

Deploying Low-carbon Technologies in Developing Countries: A view from India's buildings sector

Radhika Khosla,^{1*} Ambuj Sagar² and Ajay Mathur³

¹Centre for Policy Research, New Delhi, India

²Indian Institute of Technology, New Delhi, India

³The Energy and Research Institute, New Delhi, India

ABSTRACT

The climate change arena comprises a diverse set of interacting actors from international, national and local levels. The multilevel architecture has implications for low-carbon technology deployment in developing countries, an issue salient to both development and climate objectives. The paper examines this theme through two inter-related questions: how do (or don't) low-carbon technologies get deployed in India's built environment, and what implications can be drawn from the Indian case for effective low-carbon technology development and transfer for developing countries? By examining the multilevel linkages in India's buildings sector, the paper shows how the interactions between governance levels can both support and hinder technology deployment, ultimately leading to inadequate outcomes. The potential of these linkages is hobbled by aspects of the national context (federated energy governance and developing-country capacity limitations), yet can also be enabled by other features (the climate policy context, which may motivate international actors to fill domestic capacity lacunae). Reflecting on the India case, the paper makes recommendations for improved low-carbon technology deployment in developing countries: (1) technology development and transfer collaboration on a 'need-driven' approach, (2) development of the specific types of capacity required across the entire innovation chain and (3) domestic strengthening of the coordination and agendas across and between governance levels. © 2017 The Authors. *Environmental Policy and Governance* published by ERP Environment and John Wiley & Sons Ltd

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Introduction

THE CURRENT GLOBAL ARCHITECTURE FOR CLIMATE POLICY AND ACTION COMPRISES A MULTIPLICITY OF ACTORS, ORGANIZATIONS AND OPERATIONAL modalities that make it different from that originally anticipated in the United Nations Framework Convention on Climate Change (UNFCCC). The initial top-down international process has shifted over time

*Correspondence to: Radhika Khosla, Centre for Policy Research, New Delhi, India.
E-mail: radhika.khosla@gmail.com

to one that is largely based on bottom-up country-by-country pronouncements, as formalized in the 2015 Paris Agreement (UNFCCC, 2015a). The climate change arena is now widely populated by activities that are often outside the formal auspices of UNFCCC, including initiatives that are public, private and civil society based, operating at various scales and thereby involving different levels of governance (van Asselt and Zelli, 2014). What are the implications of working within such a fragmented climate regime, which involves a diverse set of actors from international, national and local levels? In particular, what are the opportunities and challenges this architecture poses for a low-carbon technology transition in developing countries, in keeping with international climate objectives?

The UNFCCC has long recognized the importance of low-carbon technology development and transfer for developing countries to assist in their growth, whilst fulfilling global climate objectives (UNFCCC, 2015b). The paper examines this theme by asking two inter-related questions: how do (or don't) low-carbon technologies get transferred and deployed in India's built environment, and what implications can be drawn from the Indian case for effective low-carbon technology development and transfer for developing countries?

Multilevel climate governance provides an analytical framework to help answer these questions. The framework lays out at least two different dimensions of action and influence – the vertical and horizontal – where varied actors interact between different governance levels towards a common climate outcome (Bulkeley and Betsill, 2005; Hooghe and Marks, 2003). The vertical dimension recognizes that national governments cannot effectively implement low-carbon strategies without working closely with regional and local actors, and that in many cases national strategies and implementation are influenced and supported by international climate actors and activities. The horizontal dimension acknowledges the opportunity for learning, knowledge transmission and cooperation across organizational boundaries to influence outcomes. Horizontal relationships exist at the local level, between cities, states and governments, and between technical experts, business, research and non-governmental actors. Together, coordinated interactions within a multilevel structure have the potential to narrow policy and other 'gaps' to help address the problem of climate change (Corfee-Morlot *et al.*, 2009).

The built environment in India is ideally suited to study the potential of multilevel governance. Building-level policies often draw upon international activity and knowledge to implement low-carbon solutions, and yet require the specificities of the local context to remain paramount for technology deployment. At the same time, buildings are central to climate mitigation efforts from both a global and an Indian point of view. In 2010, buildings accounted for 32% of total global final energy use and 19% of energy-related greenhouse gas (GHG) emissions, with projections for further increase (Lucon *et al.*, 2014). Specifically in India, buildings are responsible for around 35% of the total energy consumption and their energy use is increasing at 8% annually (GBPN, 2013), making them a fast-growing market for energy technologies and essential to not locking in path-dependent carbon infrastructure (Urge-Vorsatz *et al.*, 2012).

