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Stockholm Environment Institute, Working Paper 2015-15

What cities do best: Piecing together an efficient global climate governance

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WORKING PAPER NO. 2015-15

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ABSTRACT

Action by city governments is essential for achieving deep reductions in global greenhouse gas (GHG) emissions. While many cities are already engaged in pioneering efforts to achieve such reductions, greater support from national governments could help realize urban mitigation potential more fully, quickly, and cost effectively. With greater policy coordination, cities could focus on roles and actions for which they are highly capable and best positioned. We find that under a coordinated approach designed to achieve deep GHG reductions, for roughly 20% of urban GHG abatement potential, cities' ideal role is to be *policy leaders and architects*. The greatest opportunities here are in the passenger transport sector, and include improved spatial planning, promotion of walking and bicycling, enhanced transit system development, and more efficient transportation management. For another 40% of urban abatement potential, the ideal role for cities is to be *critical implementers* of nationally applied policies. Opportunities here are greatest in the residential and commercial buildings sectors. For the remaining 40% of urban abatement, cities can be *strategic partners*, taking crucial independent actions to enhance the effectiveness of policies enacted at higher levels of government. For these diverse opportunities, cities could enhance national efforts through incentives, education, permitting, and infrastructure development. A vital role for national governments will be to help coordinate and enable effective action by cities in all of these capacities.

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ACKNOWLEDGEMENTS

The authors thank Amanda Eichel at Bloomberg Philanthropies for commissioning this research and for helpful discussions throughout. Special thanks are also due to Kerem Yilmaz (NPO Solutions); Harro van Asselt, Marion Davis and Michael Lazarus (SEI); and Stephanie Ohshita (Lawrence Berkeley National Laboratory) for review. The research presented here builds upon analysis conducted previously by SEI, also funded by Bloomberg Philanthropies, and published as SEI Working Paper No. 2014-06, *Advancing Climate Ambition: How City-Scale Actions Can Contribute to Global Climate Goals*. Readers interested in the methodology for estimating urban GHG abatement potential may wish to consult that report, at http://www.sei-international.org/publications?pid=2582.

1. INTRODUCTION

Around the world, urban areas are responsible for a large and growing percentage of human-caused greenhouse gas (GHG) emissions (Seto et al. 2014). Because of this, mitigation actions in urban areas could contribute significantly to reducing GHG emissions. City governments have both direct and indirect influence over many sources of GHG emissions (Arup and C40 Cities 2014; Erickson et al. 2013; Lazarus et al. 2013; OECD 2013; GEA 2012; Collier and Löfstedt 1997; Seto et al. 2014). And a growing number of observers are calling for enhanced climate action at the city level (OECD and Bloomberg Philanthropies 2014; Harrison et al. 2013; Harrison and Muller 2014; Harrison et al. 2014; Anton et al. 2014; UN-Habitat 2013).

Recent analysis suggests that a concerted programme of mitigation measures could reduce city-caused emissions by up to 3.7 Gt CO_2e in 2030 relative to current trends, and up to 8 Gt CO_2e in 2050 (Erickson and Tempest 2014). Further analysis has shown these actions could also be cost-effective, yielding net economic savings of US$16.6 trillion between 2015 and 2050 (Gouldson et al. 2015). Investments in urban energy efficiency, for example, not only reduce energy costs, but may avoid the need for some costly energy supply investments. Data from Erickson and Tempest (2014)'s analysis suggest that urban building energy efficiency measures could avoid the need for up to 260 GW of new power supply in 2030 (and up to 730 GW in 2050). Overall, urban mitigation actions – specifically, actions that most city governments have the power to undertake – could contribute up to 15% of the global GHG reductions required to stay on a 2°C pathway (Erickson and Tempest 2014).

A key question for policymakers, however, is how best to achieve this mitigation potential. Even where cities have political will and resources, they may face realistic limits to their ambitions, especially if a majority of other cities are not similarly engaged and coordinated in pursuing GHG reductions. Lack of coordinated action amongst municipalities can lead to free-riding, where some cities refrain from action in expectation that they will benefit from the actions of others (Kousky and Schneider 2003). Emissions "leakage" is another concern, since mitigation actions in some cities may simply cause economic activity to shift to other jurisdictions (Wiener 2007; Bushnell et al. 2007). Awareness of these risks can sometimes limit the ambitions of more proactive cities (Aoki 2010; Kousky and Schneider 2003). Thus, although cities can do a great deal to advance global climate goals, they may face significant challenges if they have to go it alone. Maximizing GHG reductions within urban areas is likely to require concerted actions at multiple levels of government.

This working paper explores what a "vertically integrated" approach to city-related GHG emissions might look like. The basic idea is that different levels of government – e.g. national, state and municipal – would coordinate climate actions to be as efficient as possible, with agencies at each level doing what they do best to achieve deep GHG reductions. Understanding how this approach would work in practice – which levels of government are best suited to do what – can inform urban climate policy and advocacy efforts, and help city leaders steer clear of potential pitfalls. We focus on four questions:

- What kinds of urban mitigation actions have the greatest potential for reducing emissions?
- In an ideal scenario, what should be the respective roles of national, state, and city governments in undertaking these actions – assuming maximum ambition and policy coordination?
- Globally, what enabling actions are most needed for city governments to effectively perform their required roles?
- How might needs and priorities for vertical integration differ among countries?

We begin with a discussion of different ways to envision cities' engagement in climate policy.[1] We present a rationale for vertically integrated governance based on the comparative advantages of different levels of government in administering policies. We then outline general roles for city, state, and national governments under a vertically integrated approach to urban GHG mitigation. We identify how cities in particular can contribute to vertically integrated policy actions, and key ways in which national governments can support cities' efforts. Combining this assessment with estimates of global urban GHG abatement potentials, we then suggest some priorities for vertically integrated urban-scale climate action around the world, looking globally and at China, the United States and Brazil in particular.

2. CITY GOVERNMENTS AND CLIMATE GOVERNANCE

City governments have multiple roles to play in climate policy. Many cities today are leaders and pioneers, pushing policy forward in a bottom-up fashion (see, for example, Esty 2014). Their actions are essential for building the foundations of an effective global response to climate change. Even as cities increasingly act as climate pioneers, however, it may be useful to consider how their roles might differ – or be enhanced – if they were part of an ambitious vertically integrated approach. In particular, an assessment of vertical integration opportunities can help guide the efforts of pioneering cities as they consider what policies to pursue, how to deploy their resources, and what actions to advocate for at higher levels of government. In such a regime, cities could focus on actions for which they are highly capable and best positioned.

2.1 The limitations of leadership

Recent commitments by national governments to reduce GHG emissions represent a major step forward for global mitigation efforts, but are widely understood to fall well short of a 2°C pathway (see, e.g., Climate Action Tracker 2015). Many mayors and other leaders have called for subnational governments to help bridge the gap, and initiatives such as the Compact of Mayors and the C40 Cities Climate Leadership Group are encouraging cities to make ambitious climate commitments.

Indeed, cities (and other subnational governments) are already playing a crucial role in climate action. They are policy innovators, testing new approaches, demonstrating best practices, helping to build capacity and political support for ambitious national action, and achieving GHG reductions in their own right (Hoffmann 2011; Chan et al. 2015; Somanathan et al. 2014). It is thus important for national governments and the international community to foster local-level action and experimentation as a means of advancing climate policy (Bulkeley and Castán Broto 2013). The international community could help by establishing more effective frameworks for supporting and coordinating subnational climate action (Chan et al. 2015). National governments, in turn, could do much more to enable local government actions.

The problem is that, as noted in the introduction, cities and other subnational governments cannot tackle climate change alone. They only control a fraction of public resources that could be mobilized for climate action, and they face limits to their authority and jurisdictions that affect their ability to control GHG emissions, even from sources located in urban areas. Efforts by subnational governments to reduce emissions where they have limited or indirect influence

[1] Our analysis focuses on climate change mitigation, not adaptation, which is a high priority for many city leaders and an essential element of global climate policy. Vertical integration is also very important for adaptation, but given the inherently local nature of climate risks and adaptation measures, the distribution of roles and responsibilities will differ considerably and would need to be assessed separately.

have been largely ineffective, except when aided by national policies (Oliveira 2009) or by societal trends (Millard-Ball 2012). Larger-scale action is also often desirable to avoid free-ridership or leakage, to address sources of emissions spanning multiple jurisdictions, and/or to achieve economies of scale (Corfee-Morlot et al. 2009; Somanathan et al. 2014).

2.2 An 'ideal' role: what cities do best

In order to realize the full potential for urban climate action, it thus makes sense to identify the most effective role for cities in a coordinated, multi-level effort. From that perspective, the relevant question is not how cities can lead the way, but rather how different levels of government can best work together to address city-related GHG emissions. Given serious ambition on the part of national governments, what kinds of policies would be most appropriate for achieving urban mitigation, and what should be the respective roles of national, state, and local governments in designing, implementing, and enforcing those policies?

There are many areas where local governments are likely to have a comparative advantage in the design, development, implementation, enforcement, and evaluation of public policies, including climate change policies. Individual countries differ significantly in the discretion they afford local governments to design and implement regulations (Rodrigo et al. 2009), but even in highly centralized countries, cities may often have a role in administering aspects of urban climate policies. Conversely, national- or state-level engagement is often appropriate to achieve greater efficiency, help coordinate action, and avoid leakage and free riding. An ideal approach would follow the principles of "fiscal federalism" (Oates 1999), where "responsibility for public decision making over a particular issue … [is] given to the jurisdictional level that could better manage it" (Somanathan et al. 2014, p.1182). Under this approach, the roles and responsibilities of different levels of government would be determined by their relative strengths as governing bodies (see Table 1).

In short, action by city governments is particularly valuable where policies need to be tailored to local circumstances and responsive to local constituencies, and where policies relate to already-existing city government responsibilities and goals. Higher levels of government are best positioned to act where economies of scale are possible, where cross-jurisdictional coordination is necessary, and where standardized approaches are needed to avoid free-riding and leakage of emissions between cities. Engagement by one level of government does not preclude engagement or leadership by another; national, state, and city governments can work together to enact and administer different aspects of mitigation policies, as further illustrated below.

Table 1. When is city or national involvement in climate policy most appropriate?[2]

City government involvement in climate policy is appropriate where success depends on…	National or state involvement in climate policy is appropriate where success depends on…
• Existing local government capacities (e.g. in spatial planning, transit system development, urban infrastructure, etc.) • Access to local data and information • Mobilization of local resources • Responsiveness and tailoring to local needs and circumstances • Communication and engagement with local stakeholders • Adaptability to changing (local) conditions • Integration with other local policy objectives (e.g. reducing pollution or promoting economic development) • Targeted mitigation measures (contained within city boundaries) with low leakage risks	• Achieving economies of scale (e.g. to reduce administrative costs, or transaction costs incurred by regulated parties) • Economy-wide market transformation effects (e.g. for energy efficiency measures) • Coordinating actions across multiple jurisdictions (e.g. cross-jurisdictional infrastructure projects) • Avoiding in-country leakage of emissions • Avoiding free-riding or "race to the bottom" behaviour among subnational jurisdictions

3. CITY GOVERNMENT ROLES UNDER VERTICAL INTEGRATION

Under an ideal policy scenario, with all levels of government working together to achieve full urban mitigation potential, the need for city government innovation and experimentation would be reduced. Instead, national, state, and local governments could coordinate policies for maximum ambition, efficiency, and effectiveness. City governments' roles would differ depending on the types of policies and actions required.

