Energy Code Enforcement and Compliance Evaluation: Comparative Lessons Learned from the U.S. and China, and Opportunities for India

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ABSTRACT

Building energy codes are one of the most cost-effective tools to achieve energy efficiency in buildings. The key to realizing their full benefits is strong enforcement and compliance. Studies have shown that robust enforcement and a high compliance rate are critical to improve the energy performance of buildings and unlock deeper energy savings. However, few countries have mechanisms for measuring and verifying code enforcement. This paper will provide a brief review of code enforcement activities, assess compliance evaluation methods in different countries, particularly in the U.S. and China, and summarize key lessons learned on building energy code enforcement and compliance. The U.S. recently developed methodologies measuring compliance with building energy codes at the state level. China has an annual survey investigating code compliance rate at the design and construction stages in major cities. Some states and countries also take simple approaches to evaluating code compliance. Like many developing countries, India has only recently begun implementing an energy code and is looking for an effective way for measuring compliance. As a case study on making codes more rigorous in fast-growing developing regions, we will examine how India might apply lessons learned from the U.S., China, and other jurisdictions to develop its own compliance evaluation approach. Experiences from these countries in measuring compliance rate will help design a robust system elsewhere to ensure effective implementation of building energy codes, which in turn leads to reduction in building energy use and associated emissions.

Introduction

India is experiencing an unprecedented construction boom. The country doubled its floorspace between 2001 and 2005 and is expected to add 35 billion square meters of new buildings by 2050. Buildings account for 35% of total final energy consumption in India today, and building energy use is growing at 8% annually (Kumar et al. 2010; Rawal et al. 2012). Studies have shown that carbon policies will have little effect on reducing building energy demand (Chaturvedi et al. 2014; Yu et al. 2014). Chaturvedi et al. (2014) predicted that, if there are no specific sectoral policies to curb building energy use, final energy demand of the Indian building sector will grow over five times by the end of this century, driven by rapid income and population growth. The growing energy demand in buildings is accompanied by a transition from traditional biomass to commercial fuels, particularly an increase in electricity use. This also leads to a rapid increase in carbon emissions and aggravates power shortages in India. Growth in building energy use poses a challenge for the Indian government.

To curb energy consumption in buildings, the Indian government issued the Energy Conservation Building Code (ECBC) in 2007, which applies to commercial buildings with a connected load of 100 kW or 120kVA. Previous studies estimated that the implementation of ECBC could help save 25-40% of energy, compared to reference buildings without such energy-efficiency measures (Tulsyan et al. 2013). However, the impact of ECBC depends on the effectiveness of its enforcement and compliance. Currently, the majority of buildings in India are not ECBC-compliant. The United Nations Development Programme projected that code compliance in India would reach 35% by 2015 and 64% by 2017 (UNDP 2011). Whether the projected targets can be achieved depends on how the code enforcement system is designed and implemented.

Although the development of ECBC lies in the hands of the national government – the Bureau of Energy Efficiency under the Ministry of Power, the adoption and implementation of ECBC largely relies on state and local governments. Six years after ECBC's enactment, only two states and one territory out of 35 Indian states and union territories formally adopted ECBC and six additional states are in the legislative process of approving ECBC (BEE 2013). There are several barriers that slow down the process. First, stakeholders, such as architects, developers, and state and local governments, lack awareness of building energy efficiency, and do not have enough capacity and resources to implement ECBC. Second, most jurisdictions have not yet established effective legal mechanisms for implementing ECBC; specifically, ECBC is not included in local building by-laws in most jurisdictions or incorporated into the building permitting process. Third, there is not a systematic approach to measuring and verifying compliance and energy savings, and thus the market does not have enough confidence in ECBC.

Studies have shown that robust enforcement and high compliance rate are critical to achieving intended energy savings and that improvement in the stringency of energy codes does not matter when the compliance rate is low (Harper et al. 2012; Stellberg 2013; Yu et al. 2014). Effective compliance and enforcement unlock deeper energy savings, reduce costs, increase building resale value, and minimize environmental impact.

