



The international implications of national and local coordination on building energy codes: Case studies in six cities

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ABSTRACT

Building energy efficiency is an important strategy for reducing greenhouse gas emissions globally. In fact, 55 countries have included building energy efficiency in their Nationally Determined Contributions (NDCs) under the Paris Agreement. This research uses building energy code implementation in six cities across different continents as case studies to assess what it may take for countries to implement the ambitions of their energy efficiency goals. Specifically, we look at the cases of Bogota, Colombia; Da Nang, Vietnam; Eskisehir, Turkey; Mexico City, Mexico; Rajkot, India; and Tshwane, South Africa, all of which are “deep dive” cities under the Sustainable Energy for All's Building Efficiency Accelerator. The research focuses on understanding the baseline with existing gaps in implementation and coordination. The methodology used a combination of surveys on code status and interviews with stakeholders at the local and national level, as well as review of published documents. We looked at code development, implementation, and evaluation. The cities are all working to improve implementation, however, the challenges they currently face include gaps in resources, capacity, tools, and institutions to check for compliance. Better coordination between national and local governments could help improve implementation, but that coordination is not yet well established. For example, all six of the cities reported that there was little to no involvement of local stakeholders in development of the national code; only one city reported that it had access to national funding to support code implementation. More robust coordination could better link cities with capacity building and funding for compliance, and ensure that the code reflects local priorities. Understanding gaps in implementation can also help in designing more targeted interventions to scale up energy savings.

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1. Introduction

Building energy efficiency plays a central role in national strategies to achieve emissions reductions (Evans, 2017). In fact, 55 countries have included building energy efficiency in their Nationally Determined Contributions (NDCs), i.e., national pledges, under the Paris Agreement, and more are likely to join as countries flesh out the details on how they will achieve their emissions targets.¹ Buildings currently represent about 1/3 of total global energy demand, and this share is growing (IEA, 2013b). Buildings also have

many opportunities to save energy while simultaneously saving money (IEA, 2014a). Yet this low-hanging fruit in the buildings sector also indicates the challenges with achieving energy efficiency in the built environment.

This article focuses on building energy codes, which have significant potential to save energy. Building energy codes also represent a particularly cost-effective approach to achieving savings because they integrate efficiency measures during initial construction. Codes also play an important role because they help lock in an energy efficient footprint for the life of a building. Depending on the region of the world, buildings typically last between 30 and 100 years (Johansson et al., 2012).

The Intergovernmental Panel on Climate Change has found that building energy codes are one of the most effective mechanisms to reduce carbon emissions from the building sector in the coming decades (Lucon et al., 2014). Studies in Europe have found that codes have achieved reductions in average residential energy use

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¹ Since the research was completed, the United States has submitted notification to the UN that it intends to withdraw from the Agreement as soon as it is eligible to do so. The U.S. President has indicated that the U.S. will not implement the NDC submitted by the previous administration.

of 6–22%, depending on the country and code stringency (IEA, 2013a). Codes can also be very cost effective. A study in the United States found, for example, that current codes can save \$126 billion between 2010 and 2040, at relatively modest compliance costs (Athalye et al., 2016; Williams et al., 2014). Codes have a payback period in U.S. homes on average of 3.45 years (Paquette et al., 2010). It can be quite costly after a building is built to change windows, walls, insulation, and even heating and cooling systems, which means that more often than not, these core elements of a building tend to remain fixed for long periods. Building energy codes, when implemented, mainstream energy efficiency by requiring it in all new buildings. This in turn can help lower costs and build capacity, which can make retrofits, above-code buildings, and improvements to the code over time more achievable.

However, achieving the potential of building energy codes (and other energy efficiency policies) requires effective implementation systems. Countries like the United States and China have found that robust implementation systems can lead to compliance rates of 80–100% (DOE, 2015; Shui and Nadel, 2012). However, in many countries implementation remains one of the major challenges of reducing emissions through buildings. Most codes are implemented at the local level, while national governments typically develop the codes and NDCs.

Implementing building energy codes with a high level of compliance usually requires resources, capacity, and institutions to check for compliance. Local building permitting offices are often short-staffed, and, in developing countries, they may have limited resources to check for basic safety and health issues. Local officials may also have limited technical knowledge of energy issues in buildings. Improving compliance typically requires resources to pay for staff to review building plans and inspect construction sites (whether these are government or private third parties). It may also require investment in training and software tools to help with compliance. In addition, having a clear set of rules and reporting structures can help streamline compliance.