In some cases, city governments may be the **primary policy architects and leaders**. Spatial planning, transit systems, and waste management are examples of areas where city governments are likely to have existing technical capacity, where knowledge of local circumstances and stakeholders is paramount, and where emissions leakage risks are minimal. They are therefore prime candidates for city-led action, with enabling support from national or state governments as needed.

In other cases, city governments may be **critical implementers** of policies developed and enacted at higher levels of government. Energy efficiency standards for buildings, appliances and vehicles, for example, have the greatest impact when they are widely applied. Piecemeal adoption can lead to jurisdiction-shopping by businesses or residents seeking to avoid more stringent standards. It can also fail to achieve market transformation, where new technologies and practices become established as economically preferred alternatives due to their widespread adoption. In such situations, an ideal strategy would be for national governments to lead policy development by enacting uniform energy efficiency policy frameworks and standards (IEA and UNDP 2013). Cities may still have an important role to play: they can cost-effectively assess compliance with building energy codes, for example, by combining assessments with general building inspections. In some cases, city governments can also tailor national standards to local conditions. Both of these implementation roles rely on cities' natural competencies and knowledge of local circumstances.

[2] For examples and further discussion of these criteria, see, for example, Corfee-Morlot et al. (2009), OECD (2010), Anton et al. (2014), Oliveira (2009), Somanathan et al. (2014), Harrison et al. (2014), and OECD and Bloomberg Philanthropies (2014).

Finally, city governments can be important **strategic partners** by pursuing locally targeted actions to maximize the impact of policies orchestrated at higher levels of government. In this case, cities would not implement the national policies, but undertake separate, complementary actions. Policies to promote the adoption of new technologies, for example, often require coordinated actions at multiple levels of government to be successful. Maximizing adoption of technologies such as rooftop solar panels or electric vehicles may depend on a policy suite of national subsidies, incentives and tax reforms; national- or state-level reform of electricity tariffs and rate structures; and local build-out of electrical distribution and/or charging infrastructure. In these situations, cities may have important complementary roles involving education and outreach, incentive programmes, and permitting and zoning related to local infrastructure.

Table 2 provides examples of the different types of roles that city governments might play under a vertically integrated approach to climate action, and the corresponding roles of state or national governments. Note that these roles assume the adoption of stringent and ambitious national policies by national governments. This means cities could avoid having to "raise the bar" on national standards (as they might in a pioneering role) and instead focus on effective local implementation and complementary action. Also, each city government role generally subsumes the ones below it. That is, if a city is the policy architect and leader, it will also generally be responsible for implementation and complementary actions. Likewise, if city governments take on an implementation role, they will often be able to take on complementary policy-enhancement roles as well.

Table 2: Cities' roles in a vertically integrated approach to urban GHG mitigation

City government role	City role examples	Corresponding national or state government role
Policy architect & leader City government is the primary body responsible for policy design, formulation, application, implementation, and enforcement	• Urban spatial planning • Design/development of transit systems or transportation policies • Development of urban infrastructure projects • Waste management regulations	• Establish national policy frameworks Enable city government action through: • Capacity-building & information-sharing • Access to funding • Legal & policy alignment
Critical implementer City government is responsible for key application, implementation, or enforcement actions related to a policy	• Building code implementation & compliance-checking • Implementation of regionally coordinated, cross-jurisdictional infrastructure projects or transportation policies	• Policy design and/or standard-setting • Regional coordination • Enabling city government implementation role (through capacity-building, funding, or legal reform)
Complementary partner City government undertakes separate, complementary actions that contribute to the effectiveness, uptake, penetration, or success of a policy led by higher levels of government	• Complementary information & outreach, certification, and incentive programmes for improved building energy efficiency • Permitting or active installation of electric vehicle charging stations • Permitting, tax incentives, and/or subsidies for commercial & residential distributed energy resources (incl. solar PV)	• Policy design and/or standard-setting • Primary implementation and enforcement • Coordination/integration of actions within and across different levels of government • Enabling city government complementary actions (through capacity building, funding, or legal reform)

4. NATIONAL/STATE GOVERNMENT ROLES UNDER VERTICAL INTEGRATION

As Table 2 suggests, the respective roles of national and state governments under a vertically integrated approach will vary just as cities' roles do. The scope of national or subnational engagement will depend on what is required for successful policy outcomes (Table 1). Depending on the type of action required, national (or state) governments may serve as policy architects and leaders, as implementers and enforcers of policies, and as coordinators of action where application of a policy is required across multiple subnational jurisdictions.

In nearly all cases, a vital role for national governments will be to help coordinate and enable effective action at lower levels of government. Even where cities are best positioned to undertake mitigation actions or perform certain roles, they often face constraints in terms of budgets, technical capacity, or even legal authority. National governments can help remove these constraints. They can also provide general policy direction and incentives that promote and enhance city-level action. Much of the current literature on vertical integration focuses on these "enabling actions" for cities. Some key roles for national and state governments under a vertically integrated approach include:[3]

- **Establishing national policy frameworks and incentive structures:** National political and policy direction is often a strong enabler of urban GHG mitigation, especially when accompanied by efforts to coordinate policy formulation at multiple levels of government. Fiscal and political incentive mechanisms can also be effective for enabling city-level action, including "race to the top" mechanisms that reward the performance of governments or government staff.
- **Providing, or improving access to, financial resources:** Often city governments are best positioned to undertake mitigation measures, but they are budget-constrained. City governments frequently lack sufficient taxation or other revenue generation authority that would allow them to undertake capital-intensive projects, or face revenue streams that are weak or unreliable. Relative to national governments, cities also frequently lack access to affordable financing and may have difficulty leveraging private capital. National governments can address these shortcomings by providing direct funding support and enacting reforms to improve cities' access to private capital.
- **Strengthening capacity and improving governance structures:** City government staff may lack the skills, expertise or information they need to effectively undertake specific kinds of mitigation actions. Often, these deficits will be most acute for actions that fall outside a city's typical governing roles and responsibilities. Through training and outreach programs, national governments can assist local governments in obtaining the technical capacity they need. In addition, national governments can promote better sharing of information and expertise among different levels of government to enable "smarter" policy design and implementation. Establishing integrated institutional structures and new coordinating bodies can also improve governance related to urban-scale GHG emissions.
- **Aligning policies and eliminating conflicts:** In some cases, national or state policies may actively conflict with city government priorities, or otherwise inhibit city-level actions. For example, cities may lack the ability to adopt building codes, vehicle standards, or other kinds of mandates that go beyond national requirements. City-level

[3] This list draws on insights from Corfee-Morlot et al. (2009), Bulkeley (2010), OECD (2010), Hoornweg et al. (2011), Harrison et al. (2013), Anton et al. (2014), Harrison et al. (2014), Harrison and Muller (2014), and OECD and Bloomberg Philanthropies (2014).

actions may also be hampered by a lack of policy coordination among different agencies and different levels of government. Aligning policies and properly delegating authority can enable cities to pursue urban mitigation more effectively.

The following analysis explores the relative need for these kinds of enabling actions on a global scale, considering the roles that city governments might ideally play in a vertically integrated approach to urban GHG abatement.

5. ASSESSING GOVERNANCE NEEDS FOR CITY-SCALE GHG ABATEMENT

In the preceding sections we have examined the types of roles that governments at different levels might play in urban GHG mitigation overall. Now we look more closely at specific types of mitigation actions, both to identify the respective roles of city and higher-level governments, and to highlight the most important actions needed to enable city governments to fulfil their roles. We then provide a breakdown of global urban GHG abatement potential according to the role that cities would play in a vertically integrated approach (i.e. whether they are likely to be policy leads, critical implementers, or strategic partners).

5.1 A vertically integrated allocation of roles

Erickson and Tempest (2014) identify global abatement potentials for a range of urban climate actions, broken down by category: passenger transport, road freight transport, building energy use, and waste management. Their estimates for urban abatement potential in 2030 and 2050 are reproduced in Table 3. Again, these are actions that could plausibly be undertaken by many city governments themselves, and do not include supply-side energy and industrial policies that – in most countries – would be beyond city jurisdiction and control (even though they may affect GHG emissions within municipal boundaries).

Table 3: Global urban greenhouse gas abatement potentials in 2030 and 2050

Sector	Abatement goal (technology or practice)	Abatement potential (Gt CO_2e)	
		2030	2050
Buildings, residential & commercial	New buildings heating efficiency (passive house standards)	0.9	1.7
	Heating efficiency retrofits in existing buildings (incl. heat pumps in mid-latitudes)	0.6	0.7
	High-efficiency lighting & appliances	0.7	1.6
	Adoption of rooftop & building-integrated solar PV systems	0.2	0.4
Transport, passenger	Land use planning to reduce urban travel demand	0.2	0.5
	Mode shifting and improved transportation system efficiency	0.4	1.0
	Automobile efficiency and electrification	0.2	0.9
Transport, freight	Improve freight transportation logistics	0.1	0.2
	Improve vehicle efficiency	0.1	0.3
Waste	Increased waste collection & recycling	0.2	0.3
	Landfill gas (LFG) capture & utilization	0.0	0.3

Source: Erickson and Tempest (2014).

For each of the sectors and abatement goals in Table 3, we have identified a range of policies that could be pursued to achieve the abatement potential, and categorized the appropriate roles of cities and national/state governments in a vertically integrated approach to those policies (Table 4). These roles were identified based on whether specific actions would be best undertaken at the city, state, or national level according to the criteria discussed above and in Table 1. City government roles include being a policy leader and architect ("Lead"); a critical implementer ("Implementer"); or a strategic partner ("Partner"). For national and state governments, possible roles include leading the design and development of policies ("Lead"); implementing and enforcing policies ("Implement"); and coordinating policy-related actions among different subnational jurisdictions ("Coordinate"). Finally, for each general policy or measure, we provide examples of the specific actions that cities and national/state governments could undertake.

National and state governments can also take steps to enable city-level action, as described above. Rather than identify these in Table 4 we assess general needs for city-government enabling measures further below.