This paper focuses on compliance evaluation, which refers to a set of processes and procedures through which factual information is provided, assessed, and checked to determine whether buildings effectively meet respective energy code requirements. Compliance evaluation can play a key role in building trust among stakeholders and instill confidence in the market to deploy and invest in energy-efficient building technologies. It is crucial to develop a common methodology for compliance evaluation for purposes of accountability and credibility of the codes program. Compliance evaluation can also help state and national governments track the progress of ECBC implementation.

Like many developing countries, India has only recently begun implementing an energy code. International experience on code compliance may provide ideas on building strong compliance assessment into India's code system from the outset. In this paper, we examine lessons learned on compliance assessment from other countries, particularly from the U.S. and China, and provide recommendations on how India could apply these lessons to develop its own compliance evaluation approach.

Importance of Code Compliance Evaluation

Compliance evaluation is critical to designing effective policies, because it allows policy makers to make improvements to programs over time based on hard data. Comparison between Denmark and Sweden provides a sharp focus on the importance of evaluation in policy making. Denmark has robust evaluation of most of its energy efficiency programs and has made a concerted effort to learn from its evaluations in developing policy and long-term strategy. For example, on the issue of building energy codes, Denmark has adjusted its compliance procedures over time to improve compliance; as a result, energy consumption per unit of floorspace in all of its buildings has declined greatly in recent years. Sweden, in contrast, has not conducted substantial evaluation, and its results in terms of building energy performance, while noteworthy, have not been as robust. New buildings in Sweden today may be less efficient than they were in the late 1980s, even though the requirements are more stringent today (Evans and Yu 2013; GBPN 2013; SEA 2012).

As India just started its energy code implementation, conducting compliance evaluation can help Indian policy makers identify potential problems in ECBC implementation and make improvements accordingly. Compliance evaluation will also help India achieve its intended energy savings and emissions reductions through ECBC.

It is also important to note that compliance evaluation is different from regular compliance checks that are used to enforce energy codes. Compliance checks are part of the code enforcement procedures; code officials or third-party inspectors check and verify if a single building complies with the requirements of the codes at the design and construction stages and then issue building permits. In contrast, compliance evaluation assesses the overall compliance rate of all buildings and may involve using statistical methods instead of checking every single building. Compliance evaluation can identify major issues in code compliance based on large building stocks and survey results and help policy makers prioritize areas for improvements. Another difference is that compliance checks are usually conducted during the building's design and construction, and compliance evaluation is often used in a retrospective way to assess if buildings are code compliant (Figure 1).