The study undertaken in this paper is therefore useful for a few reasons. First, it adds to the limited developing-country perspectives on technology deployment from a climate mitigation perspective. This is important as the opportunities for technology transition have so far bypassed most developing countries, with a few major emerging economies accounting for a large fraction of existing low-carbon technology deployment, while others remain unattractive to foreign firms. Also, while the UNFCCC discourse has been largely based on a North–South technology transfer paradigm, observations of actual technology and technology facilitation activities show an increasingly interconnected world, where many developing countries are actively absorbing foreign technologies while also developing and transferring technologies themselves (Pueyo *et al.*, 2012). The recommendations in this paper can thereby also inform South–South transfers of not only technology, for which there appears to be tremendous potential since developing-country technologies could be better tailored to local needs (Dechezlepretre *et al.*, 2011; IPCC 2000), but also knowledge related to effective deployment. Finally, the paper contributes to the sparse literature on building energy governance in India. It sheds light on the sector's multilevel linkages and how they both support and hinder low-carbon technology deployment. In doing so, the paper lays out the factors that shape India's building energy outcomes: distinguishing between those that are country specific, others that are prevalent in developing countries more broadly and those borne out of the global climate discussions. This distinction allows for more nuanced technology policy recommendations, recognizing the interplay between country-specific concerns and global climate motivations.

Methodologically, the paper uses the Intergovernmental Panel on Climate Change's (IPCC's) definition of technology transfer as.

the broad set of processes covering the flows of knowledge, experience and equipment amongst different stakeholders such as governments, private sector entities, financial institutions, NGOs and research/educational institutions. The broad and inclusive term 'transfer' encompasses diffusion of technologies and technology cooperation across and within countries. It comprises the process of learning to understand, utilise and replicate the technology, including the capacity to choose it and adapt it to local conditions (IPCC, 2000).

In other words, successful application of technology to meet climate challenges requires paying attention to both the stages of the technology cycle and various dimensions of the technological change process. The former are commonly defined as research, development, demonstration, deployment and diffusion (IPCC, 2007). The dimensions of the technological change process entail the availability of locally relevant technology, finance of suitable nature and quantity for pertinent stages of the technology cycle, supporting policy frameworks and instruments consonant with the stages of the technology cycle, and the knowledge to locally enable and manage these dimensions (Sagar *et al.*, 2009). For the purposes of this paper we define the four key elements of technological change as the flows of knowledge, technology, finance and policies. We track these flows for building energy technologies – across governance levels – to assess the nature and effectiveness of their deployment in India.

Empirically, the paper draws on interviews with experts within and outside government, data from official building energy documents, and insights from supporting literature. It also draws on author experiences of direct involvement in the sector (one author (AM) headed India's Bureau of Energy Efficiency for almost a decade, and another (RK) worked alongside the state of Andhra Pradesh for two years on building energy code adoption).

The paper is organized in the following way. The India buildings study is described in the following section. The first subsection provides the institutional and policy context of the Indian built environment. The second subsection examines the multilevel arrangements that underlie low-carbon technological change in this arena. The third subsection discusses the factors that give rise to these multilevel arrangements, and how they promote or hamper technological advancement. Based on the Indian buildings study, the next section proposes recommendations for developed and developing countries engaged in low-carbon technology transfer and deployment. The paper ends with reflections and conclusions in the fourth section.

Building Energy Efficiency in India

Buildings form long lasting components of any economy and as a result shape path dependencies for energy use patterns. In India, buildings are integral to energy consumption and GHG emissions, with projections for dramatic increase over the next few decades due to increasing economic activity and urbanization, rising appliance ownership and access to modern energy (GBPN, 2013). In fact, studies suggest that two-thirds of India's commercial and high-rise buildings that will exist in 2030 are yet to be built (Kumar *et al.*, 2010), and that if unchecked, Indian building energy demand (and CO₂ emissions) could increase by as much as 700% by 2050, compared with 2005 levels (GBPN, 2014). This unprecedented future growth presents an immense technological opportunity for energy and carbon savings – it is estimated that around 30% reduction in energy use in new residential buildings and 40% in new commercial buildings may be possible through energy-efficiency measures (MoEF, 2012). Developed countries have an important role to play in realizing this opportunity, as they have already developed a range of advanced low-carbon technologies (IPCC, 2000). By way of introduction, we provide here a brief overview of India's building energy and technology policy context.

Institutional and Policy Context

India initiated several building energy and technology policy activities over the last 15 years, starting with the Energy Conservation Act of 2001. We trace the key policy undertakings during this period in Figure 1.

An initial and significant step was the setting up of the Bureau of Energy Efficiency (BEE) in 2002 as a nodal body of the Ministry of Power to conceptualize, coordinate and implement a range of efficiency policies, including for