Table 4: Allocation of policy roles in a vertically integrated approach to urban GHG abatement

Sector	Abatement goal	Primary policies and measures	Best role for…*		Possible city government actions†	Possible national or regional government actions††
			City govts.	National or regional govts.		
Buildings, residential & commercial	New buildings heating efficiency (passive house standards)	Require and promote high-efficiency new building design	Implementer	Lead Coordinate	• Checking compliance and/or enforcing national standards • Information & outreach • Local tax or other incentives & energy audits	• Set national heating efficiency standards for new buildings • Establish coordinating bodies for compliance oversight
	Heating efficiency retrofits in existing buildings (incl. heat pumps in mid-latitudes)	Require and promote high-efficiency retrofits to existing buildings	Implementer	Lead Coordinate	• Checking compliance and/or enforcing national standards • Approving qualification for incentives • Information & outreach • Local tax or other incentives & energy audits	• Establish national building retrofit standards and requirements • Establish coordinating bodies for compliance oversight • Establish retrofit incentive programmes or subsidies
	High-efficiency lighting & appliances	Require and promote high-efficiency lighting systems and appliances	Partner	Lead Implement	• Compliance checking for lighting standards††† • Information & outreach • Local incentives & energy audits	• Establish uniform national appliance and lighting energy efficiency standards • Enforce the application of standards by manufacturers
	Adoption of rooftop & building-integrated solar PV systems	Support and subsidize widespread adoption of distributed solar PV systems	Partner	Lead Implement Coordinate	• Building permit and/or zoning reform • Distribution grid planning/permitting	• Utility rate reform/ decoupling • Net metering rules • Plan & deploy "smart grid" • PV subsidies, tax rebates • Carbon pricing

* Based on criteria in Table 1, and as described in the preceding section.
† A "lead" role for cities may also involve implementation and complementary actions; an "implementation" role may also involve complementary actions.
†† Excluding measures designed to enable or enhance city government action.
†††Although cities could play an implementation (compliance-checking) role with respect to lighting systems in buildings, their primary role related to appliance and lighting standards is likely to be complementary.

Transport, passenger	Land use planning to reduce urban travel demand	Improved spatial planning and zoning for new and existing urban development	Lead	Coordinate	• Spatial planning and zoning focused on compact urban forms • Property tax reform or incentives • Development subsidies	• National policy frameworks for urban development • Inter-jurisdictional coordination • Regional transportation planning & infrastructure development
	Mode shifting and improved transportation system efficiency	Prioritize walking and bicycling; expand & promote efficient public transit systems; optimize transit system design & operations	Lead	Coordinate	• Design & develop efficient public transit systems, including associated infrastructure (bus rapid transit, light rail, etc.) • Optimize existing transit operations • Provide public transit subsidies	• National policy frameworks for transit-oriented development • Inter-jurisdictional coordination
		Deploy improved traffic management systems	Lead	Coordinate	• Congestion charges • Ramp metering • Active traffic management • Integrated corridor management • Incident management • Signal control management	• Inter-jurisdictional coordination
	Automobile efficiency and electrification	Require & promote adoption of high fuel-economy passenger vehicles	Partner	Lead Implement	• Provide local incentives for high-efficiency vehicles (e.g. reduced tolls, dedicated parking, lane usage, etc.)	• Establish and enforce uniform national fuel economy standards for vehicle manufacturers
		Promote electric vehicle adoption	Partner	Lead Implement Coordinate	• Direct installation or permitting of electric vehicle charging stations • Provide local incentives for electric vehicles (e.g. reduced tolls, dedicated parking, lane usage, etc.)	• Enact supportive electricity rates/tariffs • Approve utility investments in charging infrastructure and new generation resources • Enact policies to promote low-carbon & renewable electricity generation (e.g. carbon pricing, portfolio standards) • Provide tax rebates or incentives for electric vehicles

Transport, freight	Improve freight transportation logistics	Require and enable improved logistics planning and management	Implementer	Lead Coordinate	• Oversee local adoption of logistics management rules, requirements, and guidelines • Tailor national standards to local circumstances • Educate and inform local freight operators on logistics standards & management	• Enact national policies and standards for freight logistics management • Coordinate implementation of standards among local jurisdictions
	Improve vehicle efficiency	Require and promote adoption of high fuel economy freight vehicles	Partner	Lead Implement	Provide local incentives for high-efficiency vehicles (e.g. tax rebates, lane usage options)	• Establish and enforce uniform national fuel economy standards for vehicle manufacturers and/or freight operators
Waste	Increased waste collection & recycling	Require and promote enhanced waste collection, diversion, and recycling	Implementer	Lead Coordinate	• Oversee and enforce national waste collection, diversion, and recycling goals & quotas • Provide local incentives for improved waste management & recycling	• Establish national waste collection, diversion, and recycling goals and requirements • Provide subsidies, incentives, or contracting agreements with composting & waste digestion facilities • Coordinate application of standards across jurisdictional boundaries
	Landfill gas (LFG) capture & utilization	Require and enable greater landfill methane capture and use for energy generation	Partner	Lead Implement Coordinate	Siting / permitting related to landfill generation equipment or local energy distribution systems	• Enact LFG capture standards & requirements • Reform electricity tariffs for small-scale LFG energy generation • Upgrade distribution grids & interconnection standards to support small-scale generators

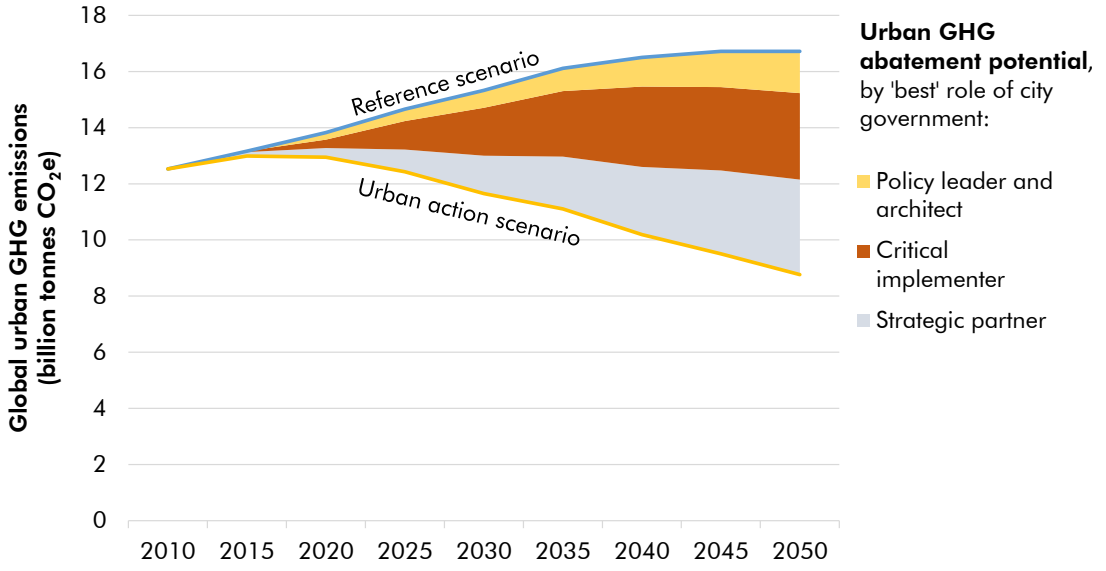
By matching our idealized allocation of governmental roles in Table 4 to Erickson and Tempest (2014)'s urban abatement estimates (Table 3), we can gain some insight into how much urban GHG mitigation depends on each kind of city-level action or involvement. Specifically, we identified the subsets of abatement potential associated with all policies where city governments would play a "leader and architect" role, a "critical implementer" role, or a "strategic partner" role (Figure 1).

It is clear that even under a fully integrated approach where national governments drive and coordinate actions on urban GHG mitigation, cities would still have critically important roles to play. For around 20% of urban abatement potential between now and 2050, we envision city governments taking the initiative as policy leaders and architects. This is because measures with significant abatement potential, such as reducing urban travel demand, deploying and optimizing public transit systems, and improving urban traffic management require a great deal of local tailoring, and depend greatly on existing city government capacities and expertise (see, e.g., Ribeiro et al. 2015). They are also not prone to leakage effects or national scaling issues that might warrant involvement by higher levels of government (though it may be important for national governments to establish high-level policy directives and frameworks).

For another 40% of urban abatement potential, we see cities as critical to the *implementation* of mitigation policies enacted at higher levels of government. Here, actions such as ensuring compliance with building efficiency standards, customizing and overseeing freight logistics requirements, and carrying out waste diversion mandates all depend on cities' capacities as local governing bodies, even though these policies may be best enacted and coordinated at higher levels of government.

Finally, in a vertically integrated scenario, 40% of urban GHG abatement potential would depend on city governments taking actions that enhance the effectiveness of policies undertaken at national or regional levels. These are policies such as improving appliance and vehicle efficiency; expanding the penetration of advanced technologies (e.g. rooftop solar or electric vehicles); and requiring capture of landfill gas. These are areas where realizing economies of scale and ensuring national uniformity are important for success, but where policies could benefit from complementary city-level actions, including local incentives, education, permitting, and development of relevant infrastructure.

Figure 1: Urban GHG abatement potential, 2010–2050, under a vertically integrated approach, by city government role



Given the strong need for city government involvement in urban GHG mitigation – even where GHG abatement is being led at the national level – a key question for policy-makers is whether cities have the resources and capacity they need to fully perform their roles.

5.2 Enabling city government actions

As described above, there are several ways in which national governments can aid and enable cities to reduce GHG emissions. These enabling actions are a critical element of any vertically integrated approach to urban GHG abatement.

The specific needs of city governments will, of course, depend on national and local circumstances. Still, based on general surveys to date (Corfee-Morlot et al. 2009; OECD and Bloomberg Philanthropies 2014; Harrison et al. 2013; Harrison and Muller 2014; Harrison et al. 2014; UN-Habitat 2013), we can broadly characterize the kinds of enabling actions needed for city governments to play the roles envisioned in Table 4. National policy frameworks and incentive structures will be important in nearly all cases. But whether cities primarily need financial support, more capacity and information, or greater policy alignment and legal authority will depend on their respective roles and the different types of actions they undertake.

For improvements to urban transportation infrastructure and transit systems, for example, a major barrier many cities face is access to funding or finance (OECD and Bloomberg Philanthropies 2014; IEA 2013). Technical capacity may be a secondary concern (though possibly significant in some cases). Policy alignment and delegation of legal authority may be important in some circumstances, such as to align transport planning (which is usually undertaken at higher levels of government) with urban planning efforts, or to enable congestion charges or other taxation-based policies (OECD and Bloomberg Philanthropies 2014; IEA 2013; Bulkeley 2010) .

For policies where city governments will primarily play an implementation role – such as checking compliance with building energy codes – sufficient technical capacity and sharing of information are critical (IEA and UNDP 2013). Higher levels of governments are often needed to provide training and educational support in these instances (Ribeiro et al. 2015). Lack of

adequate funding and resources are also frequently cited as reasons for poor implementation (Ribeiro et al. 2015), which may necessitate supplemental funding from national governments (OECD and Bloomberg Philanthropies 2014; IEA and UNDP 2013). Policy coordination is also an important enabling action, especially where adaptation of standards to local circumstances is needed (OECD and Bloomberg Philanthropies 2014; IEA and UNDP 2013).

Finally, the most pressing enabling actions for city-led complementary measures will vary by the type of measure. Capacity-building and information-sharing are likely to be the most critical for efforts aimed at outreach, education, permitting, or provision of incentives (e.g. education related to building efficiency; energy efficiency incentives; zoning and permitting for distributed solar or landfill gas-to-energy systems; low-carbon vehicle perks or incentives, etc.). For complementary infrastructure deployment (e.g. electric vehicle charging stations), access to finance is likely to be the most critical need. Needs for policy or legal reform related to these kinds of actions will vary by country.

Table 5 provides an assessment of priority enabling actions for each of the city government activities identified in Table 4, along with short descriptions of the specific types of national-government enabling actions that might be required. City government needs with respect to funding ("financial support"), technical capacity and information-sharing ("capacity"), and policy coordination or legal authorization ("policy alignment") are each given a high (●), medium (◐), or low (○) rating with respect to each set of city activities. Ratings were applied based on general conclusions in existing literature and the authors' own judgement.