This paper uses building efficiency, and building energy codes in particular, as a case study on what it may take for countries to reach their targets. Our central research questions are to identify the gaps that countries and cities are experiencing in implementing building energy codes and whether coordination with national governments is helping to fill these gaps.

2. Literature review

A small but growing body of literature has been published on development, implementation, and enforcement of building energy codes, and their role in improving energy efficiency in new and existing buildings. Implementation and robust compliance are key to capturing the full advantages of building energy codes (Yu et al., 2014). The literature examining building energy codes primarily looks either at national level trends, or at specific local case studies. Few studies to date have considered the interactions between national and local governments in developing and implementing building energy codes and other building energy policies.

One group of studies reviewed the status of building energy codes and key elements to promote code implementation in countries. Evans et al. (2017b) examined building energy codes in 22 countries at the national level, looking at key elements of implementation systems across these countries. IEA (2013a), Laustsen (2008), and Liu et al. (2010) also examine the experience with building energy codes at the national and specific case studies to assess best practices. Levine et al. (2012) reviewed building energy efficiency policies including energy codes in the United States,

European Union, China, and India. Concluding that building energy codes are the most effective policy option to reduce buildings energy use, Levine et al. (2012) listed trainings for stakeholders, regular updates to the standards, and early announcement of codes revisions as key factors in making building energy codes effective. Guo et al. (2016) and Evans et al. (2010) analyzed the building energy codes framework in China and identified the supervision and inspection systems as the key factors in the successful enforcement of mandatory building energy codes. Huang et al. (2016) analyzed and compared national and regional building energy efficiency policies in China and Japan using stakeholder interviews, literature review, and a typology from the United Nations Environment Programme on policy actions.

Another group of studies examined building energy efficiency at the local level. A report from the World Bank (ESMAP, 2011) provided a comprehensive analysis of implementation and enforcement of building energy codes in Tianjin, China. In an analysis of performance-based building codes in Hong Kong, Hui (2002) argued that this type of code requires advanced skills from building designers and code users as implementation and validation of these codes is more complicated. Evans et al. (2014) explored trends in rural building energy use in China and found that implementation of building energy codes in rural China faces a number of challenges. In a broader perspective, Fudge et al. (2016), used a “Multi-Level Perspective” framework, drawing on qualitative data gathered through interviews with local authorities in the United Kingdom. The article explored the interactions and challenges associated with the role of local government in the sustainable energy transition, concluding that there is a need to build the energy-related capacity of local authorities.

However, neither set of literature explored how the national government works with state and local governments to roll out these policies and how local players interacted with national government in policy implementation.

National-subnational coordination is critical to fulfilling clean energy goals as well as climate targets (Busche, 2010; Cox, 2016). Li and Shui (2015) and Khosla et al. (2017), taking China and India as examples, investigated how multi-level governance is used to implement building energy policies. Li and Shui (2015) conducted a comprehensive review of building energy efficiency policies in China. Khosla et al. (2017) explored multilevel connections in India's building energy sector and found that interactions between different government levels can both promote as well as impede low-carbon technology deployment. These studies only used secondary information by reviewing existing literature and data in China and India. However, first-hand information can improve the understanding of real-world challenges and opportunities in implementing building energy policies. In addition, as countries have their own circumstances, compared to the study of a single country, cross-country analysis can help address building energy efficiency issues to a broader audience.

We believe this paper fills some important gaps in the literature. First, there is limited research to date examining the real-world capacity for and coordination on implementing specific, sectoral commitments, in other words, for implementation of the core plans to reduce greenhouse gas emissions. Second, this study involves interviews and analysis of stakeholders on the ground in specific cities that have made strong commitments in their own right. And third, we take a cross-cutting look using a standard methodology examining cities in six emerging economies spanning four continents. In summary, the existing literature examines discrete elements related to building energy sector policies, but not the importance of the linkages between local, national and international actors drawing on real-world information.

3. Methodology

We based our research on both national- and local-scale analyses and interviews to understand how national governments and cities are interacting in order to implement building energy codes and related policies. Specifically, our methodology included three major components, looking at the international, national, and local scales:

1. Analysis of international commitments under the Paris Agreement regarding building energy efficiency;
2. Surveys and interviews of cities implementing building energy codes in developing countries;
3. Interviews with national officials to better understand national code efforts and linkages with city efforts.