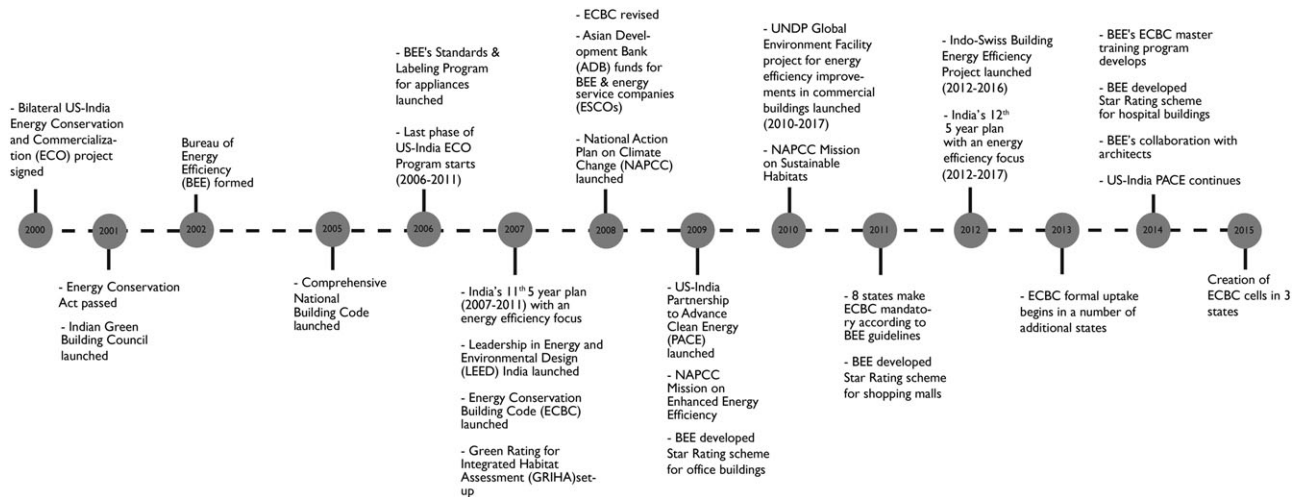


Figure 1. Timeline of key building energy technology and policy activities in India

buildings (BEE, 2002). The BEE initiated the regulation on building energy use through India's Energy Conservation Building Code (ECBC) in 2007, to set a minimum (voluntary) standard for energy performance in commercial buildings. The ECBC includes prescriptive requirements for building envelope and equipment mitigation technologies (such as wall and roof insulation, advanced window technologies, roof coatings, space heating, cooling, lighting etc.) (ECBC, 2007). However, since India has a federal structure that places electricity and buildings under the purview of both central and state governments, while the BEE can issue building energy regulations such as the ECBC, the decision to make the policy mandatory can only be taken by states (GoI, 2015; Yu *et al.*, 2014; Kumar *et al.*, 2010).

Various other policy measures were introduced over this 15 year period to support different aspects of technological change. Capacity building, in particular, received special attention to enhance the skills required for installation and operation of technologies. For instance, in 2014, the BEE in collaboration with the National Institute of Architects, Institute of Applied Studies in Architecture and Council of Architecture set up a program to create a future pool of certified building energy managers across states (BEE, 2015). Similar supporting activities exist on the R&D front: the US-India Joint Clean Energy Research and Development Center is integrating information technologies with building physical systems, adapted to Indian and US building types (Indo-US JCERDC, 2015). In addition to policy activities, additional interest is demonstrated by the different green building rating systems that populate the Indian market.

The multiplicity of actors and activities illustrated in Figure 1 suggests a mature set of policy drivers and corresponding marketplace for low-carbon building technologies. However, energy performance metrics do not support this claim. The Energy Performance Index (EPI) of the Indian building stock remains relatively poor, with the average EPI ranging from 200 to 400 kWh/sq m/year, compared with similar buildings in developed countries where EPIs are below 150 kWh/sq m/year (Seth, 2011). In terms of the building energy code, only seven of 35 Indian states and union territories had notified the ECBC almost a decade after its launch (Yu *et al.*, 2014). While this number is now increasing, code-notified states themselves are yet to see widespread implementation. The private sector, too, has adopted efficiency technologies only within a small segment of high-end real estate developers (ASCI and NRDC, 2012).

We utilize the framework of multilevel governance for India's buildings to understand their ultimately inadequate performance metrics. The framework helps identify the linkages within the sector, and how these linkages have supported or hampered low-carbon technological change.

Observed Multilevel Governance Patterns

This subsection examines the coverage and nature of the multilevel linkages within India's built environment. Conceptually, the vertical and horizontal dimensions of multilevel architectures can be leveraged to support

technological change for desired climate outcomes (Corfee-Morlot *et al.*, 2009). We examine if this is true in Indian buildings – and find, instead, that particular dimensions of technological change are privileged over others by existing linkages, with implications for the state of technology transfer and deployment.

Table 1 presents a collation of key building energy technology activities and actors, and their respective governance levels. The table lists the different activities that comprise technological change: technology R&D; financial transfer to assist different stages of the technology cycle; capacity building and analytical support; policy designs and implementation. For each activity the table describes

- 1 its vertical and horizontal origin and scope across governance levels (demonstrated by arrows between the international, national and subnational),
- 2 the main actors involved, such as government bodies, technical institutes, international aid agencies or civil society organizations, and
- 3 the broader national or international policy drivers that stimulated the activity (e.g. initiatives under India's national climate plan).

Data for Table 1 is collected from expert input, interviews within and outside government, and reviews of existing and grey literature. It is important to note that Table 1 is not exhaustive of the large number of initiatives and actors involved in India's building energy discussions, but rather draws on the significant ones (necessarily a subjective judgement) to observe the sector's multilevel trends.