Again, this is a global-level assessment; there may be significant regional variations from the general characterizations presented here. Specific needs will depend on local circumstances, each city's individual capacities and resources, and the national governing environment in which they operate. The overview presented here, however, can help to inform general advocacy and policy-making efforts directed towards promoting more vertically integrated approaches to urban GHG mitigation.

Table 5: Priority enabling actions for urban GHG abatement

Sector	Primary policies and measures	Possible city government actions	Need for enabling actions			Possible national government enabling actions
			Financial support	Capacity support	Policy alignment	
Buildings, residential & commercial	Require and promote high-efficiency new building design	• Checking compliance and/or enforcing national standards • Information provision & outreach • Local tax or other incentives & energy audits	●	●	○	• Training & education on building code compliance inspections • Provide funding support to ensure adequate staffing levels for inspections and outreach/audits • Ensure local constraints are reflected in building code design • Ensure consistency of building codes and other energy or land use policies
	Require and promote high-efficiency retrofits to existing buildings	• Checking compliance and/or enforcing national standards • Approving qualification for incentives • Information provision & outreach • Local tax or other incentives & energy audits	●	●	○	• Training & education on building energy retrofits and related inspections/audits • Provide funding support to ensure adequate staffing levels for inspections • Ensure local constraints are reflected in retrofit standards • Ensure consistency of requirements and other energy or land-use policies
	Require and promote high-efficiency lighting systems and appliances	• Compliance checking for lighting standards • Information provision & outreach • Local incentives & energy audits	◯	○	◯	• Education of city government staff to inform local outreach efforts & incentives
	Support and subsidize widespread adoption of distributed solar PV systems	• Building permit and/or zoning reform • Distribution grid planning/permitting	◯	○	○	• Education of city government staff to inform building permit regulations • Policy coordination to enable effective local grid development

Transport, passenger	Improved spatial planning and zoning for new and existing urban development	• Spatial planning and zoning focused on compact urban forms • Property tax reform or incentives • Development subsidies	○	◎	◎	• Share "best practice" information and expertise on spatial planning • Coordinate and align (regional) transport planning with urban planning objectives • Authorize tax reforms, incentives, or subsidies • Provide funding to ensure adequate planning staff & resources
	Expand and promote efficient public transit systems; optimize transit system design & operations	• Design & develop efficient public transit systems, incl. associated infrastructure (bus rapid transit, light rail, etc.) • Optimize existing transit operations • Provide public transit subsidies	●	◎	○	• Provide funding to support transit system development • Improve city government access to private financing and capital • Share best practice information and expertise on transit system design & operation • Support or enable (e.g. through legal reform) public-private partnerships
	Deploy improved traffic management systems	• Congestion charges • Ramp metering • Active traffic management • Integrated corridor management • Incident management • Signal control management	○	○	◎	• Legally enable city governments, where necessary, to enact traffic management policies including congestion charges • Provide information and expertise on best practices
	Require and promote adoption of high fuel-economy passenger vehicles	• Provide local incentives for high-efficiency vehicles (e.g. reduced tolls, dedicated parking, lane usage, etc.)	○	○	○	• Share information on best practices & policy options
	Promote electric vehicle adoption	• Direct installation or permitting of electric vehicle charging stations • Provide local incentives for electric vehicles (e.g., reduced tolls, dedicated parking, lane usage, etc.)	◎	○	○	• Provide funding, and/or improve access to private financing, to support build-out of electric charging infrastructure • Share information on policy outcomes and local best practices

Transport, freight	Require and enable improved logistics planning and management	• Oversee local adoption of logistics management rules, requirements, and guidelines • Tailor national standards to local circumstances • Educate and inform local freight operators on logistics standards & management	⭘	●	⭘	• Educate and train city government staff on logistics management requirements • Provide funding to support adequate staffing levels for ensuring compliance • Ensure local constraints or conditions are reflected in logistics management rules
	Require and promote adoption of high fuel economy freight vehicles	• Provide local incentives for high-efficiency vehicles (e.g., tax rebates, lane usage options, etc.)	◯	◯	◯	• Share information on best practices & policy options
Waste	Require and promote enhanced waste collection, diversion, and recycling	• Oversee and enforce national waste collection, diversion, and recycling goals & quotas • Provide local incentives for improved waste management & recycling	⭘	◯	⭘	• Funding to support staffing & resources necessary to carry out improved waste collection, diversion, and recycling • Ensure local constraints or conditions are reflected in waste management mandates
	Require and enable greater landfill methane capture and use for energy generation	• Siting / permitting related to landfill generation equipment or local energy distribution systems	◯	◯	⭘	• Authorize city government decision-making related to siting of LFG capture & utilization systems • Educate city government staff on LFG capture requirements

Legend

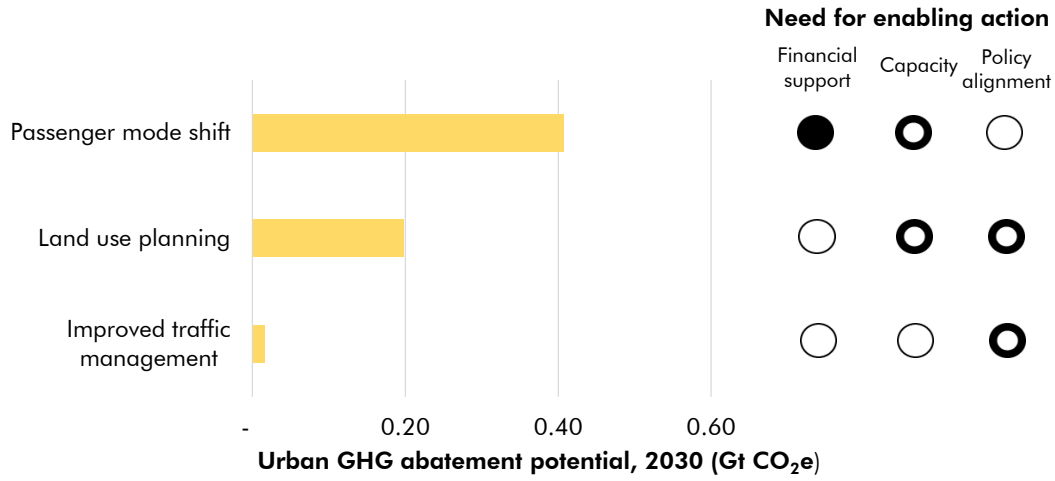
Rating symbol	Relative need for enabling actions from national/state governments or other actors (e.g. international donors)
●	High
⭘	Medium
◯	Low

5.3 Global needs and priorities for vertically integrated action

Figures 2–4 summarize our assessment of urban GHG abatement potentials (in 2030), city government roles, and priority enabling actions under a vertically integrated approach. Figure 2 presents abatement potentials in areas where city governments would play the role of policy lead, along with a summary of relative priorities for enabling action. Figures 3 and 4 do the same for areas where cities would be critical implementers and strategic partners, respectively. To reiterate our premise, all the abatement actions considered here could in principle be pursued by city governments themselves, in line with the analysis in Erickson and Tempest (2014); the allocation of roles is based on an idealized prescription for coordinated action at all levels of government. Based on our assessment, we offer some general observations on global needs and priorities for enhancing multi-level governance related to urban GHG mitigation.

First, as noted above, roughly 20% of urban abatement potential could be achieved with city governments serving as policy leaders and architects. **Here, effective vertical integration will require national governments to enable cities to take action.** City-led reduction opportunities are concentrated in the passenger transport sector, and include improved spatial planning, promotion of walking and bicycling, enhanced transit system development, and more efficient transportation management. As indicated in Figure 2, the largest near-term reduction opportunity in transportation (0.4 Gt CO_2e in 2030) involves the deployment of efficient public transit systems. Here, city governments' primary need is access to funding and finance. For other passenger transport opportunities, important roles for national governments will be to build up city government capacity and expertise, share information, coordinate regional planning, and adopt legal reforms (where necessary) to enable city actions. Finally, although city governments may be the primary actors, national governments can help to direct city actions by establishing national policy frameworks with clear goals for urban transportation development.

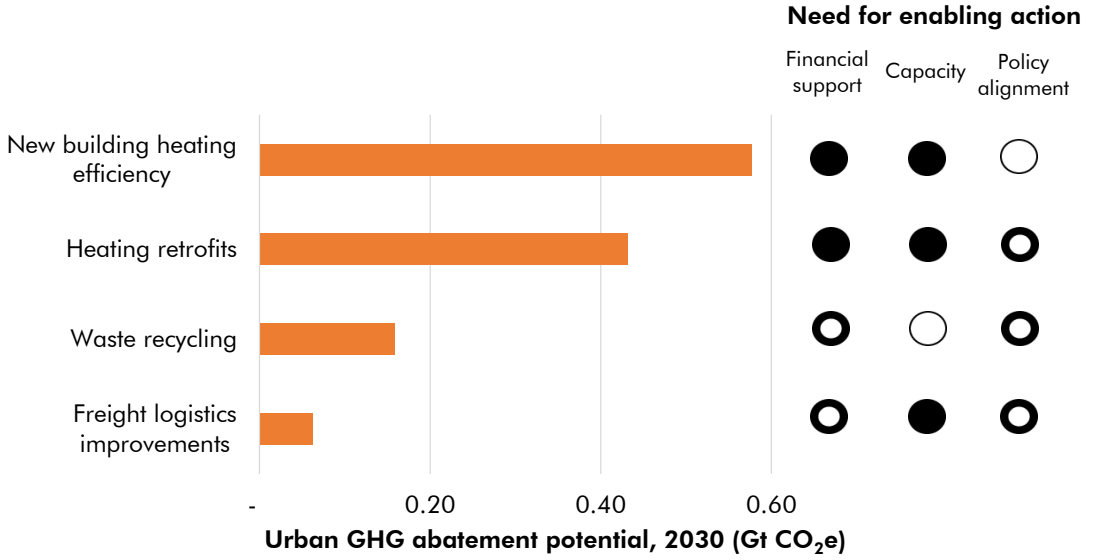
Figure 2: Abatement potentials and priority enabling actions where cities are policy leads



For another 40% of abatement potential, city governments could be effective in playing a critical implementation role. **For effective vertical integration in these areas, national and state governments can establish robust standards or model rules, and delegate aspects of implementation and enforcement to cities.** Opportunities here are greatest in the residential and commercial buildings sectors. Cities are ideally suited to oversee compliance with building

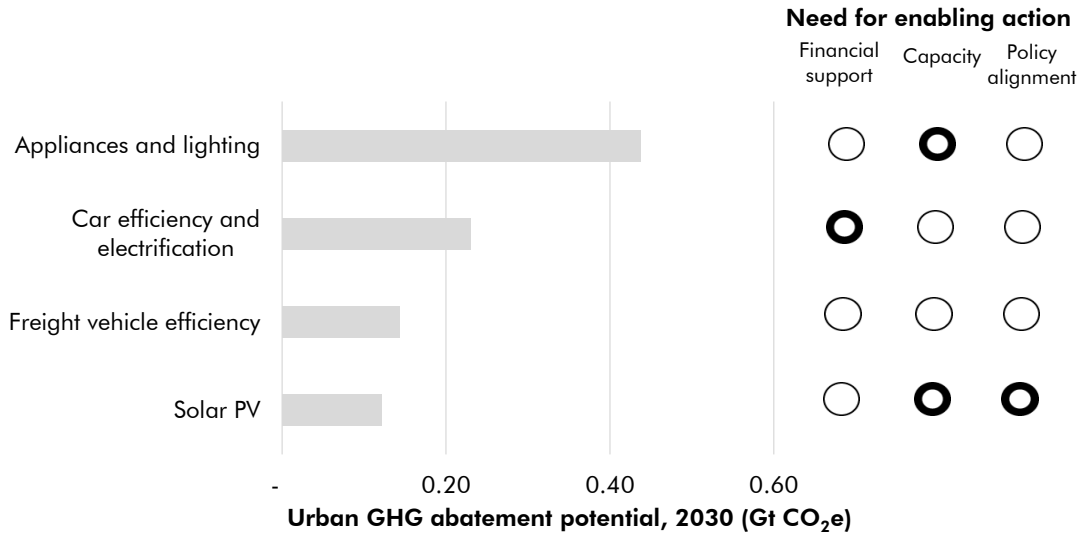
codes and retrofit requirements, especially since this can be combined with standard building inspections. However, as noted above and in Figure 3, national enabling actions are strongly needed for success. In most countries, support is needed to ensure that city governments have sufficient resources and technical capacity to oversee compliance. Furthermore, for building codes in particular, national governments may need to align standards with other energy policies and requirements to avoid conflicting directives.

