghai and Beijing, reflecting the severity of congestion experienced in these cities. Shanghai imposes a limit on the number of new license plates issued annually – 108,100 licenses in 2012, which is very restrictive considering that the population of the city is over 23 million. Beijing limits the number of new cars sold to approximately 20,000 every 2 months, using a lottery system to determine allocations. In the second round of allocations in 2014, there were a total of 2.74 million participants competing for 19,973 licenses, a winning rate of approximately 0.7%.

Urban planning and design is another critical area in bringing about a reduction in transportation emissions. A number of spatial factors are relevant, including residential density, diversity of land uses, pedestrian friendliness, destination accessibility and distance to transit [47]. In recent years, as noted by Atkinson-Palombo [48], discourses on sustainability, environmentalism, smart growth and new urbanism have begun to drive the practice and theory of planning away from sprawling development. Of particular interest is the concept of transit-oriented development, which seeks to maximize access to public transport and non-motorized transportation with centrally located bus or rail stations surrounded by high-density commercial and residential development [49]. Compact cities such as Hong Kong and Singapore are fine examples of transit-oriented development [50], but the trend is spreading internationally, even to many American cities with a history of low-density suburban land development [51–53]. However, the short-term impact of smart growth strategies on carbon emissions is limited, especially in sprawling cities. For example, in Denver, the proportion of the population using transit has continued to decline after the initiation of transit-oriented development, suggesting that the strategy has had little impact on the transport modal split [54].

The decarbonization of the building sector is also a key focus for local governments. It is increasingly common for local authorities to use building codes to promote or require the enhancement of energy efficiency and the use of renewable energy. Since 2003, an increasing number of local governments in the United Kingdom have implemented the Merton Rule, which requires new buildings to derive at least 10% of their electricity consumption from on-site renewable energy [55]. The success of the Merton Rule contributed

to the development of national energy building codes, which require all new buildings to be carbon neutral beginning in 2016. In the United States, 48 states and territories have implemented energy codes for commercial buildings and 49 have implemented energy codes for residential buildings. While some of the state code is based on outdated and ineffective energy efficiency standards, an increasing number of local governments are introducing stricter requirements [56]. San Diego fast-tracks the planning process from 24 months to 6–9 months for developments equipped with solar power systems capable of meeting at least half of the expected demand [57]. Despite the fact that significant progress has been made, several empirical studies have raised problems of poor implementation and lack of enforcement [58,59]. Another commonly cited limitation is the lack of attention with regard to embodied energy in construction materials (both initial and replacement), which can be significant when carbon-intensive materials are used [60,61].

A longstanding challenge in the building sector is the improvement of the energy efficiency of existing buildings. Despite the significant energy-saving potential identified in the existing housing stock [62], energy efficiency renovation is seldom applied on a large scale because of the presence of a number of barriers such as the high cost associated with renovation work, the undervaluation of distant payoffs and the problem of split incentives associated with rental housing [63,64]. A few pioneering cities have experimented with innovative approaches to this problem. Boulder, CO, adopted a carbon tax in 2007 and used the revenue to promote energy efficiency in homes and buildings [65]. In another pilot program, the city of Tianjin in China has been experimenting with a building-sector carbon-trading scheme since 2010 [66]. Under this involuntary cap-and-trade scheme, civil buildings and district heating suppliers are allocated mandatory energy consumption allowances annually. Regulated entities that do not have enough allowances must either make reductions or buy allowances from the market. Conversely, regulated entities with extra allowances can trade them or bank them for later use. To prevent too much price fluctuation, the government has put in place a price regulation mechanism by manipulating the number of tradable allowances in the market. However, the government has yet to specify penalties for non-compliance, and empirical research suggests that the regulators are reluctant to punish violators at the initial stage [66]. In another example, a large-scale energy efficiency retrofit of existing residential buildings is currently underway in the city of Changchun in China [67]. In this assertive approach, the government selects approximately 1000 apartment buildings to undergo energy efficiency renovation annually. In this government-led and funded model, the role of the homeowners is minimal. In fact, the program is compulsory, as once a building is chosen by the government to renovate, its owners do not have the right to refuse.