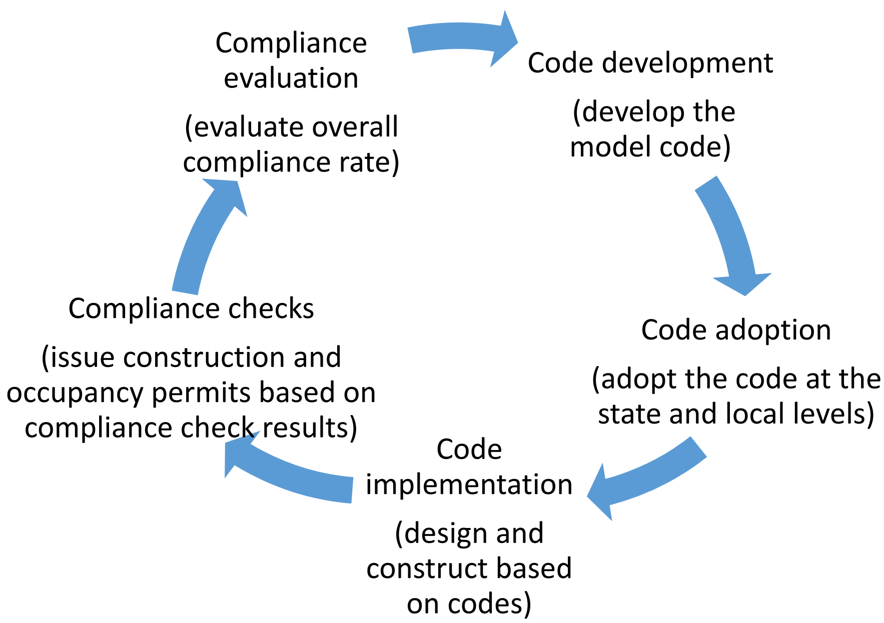

Figure 1. The cycle of energy code development and implementation. Compliance evaluation is generally the final step and many times helps to inform and improve revision of new energy codes.
Source: Developed by the authors.

Although compliance checks and compliance evaluation are different, they share steps that determine if the building is code compliant. Box 1 lists the basic steps in compliance checks, and many of these steps are also used in compliance evaluation. In addition to using evaluators to inspect buildings based energy code requirements, compliance evaluation also analyzes data collected from individual buildings and generates an overall compliance rate at the national or state levels.

Basic compliance check steps in energy code enforcement *(Source*: adapted from the U.S. Building Energy Codes Program):

- Review of building plans and specifications
- Evaluation of products, materials and equipment specifications
- Review of supporting calculations
- Inspection of the building and its systems during construction
- Review of tests, certification reports and product listings for installed materials
- Evaluation of materials substituted in the field
- Inspection immediately prior to occupancy

Code Compliance Evaluation Examples from the U.S. and China

Compliance Evaluation in the U.S.

Energy codes achieve energy savings only when projects comply with codes, yet only a few countries measure compliance consistently. China and the U.S. appear to be two countries with well-developed evaluation systems, which over time and if applied consistently, will likely help raise compliance.

Like India, in the U.S., adoption and enforcement of energy codes fall under the purview of states and localities. As building energy codes in the U.S. become more stringent, the U.S. building energy program started to focus on compliance and developed a plan to achieve 90% compliance with the model energy code by 2017, which requires active training and enforcement programs as well as annual measurement of the rate of compliance. Many states, territories, and jurisdictions are creating plans and mechanisms to measure and improve compliance with their energy codes. To support these efforts, the U.S. Department of Energy developed a guide to help state and local jurisdictions to measure and report energy code compliance, supplemented by an online tool to generate statistically representative samples.

Compliance evaluation proposed in the U.S. follows statistical methods, meaning only a sampling of buildings are assessed for the compliance evaluation. In addition, the U.S. approach does not calculate actual energy savings or energy use intensity of the buildings; it only checks if the building is constructed in accordance with building energy codes adopted by the state and local jurisdictions (PNNL 2010).

DOE’s 2010 report “Measuring State Energy Code Compliance” (Evaluation Methodology) provides specific guidelines to help states measure code compliance rates, and it divides compliance evaluation into four steps. First, the state needs to obtain the evaluation checklists for both residential and commercial buildings based on the version of the energy codes implemented in the state. Different code provisions are weighted based on their impacts on building energy consumption, namely high impact (Tier 1), medium impact (Tier 2), and low impact (Tier 3). Second, the state needs to determine which buildings in the state to inspect. The U.S. Building Energy Codes Program provides an online tool to generate a statistically significant number of buildings to inspect for residential new construction, residential renovations, commercial new construction, and commercial renovations. Factors to consider in sampling include building type and size, location by county and climate zone, and other factors. Third, the state sends out evaluators to inspect buildings according to energy codes requirements and fill checklists. Finally, the state analyzes the collected data from individual buildings and generates an overall state compliance metric based on statistical methods. The compliance rate could be calculated for individual buildings, building groups, and at the county, state, and national levels. These breakdowns are important because knowledge of the associated compliance rates or gaps at large can improve policy design and implementation.