Figure 3: Abatement potentials and priority enabling actions where cities are critical implementers



For the remaining 40% of urban abatement, cities would ideally take important actions to enhance the effectiveness of policies enacted at higher levels of government. **Here, effective vertical integration will require coordinated, independent actions at multiple levels of government, with local governments strategically complementing and going beyond national actions.** Relevant policies here are as diverse as requiring aggressive appliance, lighting, and vehicle efficiency standards; promoting distributed energy systems in buildings; expanding adoption of electric vehicles; and requiring methane capture and utilization at landfills (Figure 4). City-led complementary actions related to these policies will be similarly diverse, including incentives, education, permitting, and development of relevant infrastructure. For some city actions, a vertically integrated approach will require national or state government enabling support. By volume of abatement potential, the most pressing need for enabling action relates to information-sharing and capacity-building, particularly with respect to actions that would complement policies on efficient appliances, lighting, and distributed energy.

Figure 4: Abatement potentials and priority enabling actions where cities are strategic partners



In many countries, of course, these forms of multi-level governance and enabling support are already present to some degree. The challenge is to identify major gaps and strengthen institutional arrangements in a way that can support greater ambition for reducing city-related GHG emissions. In the next section we examine what such efforts might look like in three countries: China, the United States, and Brazil.

6. A SURVEY OF PRIORITIES IN SPECIFIC COUNTRIES

To clarify what more vertically integrated urban climate action might look like, we surveyed existing studies on policy regimes and urban GHG mitigation opportunities in China, the United States, and Brazil. Though the needs, opportunities, and governance structures of these countries differ considerably, a common theme is that more national ambition is needed to expand the scope of urban policy action and better enable city governments to play effective roles.

6.1 China

Major opportunities for urban GHG mitigation in China mirror those in the world at large. The most significant emission reductions are possible in the commercial and residential building sectors, followed by passenger and freight transport (Ohshita et al. 2015). However, China may be unique in the extent to which industry dominates urban GHG emissions – and the extent to which cities are responsible for administering industrial energy policies (Ohshita et al. 2015). This creates additional opportunities for vertically integrated urban-scale GHG mitigation.

China's system of government is officially centralized and unitary – i.e. very "vertically integrated" to begin with – but the reality of Chinese governance is more complicated. Various reforms at the national level have created a system that some observers have called "*de facto* federalism" (Zheng 2006). This means that significant autonomy and responsibility have been delegated to subnational levels of government, including cities (Lo 2013). This approach is conducive to local tailoring and policy experimentation, which in many cases the national government actively encourages. China's 2007 Energy Conservation Law, for example, holds provincial governments accountable for meeting energy conservation targets, but gives them and local authorities leeway in how this is done (Ohshita et al. 2015; Lo 2013). In 2010, a Low-

Carbon Cities and Provinces pilot programme was launched that has supported at least 36 cities in developing climate action plans and requirements that go beyond national standards (Ohshita et al. 2015).

This combination of delegation and experimentation puts much of the onus for achieving urban-scale GHG reductions on city and local governments, albeit in line with national requirements and guidance. Possible priorities for improved vertical integration largely involve better enabling city governments to take action. In some areas, however, new policies or policy reforms could help better allocate roles and achieve deeper GHG reductions. Some possible improvements include:

- *Providing more resources and capacity for new building energy code enforcement:* Relative to other developing countries, China has made great strides in reducing the growth of energy use in buildings (Price et al. 2011). In the past 10 years, China has strengthened its policies and institutional capacity around energy efficiency, including building code application and enforcement (Crossley 2013). Compliance rates for new building energy codes are high, although higher in the design phase than in the construction phase (Zhou et al. 2012). Better compliance could be achieved through improved training and capacity-building, including for city government officials responsible for building code inspections (Bin and Jun 2012). In particular, the Chinese government could provide better support for compliance checking in small- and mid-size cities (Bin and Jun 2012).
- *Providing more financial resources to enable building retrofits:* In contrast to new building code enforcement, most jurisdictions in China are failing to meet building energy retrofit targets (Price et al. 2011). An important need here is greater financial resources for city governments to ensure compliance and to bolster the incentives they offer (Bin and Jun 2012; Price et al. 2011).
- *Enacting power sector reforms to promote energy efficiency and greater penetration of distributed renewable power:* One way to fund more energy retrofits would be to incentivize investment in efficiency by China's electric utilities. Reforms that change revenue rules for utilities, direct utilities to acquire more energy efficiency, and evaluate their performance based on delivery of energy savings could channel significant new resources to energy efficiency measures (Regulatory Assistance Project 2015). City governments could be important strategic partners in helping to identify and coordinate investments. Similar reforms are needed to boost deployment of rooftop solar photovoltaic systems, for which China has failed to meet recent targets (Regulatory Assistance Project 2015). Here, cities may have a complementary role to play by helping to clarify rooftop ownership rights (Regulatory Assistance Project 2015), and by providing financial incentives to encourage a variety of distributed renewable generation (Ohshita et al. 2015).
- *Improving financing for urban planning and transit infrastructure*. Limited urban finance is probably the largest barrier to better spatial planning and development of public transit systems in China (Ohshita et al. 2015; Lo 2013). Tax reforms that allow cities to collect property taxes, and that redistribute other taxes to city governments, would help to alleviate this barrier (Ohshita et al. 2015). Better urban planning could also be enabled through further development of coordinating institutions and data gathering systems (Ohshita et al. 2015).
- *Further enhancing city-government capacities to regulate industrial GHG emissions.* In China, cities are tasked with implementing national and provincial energy and

carbon intensity targets (Ohshita et al. 2015). There are many actions that cities can take – from developing local industrial energy plans and targets, to providing technical assistance and incentives – to help meet these targets (Ohshita et al. 2015). Although the national government aids local jurisdictions in improving oversight of industrial energy management programmes, more could be done to bolster local capacities, including development of energy auditing capacity (Ohshita et al. 2015).

Notwithstanding these opportunities for improvement, China's practice of setting national policy goals and delegating implementation to subnational and local governments exemplifies an effective, vertically integrated approach to addressing urban-scale GHG emissions. Cities are encouraged through pilot programmes and flexible targets to be policy pioneers. Pilot initiatives in particular are an excellent way to gain experience and build capacity.

Achieving deeper energy savings and GHG reductions, however, may require a consolidation of capacities and lessons learned, and a move towards more ambitious, comprehensive national standards. Achieving greater GHG reductions in the building sector, for example, will likely require the bolstering of national building codes. Energy codes are still well short of "passive house" standards, and since their establishment in 1986 they have been updated infrequently (Bin and Jun 2012). A more aggressive vertically integrated approach could focus on ratcheting up national efficiency standards while continuing to build the capacity of regional and city governments to ensure compliance. Urban-scale efforts will also be aided by the establishment of national-level carbon pricing, which could establish a uniform price on carbon emissions (Reklev 2015). At the same time, more could be done to set national targets for, and direct additional resources to, transit-oriented development and infrastructure that prioritizes walking and bicycling.

6.2 United States

As in most other countries, the largest opportunities for urban-scale GHG abatement in the United States are in the residential and commercial buildings sectors (respectively), followed by passenger transport, freight transport, and waste. Energy savings in buildings comprise around two thirds of U.S. urban abatement potential, which is similar to China (ignoring industrial emissions). In the transportation sector, however, freight transport accounts for a relatively large share of the U.S. reduction opportunity, with freight traffic growing substantially faster than passenger traffic in most metropolitan areas (Brown et al. 2008).

The United States has a federal system of government, with states exercising a fair degree of regulatory autonomy, including with respect to energy and environmental regulation. Although the U.S. Department of Energy (DOE) and Environmental Protection Agency (EPA) oversee numerous policies and initiatives to promote energy efficiency and renewable energy, there is no comprehensive, national policy framework to address climate change. In recent years the EPA has begun to regulate GHG emissions from various sources under the federal Clean Air Act. The EPA's marquee effort under this approach is the recently adopted Clean Power Plan, which is designed to control CO_2 emissions from existing power plants (U.S. EPA 2015a). Even under this national directive, states are responsible for designing and implementing policies to achieve federally prescribed emission-rate targets.

With respect to managing urban-scale GHG emissions, states and cities have primary authority and responsibility. One result is that the presence, ambition and stringency of policies to address energy use, transportation, and waste management vary significantly across U.S. jurisdictions. California is the only state with an economy-wide, vertically integrated suite of policies explicitly designed to control GHG emissions (California Air Resources Board 2014), including

a framework for coordinating urban transportation and land use planning (California Air Resources Board 2015). There are no binding national building energy codes, although the federal government plays an active role in developing model codes and assists states in adopting them (Ribeiro et al. 2015). To date, however, at least 10 states have chosen not to adopt them (Levine et al. 2012). Similarly, only 20 states have adopted more comprehensive energy efficiency resource standards (Palmer et al. 2012). The federal government sets fuel economy standards for vehicles (U.S. EPA 2015b), but otherwise urban transportation policies are primarily state- and city-driven. Policies for waste management are also primarily state-driven.