Limitations and challenges

The second key area of investigation focuses on the limitations and challenges of urban carbon governance. The main limitation centers on the fragmented approach to greenhouse gas mitigation and is based on the argument that the kind of urban carbon governance practiced in many cities does not constitute a radical shift away from the growth ethic and neoliberal environmental governance [24]. As argued in the previous section, municipal governments favor self-governing and governing through enabling over measures that may invoke political resistance, unless doing so provides strong local benefits. Urban carbon policies are found to be focused on low-hanging fruits – strategies that can be easily integrated with existing goals and policies. In essence, the concern is that despite many pledges and promises, too many cities are either doing nothing or engaging in symbolic action. Such problems are not limited to smaller cities or cities in developing countries but also apply to some of the elite global cities. For example, commenting on Hong Kong's climate change responses, Ng [13] argued that Hong Kong is taking a "*rather tokenistic approach in combating climate change*." As noted by Rice, the gulf between radical rhetoric and ambitious goals on the one hand, and weak responses on the other, has become apparent:

> On one hand, cities present themselves as wanting to show leadership on climate change based on scientific consensus and economic co-benefits (suggesting ethical, environmental, and economic concerns), but their actual actions (via policy priorities and distribution of responsibility between public and private sectors) do little to prevent the climate catastrophes of carbon-centered economies. [24, p. 9]

Several large-scale and systematic surveys of municipal responses have attempted to put a figure on just how many cities have implemented effective low-carbon measures. Bedsworth and Hanak [28] surveyed 310 local governments in California, the leading state in the United States with regard to environmental policy. Their findings show that, by 2010, approximately three quarters of all jurisdictions had planned or completed carbon emissions inventories and climate action plans. This impressive adoption rate was mainly due to pressure from the state government. Nevertheless, less than half of the local governments had implemented their climate actions, indicating that many municipalities, even with the best intentions, fail to follow through on

their commitment on low-carbon urbanism. In another recent survey, also conducted in California, Millard-Ball [68] found little evidence that that climate action plans have had any causal effect on carbon emissions. Instead, climate action plans are largely "*codifying outcomes that would have been achieved in any case*" [68, p. 301]. Surveying American cities in the Pacific Northwest, Rice [24] found that only 22% of cities are (or are planning on) implementing road pricing policies, and only 33% of cities are (or are planning on) imposing mandatory energy efficiency standards on new buildings.

To understand the causes of urban carbon governance limitations, scholars turn to the key challenges municipal governments encounter in developing and implementing low-carbon policies. Politics, in particular the working of organized interests and concerned citizens, has been found to be a key factor influencing the urban carbon governance. Municipalities need to balance urban climate programs and diverse urban interests, which may support or oppose low-carbon interventions. To use the transportation sector as an example, local residents in the United States often resist transit-oriented development due to concerns over traffic, home prices and quality of life, particularly with relation to high-density construction and mixed-purpose zoning [69]. Community opposition is the primary reason for the termination of the San Francisco Bay Area project, including plans for the Rockridge, Ashby and North Berkeley stations of the Bay Area Rapid Transit system [70]. The public is also quite unreceptive toward road pricing. Attempts to introduce congestion pricing in Manchester, Edinburgh and many other European cities were unsuccessful due to strong resistance from local residents and businesses [45]. In London, the Western Extension was abolished in 2010 after the public overwhelmingly rejected the scheme [71]. No American city has successfully controlled automobile use through congestion charges [72]. New York City's proposal of congestion pricing failed to garner sufficient support in the State Legislature despite the fact that the vast majority of travel is not done with cars [73]. This suggests that a minority of powerful groups is sufficient to cause an initiative to fail. The effect of both supportive and oppositional organized interest is also meditated through the form of political institutions [74]. For example, in the American context, council-manager governments are more insulated from political pressure than mayor-council governments. The form of government also influences the approach to urban responses, with council-manager governments more likely to commit to self-governing techniques, whereas mayor-council governments are more responsive to the wider community [29].

Because climate change is conventionally perceived as related to problems of collective action between nation-states and supranational institutions, framing climate change as a local issue and bundling it with the existing set of policies can help municipal governments gain political support [14,19,20,75]. The goal here is to convince others that greenhouse gas mitigation is not only about contributing to a global public good but is also about "*solving problems locally and enjoying local benefits*" [75, p. 334]. It goes without saying that there are different framing and bundling opportunities based on differences in local contexts. While local officials in Portland, OR, ground their low-carbon initiatives in the discourse of smart growth, where energy efficiency is considered to be crucial to the health of the local economy and prevents the outflow of profits [19], the municipal authority of São Paulo, Brazil, bundles low-carbon initiatives with air pollution policies and uses the World Bank's Clear Air Initiative to simultaneously address both local pollutants and climate change [16]. In Shanxi, China, the local government has sought to bridge national priorities and local interests by integrating low-carbon projects with local campaigns of pollution control, safety supervision and the upgrade and restructuring of outdated production capacities [20]. To help municipalities leverage local priorities for greenhouse gas mitigation, Dulal and Akbar [76] proposed a policy framework that recognizes the "*coincidence of agendas*" between carbon reduction objectives and local priorities in urban development, urban transport, infrastructure and waste. Although the literature has convincingly demonstrated the importance of using local co-benefits to motivate carbon mitigation, it has also argued that localization may negatively affect the ability of local authorities to address climate change, especially in the context of developed countries [75,77,78]. Because the production of localized discourse is largely dominated by urban pro-growth coalitions, the end results serve to protect existing interests. This is an important criticism because the way in which climate change is framed is critical in determining how the issue is addressed, and the current situation tends to sideline radical solutions of climate change [79]. In short, localization is a double-edged sword that both helps local governments to overcome political resistance and restrains their options.