Thus, we began by examining national pledges (or Nationally Determined Contributions, NDCs) under the Paris Agreement. We searched in the relevant database of the United Nations' Framework Convention on Climate Change (UNFCCC) to understand what kinds of commitments countries were making regarding building energy efficiency. The most complete database covers the Intended Nationally Determined Contributions (or INDCs) submitted prior to the Paris Conference of Parties (UNFCCC, 2017); the UNFCCC has recently launched a second database of Nationally Determined Contributions, but it only includes a subset of the documents labeled as INDCs.² In particular, we searched the terms “construction”, “building”, and “housing”, and then reviewed the specific commitments to determine if they related to energy efficiency. We further searched to see if the countries with commitments related to building energy efficiency also had specific implementation plans for their NDCs (few do to date). We then reviewed the relevant text in both the NDCs and the implementation plans, checking in particular for the types of policies and programs involved in the commitments, whether the commitments involved building energy codes and whether they were based on specific, existing policies or more general plans.

To understand real-world capacity in implementing NDCs, we selected the countries and cities for the second part of this study by drawing on the “deep dive” cities that have committed to the Building Efficiency Accelerator (BEA). The BEA is an international partnership under the United Nations Sustainable Energy for All; it is led by the World Resources Institute and involves dozens of partners from around the world.³ The overall goal is to double the global rate of improvement in energy efficiency, which in turn supports global and national climate, energy and sustainability goals. Cities that join the BEA commit to implement one policy and one project, and to track their results. The BEA is testing different interventions to understand how best to support cities as they transform their building energy use. The interventions include guidance documents, targeted technical assistance, help with accessing financing, and peer-to-peer learning across the cities. The specific technical offerings are still being developed, tested and refined. The “deep dive” cities have a dedicated coordinator at the local level. The BEA “deep dive” cities involved in this research include: Bogota, Colombia; Da Nang, Vietnam; Eskisehir, Turkey; Mexico City, Mexico; Rajkot, India; and Tshwane, South Africa. Each

of these cities has selected building energy codes as their policy under the BEA. This study was designed as a baseline to understand the gaps cities face today that they would like to overcome in implementing their commitments, particularly related to codes.

We decided to use the BEA framework for several reasons. The cities have existing commitments to implement building energy codes. The local coordinator in each city provides a point of contact and facilitates information sharing. These cities also represent a diverse number of global regions, levels of development, and approaches to building energy codes. In addition, these cities are in the early stages of building energy code development and implementation, and their challenges and lessons learned are applicable to other emerging economies that attempt to develop and implement building energy codes.

We developed a survey ([Supplementary Information A](#)) to better understand the code and its implementation framework in each of the BEA cities. We adapted the survey from one that we developed for national governments under the International Partnership for Energy Efficiency Cooperation (IPEEC), so it was well-tested at the national level to ensure that the topics and terminology were well-adapted to a diverse range of approaches to building energy codes ([Evans et al., 2017b](#)). In some cases, the BEA city coordinators filled out the surveys, and in others, the research team filled them out based on information from the cities, and shared them with the cities for review.

We also held structured interviews with both city and national stakeholders to better understand coordination between the national and local governments. We selected the national stakeholders for interviews based primarily on the recommendations of the city stakeholders. In the cases of India and Vietnam, we also used experience working on building energy codes with these governments in recent years to add further nuance to our research results. Through these interviews, we wanted to understand what formal and informal coordination exists for code development, training, and implementation. We also sought to understand gaps. We compared the results from the city and national interviews in our analysis. A copy of the interview protocol is presented in [Supplementary Information B](#).

Finally, because the goal of the BEA is to achieve broad implementation of mitigation policies (and specifically building energy efficiency policies, in the case of the BEA), we also interviewed stakeholders on the potential of a toolkit to aide a broad number of cities. As part of this, we developed a structured toolkit with resources on building energy code development, adoption, implementation and evaluation ([Evans et al., 2017a](#)).

While we believe the findings in this research are valuable because of the importance of understanding national and subnational coordination on climate change mitigation, it is also important to note the limitations of this research. We include a relatively small number of cities in the research, and thus it is possible that with a broader set of cities, some of the findings would be different. Relatively few emerging economies have implemented building energy codes to date, though more have drafted building energy codes. We have also worked to interview both local and national stakeholders to get a more complete understanding of the situation and gaps in each of the cities, but in the case of South Africa, national officials were not available for comment. We thus sought to supplement our local interviews with other types of research on building energy efficiency and codes in South Africa in particular, but also in other countries. Finally, we have focused on gaps rather than potential solutions as a first step in understanding how to design impactful interventions. Testing solutions would also require a much lengthier timeframe, beyond the scope of this research.