DOE's Evaluation Methodology underscores the importance of ensuring that a state strikes a balance across building use, ownership, and design when sampling their buildings. Thus, representative building samples will include both energy-intensive building use types, such as hotels and other lodging, in addition to less-energy intensive buildings such as storage buildings. Likewise, a representative sample will include buildings with different ownership types to reduce the likelihood of bias in determining compliance. For example, in the U.S., schools are more likely to be owned and operated by state and local government. As a result, schools are more inclined to be in compliance with state and local codes, both because the owner has a vested interest in the ownership and operating costs and because it is under greater public scrutiny (PNNL 2010). Thus, a sample with more of these types of buildings could skew the results towards increased compliance.

To help states with sampling, DOE provides a simplified list of commercial building use types. The list includes retail/mercantile, warehouse/storage, education/school, lodging/hotel/motel, restaurants, religious and other buildings for public assemblies, and healthcare.[1] In addition, DOE provides states sample survey questions as one method for gaging the state of practices in certain jurisdictions.[2]

Since the Evaluation Methodology was published in 2010, DOE has taken steps to make further improvements to the methodology and also provided supplemental resources to assist states in raising compliance levels. In particular, DOE piloted the compliance methodology across several U.S. states, and the experiences of those pilot studies have led to a number of recommendations and potential changes to the DOE methodology. In particular, the pilot studies revealed that (EERE 2013):

- Consistency is challenging to achieve across studies and among individual evaluators. For this reason, additional guidance and instructions on DOE compliance checklists, evaluator training, and quality assurance of gathered data are essential.
- The checklists developed by DOE were valuable tools for local evaluators. State and local staff involved in code compliance during their normal course of code enforcement could also benefit from these checklists.
- Software tools (*COMcheck* and *REScheck*) based on trade-off and prescriptive-based compliance approaches demonstrated a strong correlation with higher compliance rates. Notably, documentation produced by software tools help to address prevalent barriers to compliance, such as lack of training, lack of resources, and lack of compliance information on plan submissions.
- Data sources for generating sample sets are not always accurate and, in some cases, are not available. State compliance evaluation studies are also costly.

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[1] The simplified list is a consolidation from sources such as the International Building Code, ASHRAE Standard 90.1, the New Buildings Institute Core Performance document, Commercial Building Energy Consumption Survey Principle Building Activities, and a New Buildings Institute-funded study of commercial energy code compliance in the Pacific Northwest. DOE also includes high rise residential buildings in this list because these buildings are under the purview of their commercial building code.

[2] DOE's sample questions can be found at http://www.energycodes.gov/compliance-evaluation.

- Access to buildings under construction was a major problem in some locations. Early engagement of state and local governmental agencies is imperative to ensure their cooperation.

The pilot studies illustrate the fact that one size does not fit all. In all the cases that DOE evaluated, deviations from the DOE methodology related to cost and/or time considerations. As a result, DOE is developing additional procedures that can address alternative approaches with these common barriers in mind (EERE 2013). Alternative approaches include post-construction evaluation, evaluation of a subset of compliance requirements, second-party evaluation (i.e., evaluation conducted by local government officials), spot-check evaluation, and trade-off and performance compliance approaches. The pilot studies show the importance of offering flexible mechanisms that can be tailored to local conditions. At the same time, it is important to acknowledge the trade-offs associated with using alternative approaches that may reduce the statistical significance of the results of code compliance evaluations, and to account for these trade-offs when assessing code compliance at the national level. The studies also served to increase dialogue with local jurisdictions, educate and heighten awareness about energy codes to building departments, and helped identify and execute training needs.

Code compliance evaluation in the U.S. has only recently started and there is not a reported national compliance rate. However, pilot studies have shown that compliance evaluation is critical to improving overall code enforcement (Harper et al. 2012), and the U.S. may achieve its 90% compliance goal by 2017 by rolling out full-scale compliance evaluation.