Three patterns characterize the nature of technological change in India's low-carbon buildings. First, most activities flow through vertical linkages in a top-down (international → national → subnational) direction, as opposed to international processes and outcomes being shaped by national or subnational level activities. Systematic horizontal linkages, on the other hand, are conspicuous by their absence. Building energy code design, capacity building, and financial support activities are all examples of largely top-down activities, where the policy push has emerged at the national or international level. States or subnational bodies thereby seldom serve as 'laboratories of experimentation' or pioneers of policy initiation. There has been a recent slow rise in bottom-up activities, particularly for technology R&D, where bilateral programs are based on shared input from both countries involved. The US–India Joint Energy Research Center provides a salient example, where the need for regionally customized building technologies was identified and followed by bilateral R&D assistance to develop applications normalized to Indian weather, construction techniques and occupant comfort (Indo-US JCERDC, 2015).

Second, and a consequence of the largely top-down nature of activities, is the profusion of international actors engaging with this space in India. This international linkage is usually mediated by domestic actors rather than through direct international intervention on the ground, making it much more collaborative in scope. As Figure 1 shows, since the early 2000s building technologies have been part of various bilateral, multilateral and strategic partnerships, which have provided significant analytical, technical and programmatic support and often propelled domestic efforts forward. The expertise from these and additional groups has played an important role over the last decade and a half, and in most cases the work occurs in cooperation with local experts, civil society partners and state governments. Examples include support from the United States Agency for International Development (USAID), Swiss Development Corporation (SDC) and Global Environment Facility (GEF), who worked with the BEE and Indian experts to develop and launch the ECBC (UNDP India-GEF, 2011; Evans *et al.*, 2009; USAID, 2011). Technical and capacity building support for ECBC adoption provides another example, where international actors (research laboratories, environmental groups etc.) are in productive collaborations with domestic groups (academic institutes, civil society, state governments) to co-produce outcomes. For instance, the US Pacific Northwest National Laboratory and Natural Resources Defense Council work with the Indian Malaviya National Institute of Technology and Administrative Staff College of India, respectively, on ECBC adoption in different states (Khosla, 2016; Tan *et al.*, 2016).

Third, the activity patterns in Table 1 demonstrate a focus on the downstream stages of the technological cycle, i.e. on deployment. Drawing from the IPCC and as discussed in the introduction, technology transfer requires suitable and adequate flows of technical R&D and equipment, operational and analytical knowledge, finance and policies. Table 1 and Figure 1 show that, of these elements, the dominant flows have pertained to knowledge sharing and development of supporting policies such as standards and ratings (often influenced by international policy contexts such as the climate negotiations). However, the other dimensions underlying technological change –

Technological Change Dimension	Technology and Policy Activities	Flows across governance levels			Illustrative List of Key Actors (Domestic-D, International-I)	Policy Context
		Inter-national	National	Sub-National		
Policies	Building energy code design and development	←→	←→	←→	D: Bureau of Energy Efficiency (BEE); Bureau of India Standards (BIS) I: United States Agency for International Development (USAID); Swiss Development Corporation (SDC); United Nations Development Program-Global Environmental Facility (UNDP-GEF)	-India's Energy Conservation Act -Energy efficiency inclusion in the revised National Building Code -National Climate Mission on Sustainable Habitat
	Building energy code adoption and implementation in states	←→	←→	↕	D: BEE; BEE's State Designated Agencies; State and sub-state departments; CEPT University (CEPT); Malviya National Institute of Technology (MNIT); Administrative Staff College of India (ASCI); Shakti Foundation; International Institute for Information Technology (IIIT) I: UNDP-GEF; Natural Resources Defense Council (NRDC); European Union; Pacific Northwest National Lab (PNNL); USAID	-Domestic political pressure to manage energy security -National policy trends supporting climate activities -Pressure from BEE to states to adopt building energy policies
	Building rating systems	←→	←→	↕	D: BEE; Indian Green Building Council; The Energy and Resources Institute I: United States Green Building Council; International Finance Corporation	-Market opportunity from India's real estate growth -Supportive national and international policies
R&D	Efficient technology R&D and demonstration	←→	↕	←→	D: Department of Science and Technology (DST); CEPT; IIIT; Indian Institute of Technology, Bombay; MNIT; Shakti Foundation; Prayas (Energy) Group; Indian Society of Heating, Refrigerating and Air Conditioning Engineers I: USAID; SDC; US Dept. of Energy; Lawrence Berkeley National Lab (LBNL); Oak Ridge National Lab; Rensselaer Polytechnic Institute; UC Berkeley; Carnegie Mellon University; Schneider Electric; Honeywell; Fraunhofer	- National policy trends supporting climate activities -Increasing international partnerships for clean energy (e.g., the US-India Joint Energy Research Center)
Finances	Financial transfer	←→			I: UNDP-GEF; KfW Bank; World Bank; International Finance Corporation; Asian Development Bank; USAID	-National and international policy trends supporting climate activities
Capacities	Capacity building	←→	←→	←→	D: BEE; CEPT; IIIT; National Institute of Architects; Council of Architecture; Shakti Foundation; MNIT, ASCI I: USAID; GIZ; SDC; NRDC; PNNL; UNDP; Alliance to Save Energy	-National and international policy trends supporting climate activities
	Analytical support	←→	←→	↕	D: BEE; CEPT; Shakti Foundation; Indian Institute of Management Ahmedabad; MNIT, IIIT I: Global Buildings Performance Network; USAID; NRDC; PNNL; LBNL; International Council for Local Environmental Initiatives; International Partnership for Energy Efficiency Cooperation; Building Energy Efficiency Taskgroup	-National and international policy trends supporting climate activities