² INDCs become NDCs when countries ratify the Paris Agreement, although in neither case are they binding.

³ Sustainable Energy for All is a global, multi-stakeholder partnership focused on concerted action to mitigate climate change in specific areas. Its Advisory Board is co-chaired by the UN Secretary General and the World Bank Group President, but the partners represent a broad spectrum of public, private and international organizations.

4. Results

4.1. Links between national energy and climate action plans and building energy efficiency

192 countries were parties to INDCs under the Paris Agreement; these are non-binding targets to limit greenhouse gas emissions. When countries ratify the Paris Agreement, their INDCs become NDCs. Many NDCs are broad, economy-wide targets, but a significant number also provide sectoral details on how countries plan to achieve their targets. 55 countries reference building energy efficiency policies and actions in their NDCs. Among the countries that mention building energy efficiency in their NDCs, 39 specifically reference plans related to building energy codes or standards. Countries that mention building energy efficiency in their NDCs collectively account for about half of global building energy use, or two-thirds if we also count the European Union. Of the five largest building energy consumers, all reference building energy efficiency and codes in their NDCs with the exception of Russia (IEA, 2014b; UNFCCC, 2017).

Countries mention several strategies for improving building energy efficiency in their national plans, including the following: building energy codes for new and existing stock, energy efficiency resource standards, rating systems, renovation targets, and energy consumption goals.

As countries prepare detailed implementation plans and strategies on their national plans, many more are expected to include building energy efficiency. For example, the European Union submitted a single NDC for all its members with an economy-wide emissions reduction target; France has published a more detailed climate strategy outlining its plans to meet the target, and buildings play a prominent role in this document. However, few countries to date have published detailed strategies. In the NDCs themselves, only 11 of the countries with building energy efficiency commitments reference existing policies and measures. The lack of detailed plans and existing policies point to significant work ahead as countries take steps to achieve their targets (UNFCCC, 2017).

As we interviewed city officials and stakeholders, we found that few if any were aware of the national government's plans on the NDCs relating to building efficiency. For the most part, national governments have not yet reached out to cities to coordinate specifically regarding the NDCs, implementation plans and potential climate financing.

Building energy codes provide an interesting and concrete example of how this coordination or lack thereof currently impacts implementation of policies that help reduce emissions.

4.2. Building energy codes

To better understand how national governments and cities are interacting in order to implement building energy codes and related policies, we surveyed and interviewed national and city stakeholders from the following cities/countries: Bogota, Colombia; Da Nang, Vietnam; Eskisehir, Turkey; Mexico City, Mexico; Rajkot, India; and Tshwane, South Africa. These results focus more on the current state of development and implementation and less on the cities' plans and goals.

4.2.1. City surveys

Cities were surveyed to better understand the code and its implementation framework. The survey (Supplementary Information A) is structured according to the following three elements: development, implementation, and compliance and enforcement. Tables 1–3 show selected results from the surveys collected.

Code Development: All the cities in this study have a national building energy code for their country, but in countries with a federal form of government, the code must be adopted at the local level; Mexico City and Rajkot have not yet adopted their national code but have committed to do so in the near future. Presently, Mexico City has energy efficiency standards that apply to both building components and energy-consuming equipment, some of which require certification. And their new national model code, IECC-Mexico, incorporates all energy efficiency standards related to buildings. Rajkot has projects to promote energy efficiency in new residential buildings. The other cities are located in countries where the national government has the authority to adopt a national code. Since 2000, Eskisehir has been covered by thermal standards (e.g., TS 825), but those standards have been incorporated into the Building Energy Performance (BEP) Regulation. Buildings are required to obtain certification under the “Regulation on Energy Performance in Building”, which is scale of A to G).

Every city reported that there was little to no involvement of the city stakeholders in the development of the current code. Out of the group surveyed, Da Nang, during the 2017 code revision, had perhaps the most extensive engagement with the national government. However, many of the countries' codes and underlying standards were developed with at least some engagement with stakeholders and experts. For example, Eskisehir reported that opinions were collected from local municipalities, related NGOs, academia, the Union of Chambers of Turkish Engineers and Architects, and so forth. In South Africa, where Tshwane is located, the creation of national standards involves an extensive stakeholder process, which includes government departments, professional and industry associations, and academia and research institutions.

The compliance options or pathways allowed in the codes of the six cities have varying degrees of flexibility. Rajkot's compliance pathway would be the most flexible (once the code is adopted), allowing for a prescriptive pathway with options for trade-offs between certain components or a simulated performance-based pathway. Other cities have solely a performance-based pathway,⁴ or have prescriptive requirements with options for trade-offs.