Compliance Evaluation in China

China is the world's largest market for new construction, adding 0.4 to 1.6 billion square meters of floor space annually. In response to this rapid growth, China has introduced several initiatives over the past few years to enhance energy efficiency in its buildings industry. Chinese codes are mandatory at the national level, but local governments can adopt more stringent codes. In support of the national requirements, China has established a multi-step protocol for enforcement of their building codes, including energy codes. Often, third parties are intimately involved in the enforcement of building codes during the construction of a project. They perform the first level check to verify that the design and construction is aligned with the codes. A second level check is performed by quality control and testing stations that review the documents submitted by third parties and do some of their own checks. Lastly, the guidelines found in China's Code for Acceptance of Energy Efficient Building Construction, introduced in 2007, make compliance of certain design elements an integral step in a construction project that may have otherwise preceded unchecked (Evans et al. 2010; Shui and Nadel 2012). For example, manufacturers seldom provide the results of thermal resistance tests for their products, but the Acceptance Code requires the construction supervisor to test samples of the material, many times sending them to a test lab.

Besides the checks included in each construction project, since 2005, the Chinese Ministry of Housing and Urban Development (MOHURD) has commissioned around ten survey teams every year to conduct an inspection of randomly selected medium and large buildings in urban areas in 31 provincial territories. The inspection is mandatory for residential new construction over 50,000 square meters and for commercial new buildings with a total investment of over 30 million yuan (~ $4.9 million[3]) (Evans et al. 2010; Shui and Nadel 2012). Compliance with building energy codes is one of the focal points of the annual inspection check. Unlike the compliance check in the U.S., the annual construction inspection in China also involves enforcement. If a building does not meet requirements of corresponding energy codes, it will receive notice to correct the problem within a certain period of time. This practice, to some extent, also leads to skewed results in compliance rates.

Cities that are selected for inspection are required to provide an inventory of the construction projects that have completed the drawing inspection stage. The inspectors, which include MOHURD officials, building energy code experts, or local code management and enforcement officials from alternate jurisdictions, verify whether relevant national and local building energy efficiency policies and regulations have been implemented. They also check whether compliance with mandatory items in design standards has been met.

The compliance evaluation of Chinese codes enforcement also involves sampling and checklists. Different from the U.S. approach that state and local jurisdictions evaluate compliance, the Chinese takes a top-down approach. MOHURD assembles 10 evaluation teams, and each team conducts compliance evaluation in two to three provinces. Four large municipalities (i.e. Beijing, Shanghai, Tianjin, and Chongqing) and the capital city of each province are always included in the national compliance evaluation. The evaluation team also randomly selects[4] one additional prefecture-level city and one additional county-level city in each province for compliance evaluation, and rural areas are not included in the evaluation. In each city, the evaluation team randomly picks several projects to assess project documentations or conduct on-site inspections. However, the number of projects evaluated is quite small. For example, in 2011, the inspection team only selected 12 buildings for compliance evaluation (six for design evaluation and six for construction inspection) in a prefecture-level city, and only six buildings were selected in a county-level city. Checklists used in compliance evaluation in China are also developed based on requirements in energy codes. However, the Chinese checklists weigh each item equally and do not differentiate requirements based on their impacts on building energy use.

In terms of information disclosure, MOHURD releases the nation-wide compliance rate on its website and lists provinces with good performance. The compliance rate during the 2011 inspection for the design stage is 100% and for the construction stage is 95.5%. However, the compliance rate is not representative at the national level for several reasons. First, China's compliance assessment system has been tested only on a relatively small scale, making it difficult to estimate a national compliance rate with high confidence. Only about 9% of China's total prefecture-level cities and 7% of total county-level cities are inspected. Second, cities in the survey are not randomly selected and more evaluations are conducted in large cities and metropolitan areas. Third, only a small portion of buildings is inspected in the selected cities and the relatively small sample size is not representative of the general population. Fourth, as the compliance rate is estimated based on medium and large projects in urban areas, it does not represent the compliance status in suburban and rural areas or in small buildings. Finally, MOHURD lacks a well-documented and transparent methodology for compliance evaluation[5], and this leads to inconsistency in data collection and evaluation. Inconsistencies in data