In addition to political conflicts, institutional capacity – the ability of local governments to achieve their objectives – can be a key barrier to urban carbon governance. A common problem is the mismatch between climate change and the bureaucratic structure of local government. As a cross-cutting environmental problem, climate change issues do not fit the organization of most municipal governments, which tend to be segmented into highly specialized departments with little cross-interaction [77].

In response, a number of municipalities have established a dedicated energy, climate or sustainability unit, either as a separate office or attached to a relevant department. In Portland, OR, for example, the Office of Sustainable Development was established to exercise broad authority over environmental issues such as waste management, recycling, energy and green buildings [77]. Nevertheless, the number of municipal governments that have undergone reorganization for the purpose of climate change remains small. In a survey of nearly 700 municipal governments, Bae and Feiock [29] found that only 25% have established a sustainability or climate office, and this institutional arrangement is causally linked to a higher rate of climate change policy adoption.

Power and authority also present institutional challenges to effective carbon governance. In some cities, the right of self-government is guaranteed by the constitution. In such cases, municipal governments have greater freedom to pursue low-carbon policies as they see fit [26]. In countries where the right is not guaranteed or is only partially guaranteed at the discretion of national or state/provincial governments, the policymaking and legislative power of municipal governments is defined and confined by higher levels of governments. In such cases, municipal governments may lack clear mandates in the use of certain policy approaches (e.g., regulatory and market-based instruments) and may even face legal obstacles if they wish to introduce some policies [80]. The scale of the issues presents another common challenge. Local governments' limited geographic jurisdiction often prevents them from pursuing certain policy options such as comprehensive urban development and transport planning [8]. Furthermore, urban responses may be obstructed or even contradicted by policies at other scales (e.g., regional and national). In Canada, for example, local initiatives on controlling automobile use are contradicted by a number of pro-road policies at the regional and national levels [81]. These studies show that it is difficult, if not impossible, for municipalities to achieve a substantial decrease in carbon emissions without strong measures at the national and international levels.

Another key challenge to urban carbon governance is the presence of financial barriers such as high upfront capital costs, perceptions of risk and legal constraints on borrowing [26,82]. Because of budgetary constraints, local governments have been faced with "*budgetary trade-offs for competing funds and potentially shifting public support for short versus longer term investments in public programs*" [30, p. 182]. Consequently, the cost of the transition to low-carbon urbanism is a factor because the cost may significantly vary across different cities. A recent survey conducted by Zahran *et al.* [83] showed that high-cost cities (i.e., industrialized cities with carbon-intensive energy systems) are less likely to commit to low-carbon transition. This finding is alarming because these cities are those that are most in need of carbon emissions mitigation.

Recent studies have shed light on the strategies adopted by municipal governments to ensure the financial sustainability of their policies. Sullivan and Gouldson [82] explored the financing of low-carbon policies in the United Kingdom context. Their findings highlight the importance of involving the private sector and institutional investors in financing low-carbon initiatives, due to the scale of investment required and local government budgetary constraints. However, financing low-carbon transformation is complex and risky to investors and local authorities alike. Of particular concern are changing interest rates and energy prices, miscalculation of scale, potential political backlashes and the reversal of public policy (e.g., emissions trading and carbon taxes). Municipal governments also look to other levels of government for funding. In her study of urban carbon governance in the United States, for example, Fisher [84] examined the coordinated effort on behalf of municipalities to secure funding from the federal government and how this represents a case of "*boomerang federalism*." However, the reliance on external funding further contributes to the development of patchwork responses, because funding opportunities are generally narrowly focused (e.g., to develop urban rail-transit) or attached to rare opportunities (e.g., sporting events, natural disasters, financial crises) [5]. For example, writing on their experiences from examining the case in Mumbai, Boyd and Ghosh [17] commented that a reliance on international funding (mainly through the Clean Development Mechanism) and the lack of an overarching climate change regime have resulted in a highly fragmented approach where none of the initiatives is connected to any others.