Code Implementation: Bogota and Da Nang do not require plan reviews or building inspection for energy code requirements and instead rely on self-certification. Eskisehir and Tshwane require plan review prior to issuing a construction permit and onsite inspection during the construction stage to inspect elements in actual buildings.⁵ These cities also use third parties, in addition to or in place of the government, to review plans prior to issuing construction permits. Eskisehir also uses third parties for onsite inspection during construction. Mexico City uses third parties to assess compliance with mandatory standards, but no guidelines have been developed for the code. Rajkot has plan review and construction inspection for the regular code but not for the energy code since it has not been fully adopted.

Four of the cities reported using software for compliance. Rajkot, where compliance can be met with either prescriptive or performance-based pathways, reported the use of software for both of these compliance pathways (ECONirman Prescriptive Tool and

⁴ The code in Colombia mandates a certain percentage savings by building type and climate zone. There is also a related guidance document that provides good practice advice. However, in practice, Bogota is working to make the code more enforceable by having a clear reference point for the energy savings and a methodology for determining compliance. This methodology may include both performance and prescriptive pathways.

⁵ Prior to BEP-TR, construction inspection companies in Eskisehir checked building design projects and inspected installation of energy efficiency measures on-site for TS 825. To the best of our knowledge, this is also the mechanism for inspection when the standards were incorporated into BEP.

Table 1
Building energy codes survey – code development.

	Name of national or model building energy code	Is the code mandatory in the city?	Involvement of city stakeholders in the development of national codes	Code compliance pathways
Bogota	Resolution 549–2015 on Sustainable Construction	Yes	None	Performance-based
Da Nang	QC09-2013	Yes	Limited, but increasing	Prescriptive with option for trade-off
Eskisehir	Regulation of energy performance of buildings (BEP-TR)	Yes	Limited	Performance-based
Mexico City	Energy Conservation Code (IECC-Mexico)	No, up to local gov't to adopt	Limited (for national model code)	Prescriptive with option for trade-off
Rajkot	Energy Conservation Building Code (ECBC)	No, up to local gov't to adopt	Limited (for national model code)	Prescriptive with option for trade-off or performance-based
Tshwane	SANS 10400XA	Yes	Limited	Performance-based

Table 2
Building energy codes survey – code implementation.

	Is there onsite inspection during construction?	Are there 3rd parties that assist with compliance checking?	Is there software for compliance checking?	Education and capacity building programs
Bogota	No	No (self-certification)	No	None reported
Da Nang	No	No (self-certification)	Yes (but rarely used)	MOC, IFC, USAID, Danish Gov't, and PNNL have held training seminars
Eskisehir	Yes	Yes	Yes, BEP-TR	BEP-TR software training; UNDP training on best practices in enforcement
Mexico City	N/A	N/A	N/A	Third-party training
Rajkot	No	No	Yes, EConirman Prescriptive Tool & EConirman Whole Building Performance Tool	The city government and IGBC are planning to hold building energy efficiency training; ECBC Knowledge Exchange Web Portal; Master Training program by UNDP Global Environmental Finance
Tshwane	Yes	Yes	Yes, energy simulation software is used, such as DesignBuilder	Courses and workshops on SANS 10400XA Energy Efficiency by SAIAT and SDC

Table 3
Building energy codes survey – compliance and enforcement.

	Is there a penalty for non-compliance with energy provisions?	Is there an incentive to exceed the code?	Is compliance tracked?
Bogota	Yes, in theory	No	No
Da Nang	Yes, in theory	No	Yes (but results not widely known)
Eskisehir	Yes	No, but planned	No
Mexico City	Yes (for their certification programs)	No	Yes (for their certification programs)
Rajkot	No	No	No
Tshwane	Yes	No	No

ECONirman Whole Building Performance Tool). Eskisehir, which has a performance-based compliance pathway for its certification process, reported that authorized building performance certification experts use national web-based building performance software (Building Energy Performance-Turkey or BEP-TR). DesignBuilder was the most common software used in South Africa, though Tshwane could use any software that complies with the Protocol for the Certification of Energy Simulation Software. Bogota and Da Nang reported that tools were rarely used, if at all, though in the case of Vietnam, the Ministry of Construction does maintain a web-based checklist program.