 Vertical flows
  Horizontal flows

Table 1. Activity map of low-carbon technological change in India's buildings (2000-2015)

technology R&D and financial transfer – have been less present in Indian buildings, even though both are important to advance technologies (the US–India R&D collaboration being a recent exception). This observation of a limited focus on the upstream parts (research, product development) of the technology cycle is consistent with the larger landscape of international collaborative and support activities. While there is consensus that technologies will help developing countries meet their particular needs, most initiatives assume that locally applicable technology is already available, often leaving R&D opportunities outside the mainstream energy innovation system and the established commercial markets in developing countries (Ockwell *et al.*, 2014).

Together, these patterns demonstrate the potential but also the limitations of linkages between and across governance levels. While well developed top-down interactions have supported and complemented domestic technology advancement, horizontal and subnational-led linkages have been leveraged less. Although the downstream stages of the technology cycle have received attention, others stages that are as necessary have not. There is also a resulting profusion of international actors, who usually operate in closer partnership with domestic bodies to co-produce climate outcomes, though their horizons can often be short term.

In the next section, we discuss the reasons for these observed patterns. In doing so, we examine their underlying drivers that are particular to India, others that apply to developing countries more broadly and those borne out of the global climate discussions – all of which inform the subsequent policy recommendations.

Explaining Observed Multilevel Patterns

Multilevel governance is regarded as an important factor in leveraging transnational expertise and promoting top-down and bottom-up adoption of best practices. However, in spite of the multilevel nature of India's buildings sector, implementation gaps remain unbridged and there is limited bottom-up innovation. Why is this the case? We discuss three factors that collectively help explain these patterns: the particularities of India's federal structure; the constraints of capacity, which is typical of developing countries, and the growing policy linkages between energy and climate change stemming from the global climate debate.

Operations and Accountability in India's Federal Structure

Building energy policies require input across central, state and local levels in India's federal structure. However, the lack of harmonization and accountability within the system has resulted in policies often being disengaged from their local implementation challenges, resulting in largely top-down technology and policy flows with weak outcomes, as observed in Table 1.

State governments hold the decision-making power regarding the adoption of building energy policies and targets, and are thus central to energy governance processes. However, as states see little benefit to such policies, the policy push still originates from the top-down BEE level. Even when states do notify low-carbon building policies (often driven by BEE support and international and domestic actors), the substate implementing agencies (such as urban local bodies) are not monitored for progress or penalized for non-compliance. The outcome is a large accountability gap within the institutional framework (Khosla, 2016; Kumar *et al.*, 2010), and an observed centralized top-down approach (the latter being a dominant feature of India's federalism across policy issues; Jørgensen *et al.*, 2015).

The Centre–state issues are compounded by overlapping responsibilities and poor coordination between national, state and local level agencies (ICLEI, 2015). Centrally, at least two national ministries engage with building energy use: the Ministry of Urban Development, which coordinates building construction, and the Ministry of Power, which houses the BEE and is the locus of energy efficiency issues. At the state level, policies are mostly managed by a similar set of departments: the Urban Development Department, which oversees building regulations (e.g. through provision of building permits), and the Energy Department, which monitors energy use. Effective policy implementation requires all these agencies to work together. However, the separation of responsibility across them has resulted in inadequate coordination both upstream with the BEE and downstream with municipal departments. Horizontal coordination at the national and state levels is similarly insufficient. It is worth noting that the lack of explicit coordination is an ongoing concern in India's energy bureaucracy, and not confined only to buildings (GoI, 2006). Similarly, the lack of state-led innovation is seen across Indian climate policy, often for reasons of capacity constraints or the lack of ownership of a plan or policy (Jogesh and Dubash, 2015).

Constraints of Capacity

A second factor that characterizes building efficiency efforts in India, and across developing countries, is that of very limited capacity. Developing countries need assistance with enhancing capacity at every stage of the technology advancement process, with appropriate institutions, networks and hardware (IPCC, 2000). However, the failure to create such capacities is consistent with the history of development assistance efforts across policy domains

(Ockwell *et al.*, 2014; Sagar, 2000). India's capacity vacuum and limited resources have opened up the space for international actors to be part of the domestic building energy landscape and co-produce outcomes, as seen in Table 1. This has often substituted for missing state and non-state capacity and propelled low-carbon building actions forward, though with restricted timelines and technological priorities.

While capacity needs have been emphasized in multiple fora, current capabilities in India do not mirror the requirements for wide-scale technology deployment (see Kumar *et al.*, 2010). The BEE has addressed some capabilities through training programs, but these are far from adequate to sustain the transformation of a major sector with a multitude of actors and activities. Even in cases where training is successfully completed, the qualified personnel are not offered significant opportunities to use their acquired skills.¹ State and local bodies, too, do not have the required knowledge to implement, monitor and assess energy technologies, nor the staff numbers to match the needs of India's real estate growth.