Multilevel governance

Turning now to the third theme, the framework of multilevel governance has proven to be a productive analytical tool in understanding urban carbon governance in relation to the governance dynamics at other scales and places. Multilevel governance originated from the theorization of the European Union as an emerging political system in the early 1990s [85]. The early definition of multilevel governance as "*a system of continuous negotiation among nested governments at several territorial tiers*" [86 p. 392] suggests that the concept is defined against the conventional hierarchical form of governance and focuses on understanding the dispersal of powers and competences to different levels of governments. Recently, multilevel governance has been linked to network governance, where transnational networks and institutions of interconnected public and private actors are playing increasingly important governing roles [87].

Normatively, this distributed form of governance is considered to be superior to centralized and hierarchical governance because it is more efficient, better reflects the heterogeneity of preferences among citizens, and facilitates innovation and experimentation [88]. Within this broad framework of multilevel urban carbon governance, three subthemes are apparent: intergovernmental relationship, transnational and regional municipal networks, and the partnership between urban public and private actors.

Scholars of urban carbon governance have drawn attention to the importance of national and regional governments in involving local authorities in climate governance. In a case study of the low-carbon transformation of Sydney, Australia, Dowling, McGuirk and Bulkeley [89] reported that an array of federal and state programs seek to encourage the adoption of retrofit technologies at the urban level, with the most common focus being the upgrade of government buildings and, to a lesser extent, households, businesses and community organizations. The authors conceptualize federal and state involvement as a case of "*governing at a distance*," meaning the indirect nature of this involvement and the reliance on soft measures to enable retrofitting rather than hard measures to mandate it [89]. The local authority of Sydney benefits from the involvement of higher level governments and demonstrates an even greater willingness and capacity to promote retrofitting [89]. Positive synergies between local and regional policies have also been found in some cities in the United States, where deep cuts in building sector emissions are made possible by local initiatives working in conjunction with statewide policies such as renewable portfolio standards [72]. Local governments in Sweden and Norway have also benefited from the tools and financial incentives made available by the national government regarding low-carbon transition [90–92]. Multilevel governance, in this sense, is important because, as mentioned previously, the institutional capacity of local governments often depends on the discretion of other levels of government.

Other researchers invoke the vertical dimension of multilevel governance mainly to note the lack of cooperative relationships among different layers of government. Studying urban carbon governance in three federal countries (Australia, Canada and the United States), Jones [23] found that municipal governments often operate in relative isolation from national and subnational governments, which provide little pressure or incentive for their municipalities to mitigate local emissions. This lack of cooperation between levels of government has compounded the difficulties local governments have in implementing climate change policies, and signifies "*a general failure by state/provincial governments to recognize the uniqueness of the 'city' in the broader context of climate change policy*" [23, p. 986]. On the other hand, many studies have argued that the absence of national leadership and the presence of inconsistent or inadequate national support do not always have a detrimental effect on urban carbon governance. Instead, the absence of national power in carbon governance creates a political space for urban policy entrepreneurs to develop subnational greenhouse gas mitigation strategies. This argument of national inertia as a driver for municipal action is most convincing in studies conducted in the United States where the federal government's stance towards climate change remains ambivalent [24,93–96] but has also been forwarded in studies in developing countries that are not required to act on greenhouse gas mitigation under the international framework, such as the city of São Paulo in Brazil [97].

Adding another layer of complexity to the debate, the latest studies from China have revealed that the central government is driving local low-carbon responses through the target responsibility system [98,99]. Under this system, the central government assigns territorial carbon targets to provinces and cities. Local officials are under contractual obligation to meet these targets. Failure to comply may lead to a negative performance evaluation and a temporary suspension of approval of investment projects. Empirical studies are inconclusive with regard to the effect of the target responsibility system. On one hand, Kostka and Hobbs [20] found that local officials in Shanxi province take a serious stance with respect to energy conservation by experimenting with novel low-carbon strategies. On the other hand, Lo [67] found that local officials in Changchun are uninterested in energy conservation and carbon control unless there are strong local co-benefits. The author also highlighted several problems with the target responsibility system, including the lack of reliable local energy statistics, weak targets and the use of energy intensity instead of absolute carbon emissions as policy objectives.

In the second subtheme, the emergence of transnational and regional municipal networks as a major player in urban carbon governance has captured the attention of many researchers. Examples of influential municipal climate networks include the Cities for Climate Protection program, the C40 Cities Climate Leadership Group, Energie-Cities, Eurocities and Climate Alliance [100–104]. From the governance perspective, these networks engage in both external governance activities, such as lobbying national and supranational actors and collaborating with other networks, and internal governance activities, such as building capacity, showcasing initiatives and facilitating the transfer of knowledge. While municipal networks do not have the authority as nation-states to engage in hierarchical control, Andonova, Betsill and Bulkeley [102] conceptualized three mechanisms through which