Most cities reported at least some education and capacity building programs for their city. Turkey has organized training programs on the use of the BEP-TR software that target regional/local enforcement agencies and building designers. Additionally, the United Nations Development Programme (UNDP) project on promoting energy efficiency in buildings has provided occasional training of stakeholders on best practices in European legislation and enforcement; however, the program is reported to have reached only a limited audience in Eskisehir. In Da Nang, the Ministry of Construction (MOC), International Finance Corporation (IFC), U.S. Agency for International Development (USAID), Danish Government, and Pacific Northwest National Laboratory (PNNL) have held multiple training seminars to build capacity. The Danish Government prepared training materials that it has shared with the Da Nang Department of Construction (DOC). These trainings have

focused on the code itself, high performance building design, and building energy simulation. Da Nang is also organizing a training series under the BEA in collaboration with IFC. The South African Institute of Architectural Technicians (SAIAT), in partnership with the Swiss Development Corporation (SDC) and the National Regulator for Compulsory Standards (NRCS) are providing courses and workshops on SANS 10400XA Energy Efficiency, targeting designers and building control officers. In Mexico, there are alliances with third parties to provide training, mainly with organizations related to the construction sector. Also, personnel from the National Commission for the Efficient Use of Energy (CONUEE) participate as trainers in diploma courses.

Compliance and Enforcement: Nearly all cities reported that there are penalties for non-compliance with energy provisions in the codes or accompanying guidelines. These could include fines, rejection of construction permits, rejection of occupancy permits, suspension/loss of licenses, and publication of names of property owners who fail to comply. However, most of the cities also reported that in practice these penalties are rare. All cities reported there were currently no incentives to go beyond the minimum level set by the code or standard, which could involve fast-tracking applications, awards, loans, and so forth. Rajkot, however, is planning to develop incentive mechanisms when the city adopts the energy code. Eskisehir is also developing above-code incentives for buildings that meet a minimum of B performance level.

We asked cities whether they and/or their national government

conducted compliance assessments. In Mexico, the number and type of certificates issued are tracked per year. In Vietnam, the Ministry of Construction did an assessment in collaboration with IFC, but the results are not widely available. Other than those cases, no other assessments on compliance were reported, and no instances were found where both the local and national government evaluated compliance.

4.2.2. Interviews

We held structured interviews with both city and national stakeholders to better understand the coordination between the national and local governments. We wanted to understand what formal and informal coordination exists for code development, training, and implementation. We also sought to understand gaps. Table 4 shows selected results from the interviews. During the interviews, we also asked for their feedback on the potential use of a toolkit and areas for future improvement.

NDCs: Out of the six countries studied, India, Mexico, Turkey, and Vietnam referenced building energy efficiency in their NDCs, and only India and Turkey referenced specific building policies and measures. Because jurisdiction over buildings typically lies at the local level, we asked whether the national government has clarified to the cities the role of the buildings sector in their NDC. In every case, the interviewees reported that there was no clarification from the national government on this issue. A few stated, however, that the national government is planning to expand on this in their NDC implementation plans.

Code Development, Implementation, and Enforcement: The interviews confirmed the results from the surveys. For example, the interviews reinforced the finding regarding limited participation of city stakeholders during the initial code development process, though four of the six cities are compelled to adopt the national code. Stakeholders in Da Nang, however, had more participation in the 2017 code revision process. For example, Da Nang's DOC had given specific recommendations to the MOC on code changes.

We asked interviewees whether there are formal lines of communication between national and local officials so that parties can share their concerns and needs. Da Nang's DOC reports directly to the MOC, which is how they shared suggestions on the new code. The Ministry of Housing (MOH) in Colombia has both physical and virtual mailing booths in which subnational entities can express their concerns related to building energy efficiency policies. However, since Bogota reported that they were not involved in code development, this channel appears to apply only to implementation. Rajkot reported that they have regular meetings with the state government to share their experience and concerns; however, similar to Bogota, they were not involved in code development. The South African Cities Network acts as a channel between South

African cities and their central government, but, similar to Colombia, it appears its applicability to code development is limited. Eskisehir reported that there is top-down communication when new regulations are issued. There are also symposiums to bring stakeholders together, but they are not specific to building energy codes. The interviewees from each of the six cities felt, however, that the communication, whether formal or informal, was largely one-way, from the national to local government.

We learned from the survey the various forms of assistance provided by the national government to support codes; however, monetary resources from the national government are much less common. Only Tshwane reported that their city may receive funds directly from their national government through city's overall budget request.