Technical knowledge is instead housed with a few experts within academia and industry, in spite of the various programs intended to increase long-term capacity. This is in part due to an institutional setup that has been unable to scale effective technology deployment, and also because of more universal barriers to building efficiency, such as the lack of information about new technologies, their higher initial cost, the absence of delivery and maintenance services etc. (IPCC, 2000). A spill-over effect of the capacity gap is the absence of monitored building energy data, which consequently inhibits rigorous economy-wide energy projections (Dukkipati *et al.*, 2014).

An additional area of capacity deficit is the ability to traverse between governance levels, made prominent by the multilevel nature of India's buildings sector. This translates to personnel who have the intellectual and policy expertise, and transactional experience, to contribute to, and indeed bridge, discussions at different levels of governance (e.g. between the subnational and national, or national and international). Currently this capacity is limited to government officers with few creative ways for expansion especially within budgetary constraints. Such capacity, while essential, is difficult to expand across developing countries.

Interacting Energy and Climate Policy Agendas

Energy and climate agendas are increasingly knit together under climate governance structures, and are likely to increase pressure on developing countries to mitigate as part of the global climate solution. In India, energy policies were historically driven by concerns around energy security and access (which led, among other things, to the Energy Conservation Act and establishment of the BEE). Over time, this motivation coincided with global concerns around climate and clean energy. Moreover, while climate change remains a subsidiary to energy-related objectives, it has affected how energy and subsequently low-carbon energy technologies are discussed and how policy is institutionalized (Dubash, 2011).

For buildings, new institutional opportunities and stimuli were created through India's climate missions on energy efficiency and sustainable habitat. At the same time, the introduction of an additional level of climate governance makes it difficult to integrate building energy and climate agendas coherently at every level and across the economy (especially given prevailing institutional and capacity weaknesses). Specifically: at the international level, discussions are mainly climate driven; at the national level, the primary concern is development, with climate attention at the periphery; for the states, the motivation is managing energy supplies and peak load; and finally, the local level is largely insulated from energy or climate debates. A telling example of these disconnected agendas is the absence of building energy efficiency from most of India's states' climate plans (see Jogesh and Dubash, 2015).

Another instance of interacting energy and climate agendas is the growing emphasis of buildings as a mitigation solution, leading to new international climate programs to improve national building outcomes. This is an additional reason for the many international actors in India seen in Table 1. One concern however is that funder-driven climate programs often focus on targets with narrow outcomes (e.g. tons of carbon saved, number of workshops held) and have limited time horizons that can risk orienting away from both domestic energy-related motivations and long-term capacity building. Take the example of GEF, which serves as UNFCCC's financial mechanism to help address global environmental issues, and provides important assistance to India: GEF requires outcomes to be reported in annual

¹Interview with a former BEE official (August 2016).

direct and indirect CO₂ emission reductions (UNDP India–GEF, 2011), as opposed to additional development and effectiveness focused metrics such as actual operational energy saved or the quality of long-term capacity created.

In summary, linkages between governance levels have shaped and often advanced the deployment of low-carbon building technologies in India. However, the potential of these linkages has been hobbled by aspects of the national context (federated energy governance and developing country capacity limitations), yet also enabled by other features (the broader climate policy context, which can help fill in for domestic constraints). A successful attempt at advancing technologies through multiple governance levels – and in fact, leveraging the opportunities afforded by multilevel linkages – will thus require a careful consideration of national and subnational characteristics.

Policy Implications for Low-carbon Technology Deployment in Developing Countries

We now draw on our India study to provide inductive recommendations for improving low-carbon technology deployment in developing countries. Such recommendations can help inform domestic and international actors, particularly as international policy interest in North–South and South–South transfers of climate technologies accelerates. So far, the opportunities for a technology transition have bypassed most developing countries, where businesses and policy makers often complain about the large distance between the bureaucratic UNFCCC processes and their own urgent needs (Pueyo *et al.*, 2012) – while other actors outside the UNFCCC have not been any more successful at catalysing such large-scale deployment. The recommendations in this section could thereby also inform the implementation arm of the UNFCCC's technology mechanism, i.e. the Climate Technology Center and Network (UNFCCC, 2010a).

Adopt a 'Need'-Driven Approach

Most developing countries prioritize economic and social development over investments in expensive low-carbon technologies. Technology transfer thus needs to be constructed around a collaborative and ongoing local assessment process, which is driven by both developed and developing countries. Importantly, the process must serve as a precursor to program design to determine indigenous priorities, technology-cycle needs and capabilities, and continue through the different stages of the innovation cycle (see van Asselt and Zelli, 2014).