municipal networks exert their influence over member cities: information sharing, capacity building and rule-setting. Information sharing is central to many municipal networks, which serve as networking platforms for their members to meet and share experiences and contacts, especially through the construction and dissemination of best practices for policy intervention [105,106]. However, information sharing should not be understood as a neutral, apolitical process. Instead, it is used both externally as a form of political leverage and internally to direct constituents [102]. Governance through capacity building involves the provision of resources (e.g., finance, labor, technology, expertise) to enable action. Again, this is not a simple process of resource transmission but rather a critical means through which municipal networks steer member cities and their actions by supporting "*appropriate*" solutions. Governing through rule-setting consists of the establishment of a set of norms and rules intended to guide and constrain constituents. For example, to become a member of the Cities for Climate Protection (CCP) program, which is an outgrowth of ICLEI-Local Governments for Sustainability, a local government must adopt a resolution to control greenhouse gas emissions. Once inducted, the local government is encouraged to complete, at its own pace, five milestones: establishing an inventory baseline and business-as-usual forecast, adopting an emissions reduction target, developing a local action plan, implementing the plan, and monitoring progress and reporting results. It should be noted that the lack of coercive power on the part of municipal networks does not prevent municipal networks from making abiding rules, as long as the rule-making process is deemed legitimate by the members [106]. These three governing mechanisms are not mutually exclusive, and municipal networks often engage in several or all of the functions.

Empirical studies on member cities both confirm and challenge the role of municipal climate networks as governance actors. On the one hand, the tremendous growth in membership in the CCP program, Climate Alliance and other climate networks demonstrates the success of municipal networks in popularizing the climate change agenda. In California, for example, 28% of cities had joined the CCP program by the end of 2008 [107]. Although getting climate change onto the urban agenda is still several steps away from fostering effective low-carbon transitions, such action is instrumental for creating a norm of participation in the governance of climate change [106]. There is also significant evidence in support of the capacity-building function of municipal networks. Studies from cities in developing countries often emphasize the importance of joining well-resourced transnational municipal networks, because resources and experiences are more limited in these cities [14,15]. An international survey conducted by Broto and Bulkeley [6] shows a significant correlation between membership in municipal networks and involvement in urban carbon governance.

On the other hand, the impacts of municipal networks in promoting climate-responsible actions have been questioned. Surveys conducted among the constituencies of the CCP program often reflect a very low rate of undertaking the five milestones approach. In Canada, although more than 200 cities (including all major urban centers) have joined Partners for Climate Protection, a local iteration of the CCP program, a mere 1% of member cities have attained milestone five, and barely 7% have moved beyond milestone three [106]. Similar findings reported by Wang [107] and Rice [24] suggest that the majority of CCP constituents have failed to follow the systematic approach encouraged by the CCP program. Clearly, this poor performance is indicative of the limitation of the voluntary nature of participation and the non-coercive mode of governance in network settings [104]. Another problem with municipal networks is their reliance on abstracting lessons from successful examples and best practices that are created under specific contextual circumstances. By leaving out implementation details, the usefulness of municipal networks for knowledge transfer is limited [105]. In other words, municipal networks primarily serve to demonstrate what can be achieved, rather than how to make it happen. Members engage with networks primarily as a "*source of inspiration, recognition, and legitimation for particular interpretation about the responsibilities of local governments in relation to urban sustainability*" [105, p. 1093]. Scholars [e.g., 108] have also challenged the conventional view that municipal networks can exert influence over national policies through advocacy or leadership and demonstration effects.

Given the inconclusive results discussed above, it is difficult to draw any firm conclusion regarding the impacts of municipal climate networks. One complexity is the diversity in municipal networks. In a large-scale survey of American cities, Krause [109] found that CCP membership has a small to moderate impact on the local implementation of low-carbon action, but Mayors' Climate Protection Agreement (MCPA) membership shows no such effect. This is primarily because the MCPA program has no monitoring mechanism and facilitates little information exchange. Another complexity is that different cities may have different expectations and experiences. Examining three large transnational municipal networks in the context of European governance, Kern and Bulkeley [110, p. 316] reported that only a small number of core member cities, usually the founders of the networks, are active in the governance and strategic planning of the networks. Therefore, municipal climate networks are "*networks of pioneers*

for pioneers" [110, p. 329]. Resources can also be a factor, as not every city is able to allocate sufficient personnel or financial resources for participating in meetings and projects and consequently may perceive themselves to be excluded [111]. Bouteligier [101] further argues that while municipal climate networks often strive to become more inclusive to cities from developing countries, members from western industrialized countries continue to exercise more influence over the selection of best practices, the determination of the agenda and the choice of partners. This results in a "*poverty of influence*" among developing cities. Bouteligier's findings problematize the transfer of best practices and knowledge within a municipal network that produces and sustains inequality and tension between members of the network:

> The inequalities that result from differences in positions and power mainly relate to the (dis)ability to shape meaning and preferences and determine the agenda or the direction of the network. These inequalities are mainly caused by differences in access to knowledge, information and decision-making. When there is no or less access, there is also less ownership and less empowerment to put issues on the agenda. [101, p. 264]

Turning to the third subtheme, in addition to the emergence of networking cities, recent years have also experienced a proliferation of public–private policy networks in urban carbon governance. This type of horizontal multilevel governance, also known as network governance, is "*broader than government*" [112, p. 660] and refers to "*sets of formal and informal institutional linkages between governmental and other actors structured around shared interests in public policymaking and implementation*" [113, p. 1244]. With respect to urban carbon governance, local governments are increasingly dependent on other local stakeholders to establish legitimacy and overcome political obstacles [19,114–116]. Furthermore, partnership with private actors can help local authorities meet technical and financial challenges through fundraising, community engagement and the polling of collective knowledge, human capital, institutional authority and organizational capacity [21]. In Växjö, Sweden, the partnership between the municipal government and the Swedish Society for Nature Conservation, the largest environmental group in Sweden, resulted in a decision for the city to become fossil fuel free [114]. It is noted that although private actors actively shape the deliberative process with their own agenda, the networks are not decision-making arenas. Instead, they "*provide input to traditional representative decision making but do not replace it*" [114, p. 136]. This is therefore a case of network governance operating under the "*shadow of hierarchy*," where public actors continue to exercise authoritative decisionmaking [117]. In Portland, OR, the long history of the networking process between the municipality, local businesses, environmental groups and community leaders has enabled the city to become the first in the United States to adopt a carbon emissions reduction strategy [19]. In Minneapolis, MN, the local council was able to quickly establish a strong coalition for Homegrown Minneapolis (a local food initiative) through six phases: initiation, coalition formation, agenda setting, resource constraints, cooperation and consensus-building [21]. The leadership approach of the political leader was identified as the most important contributing factor to the formation and operation of the policy network. In Freiburg, Germany, the low-carbon transition process is largely driven by extensive informal networks of civil society organizations that can be traced back to the 1970s anti-nuclear movement, whereas in Graz, Austria, the network is dominated by municipality and research institutions [115].

Five general observations can be made from these case studies. First, the cases described in the literature mostly originate from small- and mid-size developed cities that are well-known pioneers in civic environmentalism. There is little evidence that network climate governance works in larger, more growth-oriented cities. Second, compared to intergovernmental relations and municipal networks, network governance operates at a more local scale. Third, the nature and effectiveness of network governance depends on a number of factors, including both the capacity for civic participation (as in the case of Freiburg and Portland) and the commitment of urban political elites (as with the case of Minneapolis). Fourth, while actors often have diverse sets of interests, values and experiences, this is not a barrier to sustainable partnership as long as it is possible to locate common interests (usually economic prosperity). In fact, a diversity of participants can be considered a strength in the generation of new policy ideas. Fifth, while network governance may allow a municipal government to overcome its limitations by cooperating with other private actors, by its very nature it is less capable of overcoming contested issues:

> Network governance is based on mutual interactions between a variety of interdependent actors, each with their own motives, who come together to solve a common problem. Network governance is therefore best suited to solve collective problems that produce win–win solutions and where value conflicts or questions of justice are not at the heart of the issue. [114, p. 138]

In fact, policy networks often strongly reflect existing power structures and are consolidated platforms for

the urban elites to develop a "*common vision*" [118]. As a result, networks may serve to support and legitimize the neoliberal policy paradigm while marginalizing the alternatives, such as grassroots initiatives, to which this review now turns.

Grassroots initiatives

So far, our review has focused on municipal governments as the key actors of urban carbon governance. The fourth area of investigation challenges this singular emphasis on municipal governments and suggests that grassroots organizations and community groups also have a key role to play. Unlike the urban responses discussed previously, grassroots initiatives are started by local community groups or even individuals, often without the involvement of governments. Studies in this area argue that although grassroots initiatives are subject to many challenges and limitations, they play a significant and distinct role in urban carbon governance.

Aylett [119] argues that grassroots initiatives can be more effective than government-driven programs, especially in soliciting changes in individual behaviors. The author used Solarize Portland, a community-managed campaign for collective purchasing of residential photovoltaic systems, to make his case. The campaign began in 2009 when two local Portland, OR, residents started a neighborhood-scale bulk-purchasing scheme to reduce the cost and complexity of residential solar power [119]. The program was very successful, especially when compared to the failure of previous municipality-led schemes to promote solar electricity. One of the reasons for success is scale: Solarize Portland, operating at the neighborhood scale, relies on the mobilization of local social ties to generate demand for technological change, and as more and more people join in, creates a "*virtuous social–technical loop*" that helps to push the project forward [119, p. 874]. Where large-scale, rather than individual, technology investment is at the fore in local initiatives, grassroots projects are generally more acceptable to the local community than private investments [120]. This is because grassroots projects are more locally appropriate, involving more local people in the process, and bringing more benefits to the locality through local ownership [121]. Therefore, whereas the development of wind-power capacity has proceeded slowly in many countries because of strong local opposition, often oversimplified as not in my back yard (NIMBY)-ism [122,123], community-based wind farms are mushrooming all over the world, including in Australia, Japan, Europe and North America [124–126].