Nearly every city is challenged by a lack of capacity for full implementation of the code. Bogota, Da Nang, Eskisehir, Rajkot, and Tshwane reported that more capacity is needed to verify compliance, whether through better understanding of how to use the tools or the time it takes for a complete inspection. Eskisehir reported that the city relies heavily on third parties for plan review and inspection, and that the results from the compliance software for the requisite performance certification can be inconsistent due to user inputs.

Rajkot stakeholders reported that policies or codes at the city level should be simplified and tailored to the city's own circumstances and needs, and it would be helpful if the national government could help or guide how cities can adopt and/or develop code and General Development Control Regulations (GDCR) based on their own circumstances. They also felt that the various standards and programs on energy efficient or green buildings in India (e.g., Energy Conservation Building Code or ECBC, Indian Green Building Council or IGBC, Green Building Rating System India or GRIHA rating, etc.) creates confusion at the local level. They suggested that it would be helpful if the national government can clarify these overlapping programs/concepts and make it simpler for the local level to adopt policies.

Colombian officials reported that the country is in the initial stage of implementing Resolution 549, in which the Sustainable Construction Guide for water and energy savings was adopted. In this initial stage, only four cities are required to implement the code, and their input is being gathered as part of evaluating the effectiveness of the implementation. Bogota stakeholders suggested that wider engagement, especially with the private sector, would improve communication and implementation.

During the interviews, we also asked the stakeholders about the potential of a toolkit to assist cities and national governments in code development and implementation. We received feedback that the coverage of materials appeared to be comprehensive. Some

Table 4
Interviews.

	Is there a formal line of communication so that national and local officials can share their concerns and needs?	Does the national government provide monetary resources to your city to implement codes?	Challenges from the city perspective
Bogota	Yes (MOH has physical and virtual mailing booths)	No	Technical capacity to verify compliance; code not mandatory for private sector housing
Da Nang	Yes (DOCs report directly to MOC; stakeholder events)	Virtually none	Capacity to verify inspection; cost of compliance is high
Eskisehir	No (informal only)	No	Technical capacity among building developers to get the requisite certificate, technical capacity to verify compliance
Mexico City	No	No	Need capacity building
Rajkot	Yes	No	National code too complex; confusion on the multiple standards and programs
Tshwane	Yes (South African Cities Network facilitates)	May fund within budget if requested	Implementation challenges: lacking enforcement, tracking, and monitoring

interviewees suggested that instructions on its use could be clearer and navigation could be simpler. Overall, we heard that the toolkit could be genuinely helpful.

5. Discussion

Selected BEA cities are in the early stages of rolling out building energy codes and demonstrate different models of code development and implementation. These cities, however, face common challenges, such as inadequate resources and capacity, which prevent them from achieving maximum energy savings. Improving coordination with national governments can help cities access additional resources and address some implementation challenges. Here we analyze the gaps the cities are experiencing and highlight areas to improve building energy outcomes.

5.1. Code development & adoption

The city surveys and interviews show that code requirements (e.g. coverage and compliance approach), stakeholder engagement in code development, and the institutional setup for adoption are all critical to the initial roll-out of building energy codes.

In several countries, the national government is developing a building energy code or a national model code, but the local government has jurisdiction to adopt and/or implement the code. All the cities we surveyed only have limited participation in code development; as a result, the code developed at the national level is not may not meet the needs of local stakeholders. Taking the feedback of implementation bodies like the local government and having a more participatory code development and revision process can help get buy-in from all stakeholder groups and improve the feasibility of the code.

A well-designed compliance approach can ensure the rigor of the code and provide flexibility in implementation at the same time. There are three commonly used options to comply with building energy codes – prescriptive, prescriptive with envelope trade-off options, and performance-based compliance pathway. As shown in Table 1, not all cities allow for a range of compliance pathways in their mandatory codes. Providing some flexibility in meeting code requirements while maintaining the stringency of the requirements is important for cities and national governments, and such flexibility can ultimately allow code developers to require more stringent, yet attainable, code requirements.

In some countries, the national government only develops a model code and in order to make it effective the local government needs to modify local by-laws to adopt it. In the case of India, the Bureau of Energy Efficiency (BEE) develops the national model code, ECBC, whereas local by-laws follow the National Building Code issued by the Bureau of Indian Standards. Therefore, smooth code adoption requires not only legislative changes at the local level, but also coordination between national and local governments and across government agencies. Recognizing the importance of coordination, BEE has listed harmonization between ECBC and the National Building Code and integration of ECBC with building by-laws as its priorities (BEE, 2017).

5.2. Code implementation

Although code implementation mostly happens at the state or local level, the national government still plays an important role in providing necessary resources and facilitating information sharing across cities and states.