[3] 1 Chinese Yuan = 0.16 US dollar.
[4] There is no public documentation explaining how the cities are randomly selected.
[5] Since there is not an official MOHURD document we can refer to, most information presented in this paper was obtained from personal communications and previous studies.

collection have also been reported; reasons for this may be the lack of solid material testing and incomplete protocols for building simulation (Evans et al. 2010; Shui and Nadel 2012).

Although the Chinese system is not perfect and does not represent all buildings, along with the acceptance code, it did help improve compliance and energy performance of Chinese buildings, at least in urban areas. For medium and large buildings in urban areas, the compliance rate for the design stage doubled in the past six years and the compliance rate at the construction stage also improved significantly. Compared to the U.S., China has a shorter history and less experience in energy codes development and implementation, but much more building construction. It is more effective for China, as well as other developing countries, to establish a functioning compliance evaluation system in major cities at the early stage of code implementation than waiting for years to develop a full-fledged compliance evaluation system.

Lessons Learned on Compliance Evaluation

Compliance evaluation is essential to helping countries achieve better compliance rates and informing policy makers about progress in code implementation. Besides the U.S. and Chinese approaches, there are multiple ways to conduct compliance evaluation and states and countries can design the program based on their own needs. Below list some additional options for compliance evaluation.

Surveys of Energy Performance of Individual or Groups of Buildings

Even if compliance is not directly measured, baseline efficiency evaluations may be used to estimate compliance rates. Studies of energy efficiency programs often provide information on code compliance. For example, the State of Arkansas conducted an energy survey in 100 new homes to determine energy performance of current building practices. With a focus on assessing energy consumption of homes, the survey included a blower door test and a heating and cooling load analysis, which helps builders and prospective buyers compare estimated utility costs with the costs associated with meeting the energy code. The information collected in this survey would also help the State Energy Office improve both code compliance and energy performance. Similar studies have been conducted in other states to determine energy savings as well as code compliance through on-site inspections. (Brown 1999; Misuriello et al. 2010).

Assessments of Energy Savings in Simulated Buildings

Studies have compared model predictions, based on the design alone, with building designs and prototypes to decide if the building meets the energy standards. Many European countries take this approach to estimating energy savings and impacts of building energy standards. However, affected by behaviors and operations, actual energy use is likely to differ from model predictions. The Swedish study shows that the difference could be up to 250% (SEA 2012). To improve the results, a few jurisdictions in Sweden and France have done small evaluations that compare actual energy use to the rated energy use that the building should attain based on its code compliance documents. Australia links it to periodic energy audits after the construction is completed.

Surveys of Developers, Architects, Inspectors, or Builders

When funding is limited for more complete evaluation, or in earlier implementation stages, states or countries can use simple surveys to assess the number of compliant buildings or how the compliant process went. In other cases, these surveys are used to supplement information obtained from plan reviews and field inspections to conduct in-depth analysis to identify major problems in code implementation.

These approaches, compared to methods used in the U.S. and China, are less expensive and resource-intensive, but there are also problems associated with these simple approaches. One major issue is that the small sample size used in these surveys and assessments is not representative and the results are often not statistically robust to generalize to all buildings. Although random sampling from all buildings in a jurisdiction is the ideal way to assess compliance rate, many jurisdictions often lack resources and capacity to conduct the analysis in this way, especially when on-site inspections are required. To make it feasible, most existing studies use stratified sampling and focus on areas of highest building activity and large buildings with greater impacts on energy use and emissions. Another problem is that some studies take a simple approach that only reviews building designs. However, there might be inconsistency between building plans and actual constructions, and the modeled energy use based on designs is likely to differ from the actual energy consumption. Third, since these studies are conducted by local jurisdictions and use different methodologies, it is difficult to make a reasonable comparison across jurisdictions on their code enforcement efforts. It is also important to note that the result of compliance evaluation – compliance rate – varies by methodologies used, and compliance rate should be interpreted based on their methodologies.