Effective deployment requires, among other things, the adaptation of commercial or emerging technologies (and related practices) to suit local contexts and be optimized for local operating conditions (Sagar *et al.*, 2009). Examples are green building designs that take into account local climatic conditions and occupant use patterns (Ockwell *et al.*, 2014), or policy delivery models that consider behaviour norms or financial realities of consumers.² Effective deployment also requires enlisting full cooperation of recipient countries by aligning mitigation efforts with their development goals. This may require negotiating in instances where climate and development synergies are not available or where mitigation may only be a co-benefit of development. For instance, the global building technology literature finds that in the near term successful technology programs will be driven not by environmental benefits alone, but because they also meet other consumer-relevant goals, e.g. reducing household expenses (IPCC, 2000). Such a need-driven approach is different from existing activities that often do not unpack multiple configurations and their distributional implications, and subsequently hamper deployment (Ockwell *et al.*, 2010). More recently, the UNFCCC has been providing country support to conduct participatory technology needs assessments (TNAs) to identify, select and implement low-carbon technologies (UNFCCC, 2010b). TNA effectiveness is yet to be determined though, especially since assessments must be ongoing to engage with the changing, and often difficult to anticipate, needs of the innovation-cycle stages.

Local engagement is another essential component, which can take the form of collaborations between developed countries and networks of local users such as subnational governments and civil society organizations, who

²E.g., a pay-as-you-go model in the ICT domain allowed for rapid adoption of cellphones when consumers did not have the financial wherewithal to buy monthly packages.

ultimately reap the benefits and/or bear the costs of technologies (Sagar, 2013). Engaging with the private sector is equally relevant, and a neglect of the private sector as the owner of most mitigation technology has been systematically recognized in the UNFCCC's approach (Pueyo *et al.*, 2012). This is even more important in developing countries, where in the absence of well-functioning markets, traditional market actors – firms, financiers, entrepreneurs – may not have the incentives or the capabilities to take up the mantle themselves and fill existing gaps (Sagar, 2013). It may also require a differentiated country approach, as some developing countries are interested in avenues to enhance domestic technological capabilities and become part of the global low-carbon supply chain (Sagar, 2013; Rai and Funkhouser, 2015), while in other cases effective implementation may require pooling of markets.

Better developed and developing country understanding of recipient priorities and capabilities (technologies, finance and knowledge), with ongoing local inputs, will be fruitful for international actors working in developing countries and also increase domestic buy-in.

Differentiated Approach to Capacity Building

Flows of technology alone do not adequately enable their broad use. Operational know-how and adaptive and absorptive capability are key to enabling efficient transfers (Keller, 1996; IPCC, 2000). Domestic and international actors have a key role to play in building relevant capacities at all stages of the technology cycle and across its elements: technical, financial, business and regulation (Pueyo *et al.*, 2012; IPCC, 2000). A recent review concluded that the crucial ingredients of technology transfer were found rarely in 'hardware', but rather in people-embodied knowledge (Rai and Funkhouser, 2015).

Most developing countries struggle with questions of capacity. While international funds often focus on capacity projects, the efforts rarely translate to a domestic critical mass. It is thus important to understand the kinds of capacity needed in order to build them, as discussed below.

First, developing countries often lack 'indigenous technological capabilities' to develop and deploy technologies (see Enos, 1991). This involves not only the capital goods needed to create physical facilities, but also the skills for operation. Green building ratings in India provide an interesting example, for which studies indicate that rated buildings equipped with low-carbon technologies can often still have poor energy performance (Roychowdhury and Somvanshi, 2014). Additional to operational know-how is the knowledge to generate technical change, that is, the capacity to adapt the technology to local, changing needs, to replicate it, enhance it and eventually create a new product (Bell, 1990). This enables domestic firms to engage a wider suite of external transfer mechanisms (Rai and Funkhouser, 2015) and can be enhanced through collaborative R&D programs, as mentioned in the Paris Agreement (UNFCCC, 2015b).

Second is the strategic capacity to develop technological priorities that best meet development and climate needs by facilitating coordination between actors at multiple levels and bridging gaps. This includes the capability to take a 'bird's-eye view' for program design and cover locally relevant aspects of the innovation chain (Chaudhary *et al.*, 2012). A derivative need then is the capacity to traverse between and contribute to discussion at different levels of governance, to exchange experiences as well as leveraging synergies on technology development (Sagar, 2013).

Finally there is the organizational capacity to oversee local implementation. Attention to implementation enables 'learning by doing', which can be enhanced by explicit learning components in projects. Appropriate organizational capacity can use implementation lessons to feed into delivery models and policy design.

Notably, while the importance of creating appropriate capacity is well recognized, it is not trivial to do it well, especially for long-term issues such as energy and climate change. Effective efforts to create a local 'stock' of capacity are notoriously difficult (Sagar, 2000). In particular, though human resource development has been popular as development assistance, programs have frequently been along the organizational models of donor countries and the transferred knowledge has not ultimately been useful. Developed and developing countries could therefore pay attention to ensure that the programs are in full co-operation with all relevant stakeholders, and have appropriate time horizons and accountability. Further, programs can focus less exclusively on technical skills and instead create improved and accessible competence across the technology cycle (IPCC, 2000).