Once cities adopt building energy codes, they need to develop capacity to enforce codes. Limited capacity among government officials is a common issue in all the cities we interviewed, and

there is a strong need for capacity building at the local level. Although there are several capacity building activities going on in the cities and at the national level, there is a lack of coordination. The national government has better access to domestic and international sources, while the local government has better understanding of needs for implementation. Coordination between national and local governments can optimize resource allocation and maximize impacts. Developing a systematic training roadmap could further guide coordination and capacity building efforts in cities.

In addition to training, developing an effective enforcement structure can also improve code compliance. Using third-party inspectors can significantly accelerate code implementation, especially in places that are just starting to develop and implement codes (Evans et al., 2010; Yu et al., 2013). Two out of the six cities are using third-party inspectors to assist local code officials in compliance checking. Although third-party inspectors work at the local level, the system is most effective if a national authority issues the license or certification and holds inspectors accountable across the country.

Several cities mentioned the need for compliance checking tools in the interviews. This is an area where coordination between national and local governments is essential. Tool development is often expensive and the national government has more resources to lead tool development while the local government may have greater access to tool users who can provide feedback on ease of use and other issues. For example, national governments developed the compliance checking tools in Rajkot and Eskisehir (e.g. ECONirman and BEP-TR). Establishing a formal channel of communication between national and local governments to collect feedback from cities can help improve the design, usability, and functionality of compliance checking tools.

5.3. Code compliance and evaluation

Countries and cities often use incentives and/or penalties to encourage early deployment of building energy codes. All six cities have or are planning to have incentives or penalties to promote building energy code implementation. Most measures, such as rejection of construction permits, are under the jurisdiction of the local government, but the national government can also coordinate with cities to design and implement programs to improve compliance. For example, national and state governments can develop utility programs to encourage building energy efficiency and improve measurement and verification of building code impacts (Cooper and Wood, 2011).

Compliance evaluation is critical to assessing impacts of building energy codes, providing feedback for future code development, and instilling confidence in the market to deploy energy-efficient technologies. In the case of implementation, compliance evaluation can also help the national government track the progress in the buildings sector and help the local government access additional financing resources such as green bonds. Strong coordination on compliance evaluation is essential to provide comparative information on successes and weaknesses with implementation.

As discussed above, cities that are just starting to implement building energy codes face some similar challenges. To address these common challenges and explore the potential options of scaling up building energy code implementation, we test the idea of a building energy code toolkit. The toolkit provides a summary of each resource, suggestions on how it might be used and which stakeholders might benefit from it, as well as a link to the actual resource (the toolkit is available at http://www.globalchange.umd.edu/wp-content/uploads/2017/04/Building_Energy_Code_Toolkit_042517-final.pdf). The toolkit is also a research aide, used to

understand where there may be gaps in information and investigate whether there are simple, effective, and replicable ways of information sharing.

6. Conclusions

Based on our research, we find that improving building energy efficiency is a growing priority in countries' mitigation policies as seen in their NDCs; this includes building energy codes. At the same time, there are important gaps in developing and implementing building energy codes. We interviewed city and national stakeholders in several developing countries and found that cities lack resources to implement codes adequately. Cities would benefit from greater coordination with their national governments to ensure that the codes meet their needs and that the cities can access technical and financial resources needed for implementation. Improving coordination between national and local governments and establishing formal channels of communication can optimize resource allocation and achieve the full benefits of building energy codes. This coordination is ultimately important for achieving national mitigation goals, as well as building potential for cleaner production across the economy.

The objective of this analysis is to identify major gaps in developing and implementing building energy codes to inform policy decision making. The BEA and other initiatives are working to address these gaps and scale up building energy efficiency. The BEA has almost 30 partner cities and numerous technical, private, and advocacy partners. Through a structured global network, the BEA brings together researchers and cities and provides an opportunity to understand how different interventions work in the real world. It also helps scale energy efficiency opportunities up by helping match cities with advice and financing. Researchers can leverage this global network to test out new ideas and interventions, such as providing targeted training to different stakeholder groups, using climate finance to evaluate compliance and measure impacts, and developing tools to guide cities to develop their own buildings sector strategies. The survey carried out in our study can be repeated in BEA cities in the future to understand progress in cities and effectiveness of different policy interventions. Understanding the feasibility of various interventions helps design effective policies to implement NDCs and build capacity globally for large-scale change.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at <https://doi.org/10.1016/j.jclepro.2018.04.142>.

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