Given these limitations, the U.S. and China aim to develop comprehensive methods for compliance evaluation, based on some key components that are essential to evaluating code compliance.

1. **A statistical approach to evaluating and estimating compliance rates**. Developing a robust and statistically sound method is important for compliance evaluation. In addition, to better use results for analysis, the methodology and results need to be released in a transparent manner.
2. **Detailed compliance checklists for evaluators and code officials** to measure and decide on whether the building complies with codes. In addition, compliance checklists could identify and highlight areas that are particularly problematic, which help policy makers to allocate resources in future policy development and implementation.
3. **Priorities in compliance evaluation**. The U.S. classifies codes requirements by their impacts, and prioritizes areas for evaluation and improvement based on impacts on energy consumption. China is developing its codes system and lacks capacity to enforce energy codes at a large scale, and therefore, the initial compliance evaluation focuses on major cities.
4. **A consistent methodology.** The studies in both the U.S. and China found that consistency is challenging to achieve across studies and individual evaluators. A solid methodology, transparent reporting system, clear guidance and instructions on compliance checklists, and training of inspectors can help achieve consistent results.

5. **Robust compliance software**. Software tools such as (e.g. COMcheck and REScheck in the U.S. and PKPM-Energy in China[6]) contributed to higher compliance rates. Documentation produced by software tools provides compliance information to code officials and inspectors upon plan submissions. It also helps address prevalent barriers to compliance such as lack of training and lack of resources.

However, neither country directly measures energy or CO_2 savings from energy code implementation. Reductions in energy use and emissions are the ultimate goal for the development and implementation of energy codes. However, it is more difficult and costly to measure building energy use than to assess the compliance rate. Although neither country measures and verifies actual energy savings at present, they may add this component as the system of compliance evaluation gets mature. The City of Tokyo started to measure actual energy consumption and emissions from buildings since 2010, as it started the cap-and-trade program (Yu and Evans 2013).

Policy Recommendations on ECBC Compliance Assessment

Developing a compliance evaluation system would help the Indian government show the benefits of ECBC and build momentum for future implementation. Based on evaluation results, the Indian government can develop policies to target particular problems and improve ECBC implementation. Compliance evaluation also encourages the private sector to actively participate in energy code implementation.

As discussed above, compliance evaluation can be conducted by state/local jurisdictions or the national government. However, in either case, to ensure consistency in results, the methodology should be developed at the national level. The Bureau of Energy Efficiency (BEE) could develop a system and methodology for compliance evaluation.

The evaluation methodology needs to define statistical methods for sampling and estimation, such as how to select representative buildings based on building type and size, location, ownership, and climate condition. For example, the compliance evaluation needs to assess enough samples in both energy-intensive buildings such as hospitals and hotels and less energy-intensive buildings like office buildings. Sampling also needs to consider the size of buildings, as compliance status of large and small building might be different. In addition, building ownership, whether it is a government facility or private commercial buildings, are also likely to affect their compliance behaviors.

To have a robust evaluation system, ECBC compliance checklists are also needed. Since ECBC is developed based on the ASHRAE Standard 90.1, ECBC compliance checklists could be developed based on the U.S. checklists. ECBC checklists could also weigh requirements based on their impacts, and there are some studies of Indian buildings that can help identify high-impact requirements and provisions (Rawal et al. 2012). Moreover, compliance checklists and other supporting materials can also benefit ECBC enforcement.