Although numerous cities are taking action individually to reduce GHG emissions from urban activities (Steinhoff et al. 2015), the current decentralized nature of U.S. climate policy means there are significant opportunities for improved vertical policy coordination aimed at urban areas. Some possible opportunities include:

- *Establishing stronger national policy frameworks for GHG mitigation:* Unsurprisingly, municipalities are far likelier to take action on climate change when they are in states with strong climate policy frameworks, such as California and New York (Steinhoff et al. 2015). Coordinated policies and strong national standards are necessary to ensure broad participation in urban climate action, and avoid free-riding and leakage effects at the state and local level (Brown et al. 2008). Existing studies have highlighted the fragmented nature of federal programmes supporting local housing, transportation, energy and environmental initiatives (Brown et al. 2008), and have called for federal policies to enact carbon pricing, promote renewable energy, reform electricity regulations, increase energy research and development, and improve information collection and dissemination related to urban-scale GHG emissions (Brown et al. 2008; Steinhoff et al. 2015).
- *Expanding adoption and improving enforcement of building energy efficiency codes:* Improved end-use energy efficiency – including adoption of strong building energy codes – could play a key role in helping states comply with the Clean Power Plan (ACEEE 2015). As noted above, however, national building energy codes have not been universally adopted. Furthermore, even where codes are in place, compliance rates may be as low as 50–60% in finished buildings (Levine et al. 2012). Lack of compliance is often due to limited capacity and resources at the city government level (Ribeiro et al. 2015; IMT and NRDC 2014). Continuing to strengthen national model energy codes, requiring states to adopt them, and providing additional resources for city governments to enforce them could greatly reduce U.S. GHG emissions from urban activity and aid in the achievement of national abatement goals under the Clean Power Plan.
- *Expanding and improving federal funding for urban transportation planning and infrastructure:* Although a number of U.S. cities are pursuing policies to promote compact urban forms and transit-oriented development, even the most progressive cities have room for improvement (Ribeiro et al. 2015). A primary barrier is access to funding for major infrastructure improvements (Steinhoff et al. 2015). Adding to the challenge is the prioritization of road and highway maintenance rather than transit system development in federal and state transportation funding (Ribeiro et al. 2015; Brown et al. 2008). Fully unlocking U.S. mitigation potential for urban passenger transport will require a vertically coordinated approach that bolsters and reorients national transportation funding, provides greater national financial support for urban planning and transit development, and adopts national policies to encourage more private investment in sustainable urban infrastructure projects (Steinhoff et al. 2015).

- *Providing better coordination of freight transport systems:* In the United States the locations of freight terminals are largely decided by city governments, which can lead to logistical inefficiencies where facilities serve larger metropolitan areas with multiple jurisdictions. Improved planning requirements and coordination at the national and state levels could improve local logistics and significantly reduce freight transport emissions (Brown et al. 2008).
- *Expanding utility rate reform to promote more energy efficiency and distributed renewable power:* As in China, there are opportunities in the United States to incentivize more utility investment in energy efficiency and enable the adoption of distributed energy resources, including renewables. Although a number of states have adopted rate "decoupling" rules for electricity and gas utilities,[4] like most energy efficiency policies these rules are far from universal (Morgan 2013). "Net metering" rules that allow distributed energy systems to sell power back to the grid have been widely adopted, but with significant differences among states (Durkay 2014). More widespread and coordinated adoption of consistent rules for promoting energy savings, combined with city-level action to encourage efficiency and distributed energy investments, could achieve significant GHG reductions (Brown et al. 2008).
- *Adopting more vertically coordinated policies to promote electric vehicles:* Under the right conditions, greater use of electric vehicles could significantly reduce GHG emissions from U.S. urban transport (Michalek 2015). The U.S. federal government and a number of states and cities are promoting electric vehicle use through a range of coordinated policies, including fuel economy standards, zero-emission vehicle programmes, subsidies, charging infrastructure funding and incentives, and a variety of local benefit and incentive programmes (Lutsey et al. 2015; Ribeiro et al. 2015). These efforts could be more widely adopted and expanded to further reduce U.S. urban transport emissions.

U.S. jurisdictions at multiple levels are pursuing a wide range of policies that are helping to contain urban-scale GHG emissions. The greatest challenge is a lack of political direction and policy coordination at the national level, leading to significant variations among states and cities. Urban actions to reduce GHG emissions could substantially assist the United States in meeting its overall climate policy goals (Steinhoff et al. 2015). Ultimately what is needed, however, is a more comprehensive and ambitious national policy regime. Replicating a multi-level, complementary policy approach like California's at the national level could both leverage and deepen urban GHG reductions.

6.3 Brazil

In Brazil, urban abatement potential is dominated by transport (passenger and freight) and the residential and commercial building sectors. Transport makes up the largest contribution to Brazil's GHG emissions from energy use (Lucon et al. 2015). There is an urgent need to make transportation improvements in Brazil's largest cities, not only to reduce GHG emissions, but to improve mobility and air quality. Electricity use in residential and commercial buildings accounts for about 50% of total power consumption in Brazil. While a large portion of electricity in Brazil is from hydropower, new demand is increasingly being met with fossil fuel

[4] Under decoupling policies, utility profits are realized independent of sales volumes, thus removing any disincentive for utilities to invest in consumer energy savings, or to allow on-site generation by customers.

electrical production. Energy efficiency has a key role to reduce electricity demand, improve electricity reliability, and reduce energy costs for households.

Brazil is a federal republic; the independence of states and local levels of government is guaranteed under the Constitution. In contrast to the trend toward centralization in other Latin American countries, in Brazil the trend has been for subnational governments to exert ever more authority. While the majority of tax revenue is collected at the federal level, a third of the revenue in Brazil is controlled by state and local governments (Ter-Minassian 2012).

States and cities legally have a fair degree of regulatory authority to implement emission reduction policies, but in practice there has been resistance at the federal level driven by a desire for more centralized authority. This tension was seen recently as efforts by the state of Rio de Janeiro to establish a carbon market met with significant resistance from the federal government, even though the state legally had the regulatory authority to put the system in place. On other issues, however, such as air quality, many states have used their authority to enact more stringent standards than those set by federal regulations.

Cities play a key role in Brazil. Brazil has one of the largest urban populations in the world, nearly 175 million people. Urban development is a key national priority in Brazil, and national efforts to address poverty and equity will be focused in cities. Analyses by Kahn and Brandao (2015) and Lucon et al. (2015) highlight significant opportunities for urban GHG abatement in Brazilian cities. Some of the greatest potential lies in distributed renewable energy penetration, shifting modes of transportation, improving fuel efficiency of vehicles, increasing the energy efficiency of residential and commercial buildings, and improving waste management reforms. Some of opportunities for vertically integrated policy reforms to achieve the potential in each of these areas include:

- *Reforms at multiple levels to enable distributed energy penetration:* There is projected to be substantial potential for the expansion of renewable energy in Brazil, especially wind and solar. While the costs, especially for wind power, have come down significantly in recent years, expansion of wind power has been slow. Challenges with grid interconnections and reliability to meet baseload and peak demand have been barriers to the development of renewables (Lucon et al. 2015). At the federal level, the Climate Fund Programme of the Ministry of the Environment could be a vehicle for federal incentives to support wind and solar (Lucon et al. 2015). In 2012, federal legislation authorized net metering for residential and commercial entities for solar installations up to 1 MW in capacity. Under the law, local governments can have a key role in enabling renewable power production through regulation, incentives and education. These could include facilitating permitting of rooftop solar installations or providing property tax incentives. Effective communication and outreach to households, as well as serving as a convener of municipal corporations and builders, developers and architects can accelerate the development and deployment of renewable energy (Bakshi 2012).
- *Expanding city government roles in energy efficiency labelling and outreach programmes:* In 2009 a federal voluntary building energy labelling system for commercial, public and services buildings was released, followed by a residential labelling scheme in 2010 (Scalco et al. 2012). Following the guidelines defined by this Brazilian Labelling Programme, there is the potential to achieve 50% energy savings for new buildings and 30% energy savings through building retrofits (Kahn and Brandao 2015).

The federal government has supported energy efficiency improvements through demonstration projects, such as the application of the building labelling programme to a federally funded building in Brasilia, and government procurement, such as the requirement that homes built through the federal housing assistance programme "Minha Casa, Minha Vida" must include solar water heaters (Lucon et al. 2015; Amorim et al. 2010).

Cities in Brazil can play a critical role in the implementation of national guidelines and standards, through regulation, education/outreach, and checking compliance. For example, the city of São Paulo passed a solar ordinance requiring that all new residential, commercial and industrial building install solar water heating systems (da Schio 2012). This ordinance is part of the city's building code and in line with the national building energy efficiency programmes. In 2012 Rio de Janeiro established a programme where new commercial and multifamily residential buildings that implement sustainability measures and achieve specific green building standards are eligible to receive tax benefits (World Green Building Council 2014).

- *Diversifying and integrating transportation systems:* Modal shift, especially related to freight transport, is a key need in Brazil. Currently freight transport inefficiently relies on roads, without suitable, more efficient alternatives such as rail or waterways (Lucon et al. 2015). While investment is a critical part in improving rail and waterway infrastructure, Lucon et al. (2015) emphasize the potential gains to be made by improving coordination of transportation planning and streamlining regulatory permitting requirements. Specifically, they recommend that the multi-level environmental licensing laws in Brazil be streamlined at the national level by the Ministry of Environment. They find this could be accomplished without compromising environmental integrity. Local governments have a role to ensure improvements made at the federal level are implemented by overseeing the local adoption of logistics management rules and requirements for freight transport.
- Brazil's national plan for improving urban mobility through infrastructure improvements and reducing reliance on personal vehicles is projected to reduce GHG emissions from passenger road transport by a total of 19.5 Mt CO_2e by 2020 relative to business as usual. The Ministry of Cities could encourage local governments to create local mass transit plans under the National Mobility Plan by offering incentives and other forms of support (Lucon et al. 2015). Local governments have the authority to design and implement several traffic management systems such as parking restrictions, as has been done in São Paulo and other cities in Latin America (Lucon et al. 2015), and congestion charges. As in the U.S, Brazilian city leaders are interested in expanding mass transit, but lack of funds for major infrastructure improvements is a primary barrier. Cities also find it difficult to secure finance for such projects. Federal support via federal banks or coordination with development banks through the federal government is needed to support local action on transportation.
- *Promoting vehicle electrification and transportation biofuels:* Vehicle and fuel efficiency standards are dependent on federal regulations, though cities can and do set air quality regulations. In 2012, the Sectoral Plan for Transport and Urban Mobility for the Mitigation of Climate Change (PSTM), included a proposal to develop energy efficiency standards for the light- and heavy-duty vehicle fleets (MMA, 2012). However, the current National Plan of Logistics and Transport (PNLT) includes only business-as-usual gains in energy efficiency of vehicles. There have been limited incentives and regulation at the national level to support bringing Brazilian vehicle

standards in line with international best practices (Lucon et al. 2015). Some federal policies have actually exacerbated the challenges, including fuel subsidies for fossil fuels that make ethanol less attractive, and a temporary elimination of taxes applied to new cars that led to higher auto sales and more vehicle travel.

Although vehicle standards need to be set at the federal level, local government can enable effectiveness of regulation by requiring mandatory inspections and maintenance programmes for vehicle licensing (Lucon et al. 2015). This could start with heavy duty vehicles and be voluntary for light-duty vehicles.

To date there has been limited uptake of electric vehicles in Brazil. One exception is the city of Curitiba, which has implemented a hybrid bus system. Local and federal authorities could coordinate to incentivize further electrification of public transit buses (D'Agosto et al. 2013). Local governments could enable local permitting of the charging stations and provide local incentives for the transit system, while at the federal level, tax incentives for public transit vehicles or other supporting electricity utility infrastructure could be provided.