What distinguishes grassroots initiatives in urban carbon governance is not just that they are more effective and acceptable but that they offer fundamentally different visions and solutions. The Transition Town movement is perhaps the most successful example in this regard and, for this reason, has attracted a significant amount of research interest. Transition Town originated as a school project at an adult education college in Kinsale, Ireland. The school project was led by Rob Hopkins, a permaculture teacher, and aimed to formulate a plan for Kinsale to gradually reduce its dependency on oil. Hopkins brought the experience to Totnes, where he and others founded the first Transition Town initiative. From there, the movement rapidly grew into a global phenomenon. In 2009, according to a survey conducted by Seyfang [127], there were 94 initiatives in the United Kingdom and a further 40 worldwide. Fast-forward to 2013 and there were 1107 initiatives in more than 43 countries across the globe [201]. The mainstreaming of the movement has been attributed to the effective use of mass-communication technologies to spread the message globally [128]. Another reason is the emphasis on inclusiveness and pragmatism [129]. Anyone with an idea is encouraged to join the movement and start a project.

At the heart of the imagination of transition urbanism is the belief that societies have grown too dependent on the nexus of globalization, neoliberalism and oil-dependency, thereby making themselves vulnerable to the inevitable – if not imminent – peaking of oil production. To avoid an economic meltdown that would be more severe than the 1973 oil crisis, it is necessary for communities to prepare now for a post-oil future through economic localization and improving resilience [130]. Localization refers to the reduction of economic dependency of cities on distant communities and is considered by the movement as the most important pathway to resilience [130]. Fundamentally, localization involves reducing trade through import substitution and, as such, directly challenges the dominant neoliberal discourse that equates trade liberalization with growth and prosperity [131]. However, localization as understood by most activists, including those leading the Transition Town movement, is not about autarky or complete self-reliance. Rather, it is about rejecting the perception that trade is always desirable. As North [131, p. 587] puts it, localization is about "*producing as much as possible as locally as possible, then within the shortest possible distance, with international trade only as a last resort for goods and services that really cannot be produced more locally.*" In addition to being characterized as an environmental movement, Transition Town, like many other grassroots initiatives, also has a strong undercurrent of community development, defined as a political act based on a commitment to human rights and social justice [132]. This community orientation is reflected in the number of community development principles adopted by the movement, such as community

visioning, inclusion and diversity, building partnership and awareness-raising [130]. Transition Town and other grassroots initiatives are therefore valued not only for their environmental benefits but also for a range of social benefits, such as community empowerment and the fostering of social capital.

In practice, one of the spotlights of Transition Town has been local food production, reflecting both the fact that food is a basic human need and the movement's intellectual foundation in the permaculture movement [128]. The initiatives around local food include formatting local food networks between local food producers and local consumers, retailers and restaurants; growing food in public and unused spaces; swapping and saving seeds; and supporting community gardens. Another important initiative is to establish local currencies to promote local consumption, although the complexity means that there are only a handful of successful schemes operating in the United Kingdom [133]. The principal aim of the local currency schemes is to encourage more consumption of local products, but the currencies also function as a tool for social inclusion, community development and place marketing [133].

There has, to date, been no concrete measurement of the impacts of transition urbanism in terms of reducing carbon emissions and energy consumption, but debates have been waged on the political impacts of the movement. Transition Town has often been characterized, and self-characterized, as an apolitical movement because of its reluctance to take a strong political stance on specific issues [132]. However, such name-tagging can be misleading because the movement is firmly against neoliberal visions of deregulated, globalized, growth-oriented economies, and challenges the existing system of power by demonstrating feasible alternatives [133]. For this reason, the term "*generative politics*" is sometimes used to describe the movement [134]. While generative politics may have the advantage of building coalitions out of multiple interests, it runs the risk of co-optation by existing power structures and becoming a passive participant in governance with limited ability to "*rock the boat*" [132]. Evidently, this nonconfrontational approach has failed to achieve a consensus even among transition groups, resulting in ideological debates, delays, loss of membership and lack of focus [135].