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[6] Most Chinese building designers use software to make sure that their designs comply with the requirements of building energy codes. There are multiple tools that could be used for this purpose in China; PKPM-Energy is one of these tools, but has greater market share than the others. Local quality supervision stations and third-party inspectors refer to the report generated by PKPM-Energy to check and verify code compliance of buildings. However, it is worth nothing that PKPM-Energy is not a tool for overall compliance evaluation and is not used or adopted by the Chinese Ministry of Housing and Urban Development for its compliance evaluation process.

Below summarizes the categories that can be included in ECBC compliance checklists:

- General information of the building: basic information of the building (name, address, floor area, state/city/jurisdiction, climate zone, building type (e.g. office, school, hotel, hospital, etc.), building ownership (e.g. state-owned, local government-owned, national account, or private), inspection date, and the responsible evaluator;
- Project type: new building, addition, or renovation;
- Selected compliance approach: prescriptive, trade-off, or performance;
- Code version: ECBC (if so, whether compliance software is used) or above-code program (e.g. Leadership in Energy and Environmental Design);
- Compliance status: compliant, not compliant, not observable, or not applicable;
- Plans review verification: record of values and parameters found during plan review;
- Field verification: fillings of observed values based on field inspection, checks against values provided during plan review, and determination of compliance.

The state can tailor the standard evaluation methodology to its needs. The state or local governments may amend ECBC or develop localized interpretations of ECBC that might result in modifications to ECBC requirements. Therefore, compliance checklists need to be climate zone specific or state specific. Moreover, most states only have limited capacity to enforce ECBC and can start from high-impact provisions and expand to full-scale ECBC implementation later.

Compliance evaluation at the state level requires coordination with BEE, as it shows in case studies that consistency in methodology is important to produce comparable results. Compliance evaluation also requires coordination between state and local governments, as urban local bodies may collect compliance data while the state government analyzes data. Moreover, the state can list and compare compliance results among local jurisdictions and generate peer pressure for local jurisdictions to improve their performance. Municipalities with good compliance rates could also be rewarded. This rewards approach, if taken, also requires checks and balances to avoid data manipulation. One way of doing this is that BEE conducts random checks to ensure that all reported data are correct and valid.

Compliance evaluation at the national level can be rolled out and implemented in the following steps. The initial stage of compliance evaluation can target methodology development and compliance evaluation in pilot regions and states. Then, national and state governments need to provide training and build capacity on compliance evaluation. Since the majority of trainings for evaluators overlap with conventional codes training, adding compliance evaluation into code implementation roadmap will not bring too much burden to the system. After the success in pilot states, compliance evaluation can be rolled out at the national level. There could be incentives to encourage state to conduct compliance evaluation. For example, the state's compliance rate could be used as one criterion to select states that receive the grant and assistance from BEE and other organizations. Finally, since ECBC is linked with the Energy Conservation Act, which sets targets for energy use intensity, beyond simple compliance evaluation, BEE could also develop a system to measure and verify actual energy and emissions savings induced by ECBC.

Conclusions

Building energy codes are one of the most cost-effective tools to achieve energy efficiency in buildings. The key to realizing their full benefits is strong enforcement and compliance. Studies have shown that robust enforcement and a high compliance rate are critical to improving the energy performance of buildings and unlocking deeper energy savings. Both the U.S. and China have comprehensive compliance evaluation programs, and some key components of these programs include robust and consistent methods for compliance evaluation, applicable checklists of code requirements, and balances between deep energy savings and comprehensive coverage of building stocks. India can use these lessons learned from other countries to develop its own compliance evaluation approach. This requires the development of robust methodologies and technical support documents at the national level, as well as support and implementation at the state and local levels. Moreover, India has an opportunity to move beyond the existing efforts in the U.S. and China and measure actual energy savings and avoided CO_2 emissions through ECBC implementation. How to measure actual energy savings in buildings is not discussed in this paper and can be studied in the future work.

Experiences from the U.S., China, and India in measuring compliance rate will help design a robust system elsewhere to ensure effective implementation of building energy codes, which in turn leads to reduction in building energy use and associated emissions.

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