In many sectors, recent adoption of national guidelines can serve to provide policy direction for local and state governments. The critical next juncture is to ensure that these guidelines are implemented successfully at the state and local levels. Brazil is a very heterogeneous country, and a key challenge is to ensure that all urban areas, not just the wealthiest cities, are also supported to move towards a low-carbon development path. Looking ahead, there is also need to ratchet up national standards, through mandatory standards and local enforcement, including adoption of mandatory building energy codes.

7. CONCLUSIONS

Action by city governments is essential for achieving deep reductions in global GHG emissions, andmany cities are already playing a crucial role in mitigating climate change. Cities can be policy innovators, testing new approaches, demonstrating best practices, and paving the way for ambitious national action. Using policy levers currently at their disposal, cities can contribute substantially to both global and national climate policy goals.

Greater action and support from national governments, however, could help reduce city-related GHG emissions more fully, quickly and cost-effectively. Under an ideal policy scenario, with all levels of government working together to achieve full urban mitigation potential, the need for city government innovation and experimentation would be reduced. Instead, national, state and local governments could coordinate policies for maximum effectiveness. With greater policy coordination, cities could focus on roles and actions for which they are highly capable and best positioned.

Cities have distinct comparative advantages as governing bodies that make them a logical choice for directing, administering, and complementing urban mitigation strategies. In a coordinated and vertically integrated approach to urban GHG abatement, city governments will have different roles to play depending on the types of policies and actions required. For about 20% of urban GHG abatement potential, we view cities as policy leaders and architects, with supporting actions from national governments as appropriate. For another 40% of urban abatement potential, cities could act as critically important policy implementers. For the remaining 40% of urban abatement, cities can take crucial independent actions to complement and enhance the effectiveness of policies enacted at higher levels of government.

Comprehensively engaging cities in climate policy will require certain enabling actions. Globally, the predominant need in terms of overall abatement potential is to build cities' technical capacity, whether they serve as policy leads, implementers, or strategic partners. This is especially true for actions to address energy use in residential and commercial buildings; about two-thirds of urban abatement potential in 2030 could come from these actions (and more than 55% in 2050). Here, in a fully vertically integrated scenario, city governments could play essential implementation and complementary-action roles. Training and education for city government staff on the application of building codes and ensuring compliance with them will be essential.

Increased access to financial resources is a close second in terms of priority enabling actions. Efforts to improve transportation efficiency, for example, may require major investments in public transit systems, for which city governments will need new sources of revenue. Vehicle electrification may also require significant local infrastructure investment. Aside from capital investments, cities will need staffing and resources to carry out important implementation roles, especially related to energy efficiency. Funding from national or state governments, as well as financial backing or fiscal policy reforms that improve cities' access to capital, will be a critical part of vertically integrated approaches.

Finally, national governments can in many cases enable city action by better aligning policies and eliminating conflicts or constraints on city government authority. This is especially true for areas where the cities' ideal role is to be policy leads and implementers. Specific reforms will depend on the country context, but greater vertical integration will generally require national governments to create regional coordinating bodies, authorize local taxes or subsidies, and ensure that other policies and mandates affecting city decision-making are aligned with climate policy objectives.

Many cities are already taking aggressive actions to reduce GHG emissions. Under transnational initiatives such as the Compact of Mayors, cities are playing the role of policy innovators, helping to build capacity and political support for more ambitious national action, demonstrate best practices, and achieve GHG reductions in their own right. National governments, in pursuing more vertically integrated policy frameworks, can build on cities existing efforts and help harness the potential for urban GHG abatement. Our survey of opportunities in China, the United States, and Brazil indicates that, while there are elements of vertically integrated policy approaches in all three countries, the greatest needs are for national governments to increase the ambition of national policies, and to better enable city governments to be effective in their roles. This could include engaging cities in efforts to control additional sources of emissions, as Chinese cities are doing with respect to industrial energy-use targets.

As progressive cities engage with one another and with state and national governments on climate policy, it will be important to work towards integrated policies that achieve deep GHG reductions from urban activities. The assessment presented here can be used as a starting point for envisioning these policies and prioritizing enabling actions by national governments – or the international community – aimed at enhancing cities' resources, capacities, and authorities related to GHG mitigation.

REFERENCES

ACEEE (2015). States don't need to gamble with EPA rulemaking. Energy efficiency can achieve two-thirds or more of Clean Power Plan targets. 18 June. http://aceee.org/blog/2015/06/states-dont-need-gamble-epa.

Amorim, C. N. D., Cintra, M. S., Silva, C. F., Fernandes, J. T. and Sudbrack, L. O. (2010). Energy Efficiency Code in Brazil: Experiences in the First Public Building Labeled in Brazilia. Fourth National Conference of IBPSA-USA, 11-13 August, New York, NY. http://www.ibpsa.us/publications/energy-efficiency-code-brazil-experiences-first-public-building-labeled-brasilia%E2%80%A8.

Anton, B., Cambray, A., Dupar, M., Westerlind-Wigstroem, A. and Gogoi, E. (2014). *Close to Home: Subnational Strategies for Climate Compatible Development*. CDKN Working Paper. ICLEI, Climate & Development Knowledge Network, Overseas Development Institute, and PwC. http://cdkn.org/resource/close-to-home-subnational-strategies-for-climate-compatible-development/.

Aoki, K. (2010). Determinants of the Possibilities and Impossibilities of the Japanese Local Governments' Progressive Low Carbon Measures: Case Studies of the Policy Processes at the Tokyo Metropolitan Government, Nagano, and Iwate Prefectures. 2nd UNITAR-Yale Conference on Environmental Governance & Democracy, 17 September, Yale University, New Haven, CT, US. http://conference.unitar.org/yale/sites/conference.unitar.org.yale/files/Paper_Aoki.pdf.

Arup and C40 Cities (2014). *Climate Action in Megacities: C40 Cities Baseline and Opportunities: Version 2.0*. Arup for C40 Cities, London and New York. http://www.arup.com/Projects/C40_Cities_Climate_Action_in_Megacities_report.aspx.

Bakshi, S. K. (2012). Role of local governments in fostering the transition to sustainable lifestyles and livelihoods and improved well-being. Global Research Forum on Sustainable Consumption and Production Workshop, 13-15 June, Rio de Janeiro, Brazil. http://grf-spc.weebly.com/uploads/2/1/3/3/21333498/grf-2012-rio-kapur.pdf.

Bin, S. and Jun, L. (2012). *Building Energy Efficiency Policies in China - Status Report*. Global Buildings Performance Network. http://www.gbpn.org/reports/building-energy-efficiency-policies-china-status-report.

Brown, M., Southworth, F. and Sarzynski, A. (2008). *Shrinking the Carbon Footprint of Metropolitan America*. Brookings Institution, Washington, DC. http://www.brookings.edu/research/reports/2008/05/carbon-footprint-sarzynski.

Bulkeley, H. (2010). Cities and the Governing of Climate Change. *Annual Review of Environment and Resources*, 35(1). 229–53. DOI:10.1146/annurev-environ-072809-101747.

Bulkeley, H. and Castán Broto, V. (2013). Government by experiment? Global cities and the governing of climate change. *Transactions of the Institute of British Geographers*, 38(3). 361–75. DOI:10.1111/j.1475-5661.2012.00535.x.

Bushnell, J., Peterman, C. and Wolfram, C. (2007). *Local Solutions to Global Problems: Policy Choice and Regulatory Jurisdiction*. 13472. National Bureau of Economic Research. http://www.nber.org/papers/w13472.

California Air Resources Board (2014). Assembly Bill 32 - California Global Warming Solutions Act. http://www.arb.ca.gov/cc/ab32/ab32.htm.

California Air Resources Board (2015). Senate Bill 375 Regional Targets. http://www.arb.ca.gov/cc/sb375/sb375.htm.

Chan, S., Asselt, V., Harro, Hale, T., Abbott, K. W., et al. (2015). *Reinvigorating International Climate Policy: A Comprehensive Framework for Effective Nonstate Action*. ID 2654214. Social Science Research Network, Rochester, NY. http://papers.ssrn.com/abstract=2654214.

Climate Action Tracker (2015). *Effect of Current Pledges and Policies on Global Temperature*. Ecofys, Climate Analytics, PIK, New Climate Institute. http://climateactiontracker.org/global.html.

Collier, U. and Löfstedt, R. E. (1997). Think globally, act locally? Local climate change and energy policies in Sweden and the UK. *Global Environmental Change*, 7(1). 25–40. DOI:10.1016/S0959-3780(96)00025-8.

Corfee-Morlot, J., Kamal-Chaoui, L., Donovan, M. G., Cochran, I., Robert, A. and Teasdale, P.-J. (2009). *Cities, Climate Change and Multilevel Governance*. Organisation for Economic Co-operation and Development, Paris. http://www.oecd-ilibrary.org/content/workingpaper/220062444715.

Crossley, D. (2013). *Energy Efficiency in China*. Reprint of Climate Spectator series, 12-14 February 2013. The Regulatory Assistance Project. http://www.raponline.org/document/download/id/4414.

D'Agosto, M. de A., Ribeiro, S. K. and de Souza, C. D. R. (2013). Opportunity to reduce greenhouse gas by the use of alternative fuels and technologies in urban public transport in Brazil. *Energy systems*, 5(2). 177–83. DOI:10.1016/j.cosust.2013.03.003.

da Schio, N. (2012). *Local Government Regulation Ordinances and Laws to Promote Renewable Energy: City in Focus Sao Paulo, Brazil*. International Renewable Energy Agency, Abu Dhabi, UAE. https://www.irena.org/Publications/RE_Policy_Cities_CaseStudies/IRENA%20cities%20case%206%20Sao%20Paulo.pdf.

Durkay, J. (2014). *Net Metering: Policy Overview and State Legislative Updates*. National Conference of State Legislatures, Denver, CO, and Washington, DC. http://www.ncsl.org/research/energy/net-metering-policy-overview-and-state-legislative-updates.aspx.

Erickson, P., Lazarus, M., Chandler, C. and Schultz, S. (2013). Technologies, policies and measures for GHG abatement at the urban scale. *Greenhouse Gas Measurement and Management*, 3(1-02). 37–54. DOI:10.1080/20430779.2013.806866.

Erickson, P. and Tempest, K. (2014). *Advancing Climate Ambition: How City-Scale Actions Can Contribute to Global Climate Goals*. SEI Working Paper No. 2014-06. Stockholm Environment Institute, Seattle, WA, US. http://sei-international.org/publications?pid=2582.

Esty, D. C. (2014). Bottom-Up Climate Fix. *The New York Times*, 21 September. http://www.nytimes.com/2014/09/22/opinion/bottom-up-climate-fix.html.

GEA (2012). *Global Energy Assessment – Toward a Sustainable Future*. Cambridge University Press, Cambridge, UK and New York, and International Institute for Applied Systems Analysis, Laxenburg, Austria. http://www.globalenergyassessment.org.

Gouldson, A., Colebrander, S., Godfrey, N., Sudmant, A., Millward-Hopkins, J., Fang, W. and Zhao, X. (2015). *Accelerating Low-Carbon Development in the World's Cities*. A New Climate Economy contributing paper for Seizing the Global Opportunity: Partnerships for Better Growth and a Better Climate. London and Washington, DC. http://2015.newclimateeconomy.report/misc/working-papers/.