In addition to concerns about the apolitical nature of the movement, scholars have also noted that the scale of operation remains a contentious issue for transition urbanism [129,133,135]. Any city of significant size consists of many neighborhoods. Should one establish one citywide transition group, or multiple groups at a subcity level? Currently, the latter approach is far more popular. However, such a segmented vision of the city contradicts the reality of the city as an integrated urban economy [129]. Furthermore, programs and ideas (e.g., local food and currencies) that originated from a small town setting have difficulty translating to big cities:

> The Transition movement's visions of localised resilience that can seem to hark back to a small town feeding itself from its agricultural hinterland and employing itself through locally owned businesses can be harder to envisage and materialise in a globally connected city where the high street has long been superseded by the supermarket and out-of-town shopping centre. [133, p. 1427]

Thus, while advocates of Transition Town are critical of the unsustainable, oil-dependent nature of global cities, they fall short on articulating an alternative and how to move towards it.

Concluding remarks

This review has surveyed some of the influential perspectives and issues in urban carbon governance, which in the last few years has become a truly global phenomenon. The literature has provided convincing evidence that local actors, especially but not limited to municipal authorities, play a key role in formulating and implementing urban responses to climate change. The analysis of governing techniques shows that local governments prefer "*soft*" interventions or no interventions rather than "*hard*" interventions such as regulations, unless such interventions can be justified by local co-benefits. As a result, the low-carbon governance at the local level is highly fragmented. Further, the governance process, often dominated by the interests of political and business elites, may serve to maintain the status quo while marginalizing alternatives. Consequently, a gap between the rhetoric, which continues to grow, and the reality has emerged. Various local political and institutional factors have been used to explain the gap. The multilevel governance perspective has shown that urban carbon governance is also shaped by actors at other scales and in other places. Of particular importance is the role played by higher-level governments, transnational municipal networks and local policy networks. Further, the emergence of grassroots initiatives has become an exciting new development of urban carbon governance.

Together, these different perspectives have expanded our understanding of the complexity and plurality of urban carbon governance as a global phenomenon, yet they also arrive at some common conclusions. Most significantly, urban carbon governance consists of largely fragmented and decentralized processes. Urban and local actors are mostly left on their own to figure out their responses to climate change. The emergence of new forms of cooperative and network governance has further challenged the salience of state control.

Andonova and Mitchell [136] commented on this rescaling of global environmental politics:

> Global environmental politics and governance have been rescaled vertically down toward provincial and municipal governments and up toward supranational regimes. They have also been rescaled horizontally across regional and sectoral organizations and networks and across new issues, such as development, security, and trade among others. [136, p. 255]

At the same time, this review has also uncovered new evidence that challenges, rather than conforms to, this paradigm. For example, empirical studies from China have convincingly argued for the central government and its ability to use hierarchical governance to control subnational governments as the most important driving force of local climate action. Chinese cities also differ from "*the norm*" in the sense that the involvement of the civic society and transnational municipal network in urban carbon governance has been minimal. Consequently, the reconfiguration of traditional intergovernmental relationships, rather than state–society relationships, is the most crucial factor in the governance of carbon and energy in Chinese cities.

Despite these important and valuable insights, this review has discovered some significant gaps in current knowledge. The first issue is that, although the empirical literature has identified a large number of local actions on climate change mitigation, the causality chain linking these actions to final outcomes has been largely ignored and, as a consequence, the effectiveness of local low-carbon responses remains unclear and ambiguous. Second, given the large number of independent variables involved in urban carbon responses identified in the literature, it is unclear what the crucial factors that differentiate successful from less successful urban carbon governance are. For example, what is the relative importance of top-down influences, the choice of governing techniques, local politics, the institutional capacity of local authorities, the involvement with transnational municipal networks and the strength of the civic society in developing effective urban low-carbon responses? Also, how does the importance of these factors vary across different urban contexts? A third, related issue is the lack of studies on the interrelationships among the key variables of urban carbon governance. In particular, a conceptual framework that considers both local and multilevel factors would be useful in structuring and guiding future research. Fourth, the role of time-related factors in the development of urban responses has been largely ignored. The literature focuses on static aspects. However, a climate change policy does not appear suddenly but evolves gradually over a long period of time. Longitudinal studies can help identify changes in urban low-carbon responses and shed light on the effects of time-related factors. Finally, the recent expansion of research in geographical terms notwithstanding, cities from developing countries remain an understudied group. If past trends offer any indication, the future of the governance and politics of low-carbon cities is likely to become even more diverse. Many key innovations and experimentations will come from cities in developing countries, as exemplified by the case of China. Consequently, examining cities in developing countries provides the basis for further diversification of theories for this field. The central challenge for scholars is thus to incorporate these emerging actions into the understanding of urban carbon governance, which no doubt will stimulate a new wave of theoretical innovation and refinement.

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