Strengthen Linkages and Integrate Agendas across Governance Levels

The climate action space often encompasses sectors that themselves operate at multiple levels, in addition to the levels at which climate actions are undertaken, increasing the complexity of governance. This is especially true of demand-side sectors, which are often embedded in networks of institutions and practices and yet are necessary for transitioning to a low-carbon society (Creutzig *et al.*, 2016). Developing countries must thereby take the lead to strengthen their linkages and respective agendas across governance levels – to enable appropriate flows of knowledge regarding needs, possible solutions and delivery mechanisms, and allow resources to reach where they are most needed.

The first interface for developing countries to enhance is that between the national and the international. Countries can leverage the growing profusion of initiatives targeted at climate mitigation by investing in better coordination with international fora, communicating their specific needs and appropriately shaping the international agenda. At present, these countries seldom provide input or participate in global program design (Brewer, 2008). Consequently, it is unclear whether domestic concerns and local country contexts are understood internationally where many low-carbon programs are initiated. For example, country-specific contexts such as the importance of the role of states in India's institutional structure or the lack of domestic climate-related capacity in India to effectively operationalize policies may not be recognized internationally. The weak links between international institutions and the national enabling environments has been recognized in the literature already, pointing to the lack of integration between national planning processes and existing UNFCCC instruments to promote technologies (Pueyo *et al.*, 2012).

It is equally important to strengthen the linkages between the national and local levels, since the effectiveness of any climate program ultimately depends on outcomes on the ground. Further, innovative subnational policies can often function as a repository for potentially transformative ideas that can be scaled up, if linked to larger national and global climate process (Jørgensen *et al.*, 2015). Indeed, it is upon national governments to establish the contextual factors that can shape vertical transfers and foster the creation of new markets (IPCC, 2000). This is well demonstrated by China's strategic approach to technology and industrial policy, which resulted in a competitive renewables market in a remarkably short time (Zhi *et al.*, 2014; Dai and Xue, 2015). Overall, developing country governments can be the most influential actors for promoting a favourable environment for technology-based participation among international entities and the private sector, and equally for scaling up subnational initiatives. For international actors this means a focus on working with national actors so as to build linkages with local actors, and ensure alignment with national priorities and long-term scalability.³

Finally, returning to the climate arena within which these different linkages exist, the complexity of the national climate debates in developing countries can often lead to actors with differing agendas and a lack of clarity about who is responsible for policy implementation. A unified national approach that better integrates co-existing and interacting development and climate policies (including through political and financial goals), and thereby their national, subnational and international linkages, is thus necessary for developing countries with complex and often blurred development–climate linkages. This would help resolve the tensions that can arise between the different levels and also result in greater buy-in by the leadership and civil society, which is ultimately essential for actions to add up to a significant contribution towards climate change.

Conclusions

Climate action is increasingly shaped by various government and non-government actors at the international, national and subnational levels, often outside the UNFCCC auspices. The resulting multilevel governance in the climate arena influences the deployment of low-carbon technologies at scale, especially in developing countries where the uptake of such technologies is important for meeting the dual objectives of development and climate

³By contrast, in the case of early conversations on joint implementation of climate mitigation, international donors sidestepped national governments to promote their approach and effectively short-circuit local debates (Kandlikar and Sagar, 1999).

change. What are the implications of this interplay between multilevel climate governance and technology transfer in developing countries?

We answer this question by examining the case of low-carbon building technologies in India. We find that the interactions between governance levels can both support and hinder technology deployment, but ultimately lead to inadequate outcomes. In particular, top-down vertical linkages and a focus on the downstream stages of the technology cycle are privileged over others. There is also a resulting profusion of international actors, who usually operate in close partnership with domestic bodies to co-produce climate outcomes (thereby substituting for domestic capacity lacunae), though their horizons and performance metrics can often differ from those that are domestically relevant. Overall, the advancement of low-carbon technologies in India's buildings has been insufficient and has not yet maximized the potential energy and climate policy opportunities.

These multilevel patterns in India's built environment are shaped by country-specific institutional characteristics (federated energy governance), capacity constraints that are typical of developing countries, and interactions between domestic energy and international climate policy contexts. Notably, at times these factors weaken central and local coordination between top-down international and national strategies and bottom-up subnational initiatives. At other times they open up institutional spaces for new actors to engage in and advance Indian efforts (though without leading to the required transformational change in the sector).

A successful attempt at advancing technologies through multiple governance levels – and in fact, making effective use of the opportunities afforded by such linkages – will thus require a careful consideration of national and subnational characteristics. Reflecting on the Indian case, developed and developing countries can improve low-carbon technology deployment through North–South and South–South transfers in three ways. First, collaborate on a 'need-driven' approach that incorporates local technology needs and contexts across the technology cycle; second, develop the different types of capacity required across the entire innovation chain so as to assess, select, import, develop and adapt appropriate technologies; third, strengthen horizontal and vertical governance linkages across and between levels. Most particularly, there is a need to integrate energy and climate agendas across levels. If undertaken, such efforts can help support a technology transition where it is urgently needed in developing countries, and more effectively leverage the currently dormant opportunities facilitated by the global climate policy architecture.

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