Harrison, N. and Muller, S. (2014). *What National Governments Can Do to Accelerate Subnational Action on Climate*. Ecofys for LEDS Global Partnership, Utrecht, Netherlands. http://www.ecofys.com/en/news/what-national-governments-can-do-to-accelerate-subnational-action-on-climat/.

Harrison, N., Muller, S., van Staden, M., Marques, A., Benioff, R. and Kelly, A. (2014). *Integrating National and Sub-National Climate Action: Resource Guide*. Low Emissions Development Strategies (LEDS) Global Partnership Working Group on Sub-national Integration. http://en.openei.org/wiki/LEDSGP/planning/NationalSubnationalLEDS.

Harrison, N., Roeser, F., Halcomb, J. and Lindner, S. (2013). *Sub-National Involvement in NAMA Development*. Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH. http://mitigationpartnership.net/giz-2013-sub-national-involvement-nama-development.

Hoffmann, M. (2011). *Climate Governance at the Crossroads*. Oxford University Press, New York.

Hoornweg, D., Freire, M., Lee, M. J., Bhada-Tata, P. and Yuen, B. (2011). *Cities and Climate Change : Responding to an Urgent Agenda*. World Bank. https://openknowledge.worldbank.org/handle/10986/2312.

IEA (2013). *A Tale of Renewed Cities: A Policy Guide on How to Transform Cities by Improving Energy Efficiency in Urban Transport Systems*. Policy Pathway. International Energy Agency, Paris. http://www.iea.org/publications/freepublications/publication/renewed_cities_web.pdf.

IEA and UNDP (2013). *Modernising Building Energy Codes to Secure Our Global Energy Future*. International Energy Agency and United Nations Development Programme. http://www.iea.org/publications/freepublications/publication/policy-pathways-modernising-building-energy-codes.html.

IMT and NRDC (2014). *Establishing a Plan to Achieve Energy Code Compliance in Cities*. City Energy Project. Natural Resources Defense Council and the Institute for Market Transformation. http://www.imt.org/resources/detail/establishing-a-plan-to-achieve-energy-code-compliance-in-cities.

Kahn, S. and Brandao, I. (2015). *The Contribution of Low-Carbon Cities to Brazil's Greenhouse Gas Emissions Reduction Goals*. Briefing on urban energy use and greenhouse gas emissions. Federal University of Rio de Janeiro (UFRJ) and Stockholm Environment Institute, Rio de Janeiro and Seattle, WA, US. http://www.bloomberg.org/press/releases/brazilian-cities-aligning-growth-with-sustainable-urban-development/.

Kousky, C. and Schneider, S. H. (2003). Global climate policy: will cities lead the way? *Climate Policy*, 3(4). 359–72. DOI:10.1016/j.clipol.2003.08.002.

Lazarus, M., Chandler, C. and Erickson, P. (2013). A core framework and scenario for deep GHG reductions at the city scale. *Energy Policy*, 57. 563–74. DOI:10.1016/j.enpol.2013.02.031.

Levine, M., de la Rue du Can, S., Zheng, N., Williams, C., Amann, J. and Staniaszek, D. (2012). *Building Energy-Efficiency Best Practice Policies and Policy Packages*. LBNL Paper LBNL-6006E. Lawrence Berkeley National Laboratory. http://escholarship.org/uc/item/5206n1xr.

Lo, K. (2013). A Critical Review of China's Rapidly Developing Renewable Energy and Energy Efficiency Policies. *Renewable and Sustainable Energy Reviews*, 29. 508–16. DOI:10.1016/j.rser.2013.09.006.

Lucon, O., Romiero, V. and Fransen, T. (2015). *Bridging the Gap Between Energy and Climate Policies in Brazil: Policy Options to Reduce Energy-Related GHG Emissions*. World Resources Institute, Washington, DC. http://www.wri.org/publication/bridging-gap-between-energy-and-climate-policies-brasil.

Lutsey, N., Searle, S., Chambliss, S. and Bandivadekar, A. (2015). *Assessment of Leading Electric Vehicle Promotion Activities in United States Cities*. International Council on Clean Transportation. http://www.theicct.org/leading-us-city-electric-vehicle-activities.

Michalek, J. J. (2015). *Electric Vehicle Benefits and Costs in the United States*. Carnegie Mellon Vehicle Electrification Group. http://www.cmu.edu/epp/policy-briefs/briefs/Electric-Vehicles-Costs-Benefits.pdf.

Millard-Ball, A. (2012). Do city climate plans reduce emissions? *Journal of Urban Economics*, 71(3). 289–311. DOI:10.1016/j.jue.2011.12.004.

Morgan, P. (2013). *A Decade of Decoupling for US Energy Utilities: Rate Impacts, Designs, and Observations*. Graceful Systems LLC. http://aceee.org/collaborative-report/decade-of-decoupling.

Oates, W. E. (1999). An Essay on Fiscal Federalism. *Journal of Economic Literature*, 37(3). 1120–49. DOI:10.1257/jel.37.3.1120.

OECD (2010). *Cities and Climate Change*. OECD Publishing, Paris. http://www.oecd-ilibrary.org/governance/cities-and-climate-change_9789264091375-en.

OECD (2013). *Green Growth in Cities*. OECD Green Growth Studies. OECD Publishing, Paris. http://dx.doi.org/10.1787/9789264195325-en.

OECD and Bloomberg Philanthropies (2014). *Cities and Climate Change: Policy Perspectives*. Prepared as an input to the OECD Leaders Seminar with Michael R. Bloomberg, UN Special Envoy for Cities and Climate Change. http://www.oecd.org/env/cc/Cities-and-climate-change-2014-Policy-Perspectives-Final-web.pdf.

Ohshita, S., Price, L., Zhou, N., Khanna, N., Fridley, D. and Liu, X. (2015). *The Role of Chinese Cities in Greenhouse Gas Emission Reduction: Briefing on Urban Energy Use and Greenhouse Gas Emissions*. China Energy Group, Lawrence Berkeley National Laboratory, and Stockholm Environment Institute, Berkeley, CA, and Seattle, WA, US. http://www.bloomberg.org/press/releases/chinese-cities-as-leaders-in-greenhouse-gas-emissions-reduction-efforts/.

Oliveira, J. A. P. de (2009). The implementation of climate change related policies at the subnational level: An analysis of three countries. *Habitat International*, 33(3). 253–59. DOI:10.1016/j.habitatint.2008.10.006.

Palmer, K. L., Grausz, S., Beasley, B. and Brennan, T. J. (2012). *Putting a Floor on Energy Savings: Comparing State Energy Efficiency Resource Standards*. http://www.rff.org/News/Features/Pages/Energy-Efficiency-Resource-Standards-Comparisons-and-a-Closer-Look.aspx.

Price, L., Levine, M. D., Zhou, N., Fridley, D., Aden, N., et al. (2011). Assessment of China's energy-saving and emission-reduction accomplishments and opportunities during the 11th Five Year Plan. *Energy Policy*, 39(4). 2165–78. DOI:10.1016/j.enpol.2011.02.006.

Regulatory Assistance Project (2015). *Low-Carbon Power Sector Regulation: Options for China*. World Bank / ESMAP. www.raponline.org/document/download/id/7582.

Reklev, S. (2015). Tight controls, strict penalties, and a stability reserve: draft of China's national carbon market rules emerges. *Carbon Pulse*, 28 October. http://carbon-pulse.com/exclusive-draft-of-chinas-national-carbon-market-rules-emerges/.

Ribeiro, D., Hewitt, V., Mackres, E., Cluett, R., Ross, L. M., Vaidyanathan, S. and Zerbonne, S. (2015). *The 2015 City Energy Efficiency Scorecard*. U1502. American Council for an Energy-Efficient Economy. http://aceee.org/local-policy/city-scorecard.

Rodrigo, D., Allio, L. and Andres-Amo, P. (2009). *Multi-Level Regulatory Governance: Policies, Institutions and Tools for Regulatory Quality and Policy Coherence*. 13. OECD Publishing. https://ideas.repec.org/p/oec/govaaa/13-en.html.

Scalco, V. A., Fossati, M., de Souza Versage, R., Sorgato, M. J., Lamberts, R. and Morishita, C. (2012). Innovations in the Brazilian regulations for energy efficiency of residential buildings. *Architectural Science Review*, 55(1). 71–81. DOI:10.1080/00038628.2011.641731.

Seto, K. C., Dhakal, S., Bigio, A., Blanco, H., Delgado, G. C., et al. (2014). Chapter 12: Human settlements, infrastructure, and spatial planning. In *Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. O. Edenhofer, R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, et al. (eds.). Cambridge University Press, Cambridge, UK, and New York. https://www.ipcc.ch/report/ar5/wg3/.

Somanathan, E., Sterner, T., Sugiyama, T., Chimanikire, D., Dubash, N. K., et al. (2014). National and sub-national policies and institutions. In *Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. O. Edenhofer, R. Pichs-Madruga, Y. Sokona, E. Farahani, E., S. Kadner, et al. (eds.). Cambridge University Press, Cambridge, UK and New York. https://www.ipcc.ch/report/ar5/wg3/.

Steinhoff, M., Wei, J. and Taylor, K. (2015). *Measuring up 2015: How U.S. Cities Are Accelerating Progress towards National Climate Goals*. WWF and ICLEI-USA. Measuring up 2015: How U.S. Cities Are Accelerating Progress towards National Climate Goals.

Ter-Minassian, T. (2012). *Reform Priorities for Sub-National Revenues in Brazil*. Department of Research and Chief Economist, No. IDB-PB-157. Inter-American Development Bank. http://www.iadb.org/wmsfiles/products/publications/documents/36903959.pdf.

UN-Habitat (2013). *Addressing Urban Issues in National Climate Change Policies*. Cities and Climate Change Initiative, Policy Note 3. United Nations Human Settlements Programme. http://unhabitat.org/addressing-urban-issues-in-national-climate-change-policies-cities-and-climate-change-initiative-policy-note-3/.

U.S. EPA (2015a). Clean Power Plan for Existing Power Plants. 28 October. http://www2.epa.gov/cleanpowerplan/clean-power-plan-existing-power-plants.

U.S. EPA (2015b). Transportation and Climate: Regulations & Standards. 3 November. http://www3.epa.gov/otaq/climate/regulations.htm.

Wiener, J. (2007). Think Globally, Act Globally: The Limits of Local Climate Policies. *University of Pennsylvania Law Review*, 155. 101–19.

World Green Building Council (2014). *Rio de Janeiro*. Green Building City Market Brief. http://www.worldgbc.org/files/2614/0982/5905/Rio_de_Janeiro_-_City_Market_Brief_Final.pdf.

Zheng, Y. (2006). Explaining the Sources of de facto Federalism in Reform China: Intergovernmental Decentralization, Globalization, and Central–Local Relations. *Japanese Journal of Political Science*, 7(02). 101–26. DOI:10.1017/S1468109906002222.

Zhou, N., Mcneil, M. and Levine, M. (2012). Assessment of building energy-saving policies and programs in China during the 11th Five-Year Plan. *Energy Efficiency*, 5(1). 51–64. DOI:10.1007/s12053-011-9111-0.

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