To Comply or Not to Comply—What Is the Question?

Allen Lee, Dan Groshans, Cadmus, Portland, OR

ABSTRACT

For at least two decades, building energy codes have been examined as a key means of accomplishing energy-efficiency market transformation. Building codes can produce major energy savings, but skeptics have questioned if promised savings materialize. If not, this poses major problems, reducing confidence in the validity of key resource planning assumptions.

Utilities and other program administrators offer special expertise, experience, and resources that can support code development, enforcement, and compliance. Recently, research and policy have addressed how program administrators can advocate for building codes and enhanced code compliance to produce significant savings cost effectively. Given the potential benefits, such efforts can prove very cost-effective from a program administrator's perspective. Though program administrators have started to pursue these efforts, major questions remain: How is code compliance defined? What compliance level is actually achieved? How can compliance be measured? How does compliance impact energy savings? How can the effect of compliance enhancement programs be assessed?

This paper addresses several of these questions, using results from a number of recent code compliance studies to discuss compliance measurement current practices and areas requiring further research. One of the most challenging issues is how to measure compliance enhancement programs' effects on changes in compliance and energy savings. This paper discusses obstacles that must be overcome to measure these effects and describes efforts to do so. The paper closes with recommendations on ways to bring consistency and accuracy to compliance measurement, and to provide approaches and results facilitating expansion of compliance enhancement programs.

Introduction

For at least two decades, energy-efficiency advocates and planners have examined building energy codes as a method for accomplishing energy-efficiency market transformation. This effort got a boost when the American Recovery and Reinvestment Act of 2009 (ARRA) required all 50 states that accepted State Energy Program funding to: (1) adopt a residential building energy code meeting or exceeding the 2009 International Energy Conservation Code (IECC); (2) adopt a commercial building energy code meeting or exceeding the ASHRAE Standard 90.1-2007; and (3) develop and implement a plan to achieve 90% compliance with the target codes by 2017, including measuring current compliance each year.

A growing number of utilities and other energy-efficiency program administrators have become aware of the significant energy savings energy codes can provide. Recognizing these opportunities, the energy-savings potential, and challenges, numerous utilities and other organizations have thus started researching policies and processes needed to facilitate utility involvement in supporting building energy codes (Groshans & Lee 2013; Lee et al. 2013c; Misuriello et al. 2012).

Although building energy-efficiency codes can produce significant energy savings, savings cannot be guaranteed without the assurance of code compliance through effective enforcement. Skeptics have questioned whether, due to non-compliance, savings promised by codes are actually realized. If savings are not realized, major consequences result. For example, new building programs usually are premised on the baseline being code, but buildings not built to code present an erroneous baseline, and program savings will not be estimated accurately. If a utility invests resources in supporting building codes, the savings must be realized for the investment to pay off. Most importantly, if code compliance falls below 100%, resource plans relying on the code to deliver all predicted energy savings will face a shortfall. To provide more reliable energy-savings estimates from codes and to allay concerns of resource planners, program managers, regulators, and others, several code compliance questions must be answered:

- How is code compliance defined?
- How can compliance be measured?
- What compliance level is actually achieved?
- What is the relationship between compliance and energy savings and how does non-compliance impact energy savings?
- How can the effect of compliance enhancement programs be assessed?

This paper addresses these questions, based on the latest research conducted by the authors and others. Given the increasing focus on codes, responses to these questions continue to evolve, and final consensus has yet to be reached for all of them. Consequently, this paper provides a "snapshot" of the current situation, and a resource for stakeholders interested in implementing and evaluating energy code programs.

What Is Energy Code Compliance and Why Is It Important?

Building codes are regulations or laws, enacted by a governmental authority, to protect public health, safety, and general welfare as relating to the construction and occupancy of buildings and structures. Officials of local or state governments enforce such codes, though the process of doing so varies by state and jurisdiction. Still, some practices have become relatively common. Code compliance is usually confirmed through reviews of building plans submitted with building permit applications, followed by one or more site inspections during different construction stages. Typically, once code officials have verified all code requirements have been achieved, they issue a certificate of occupancy, and the building can be occupied. In theory, every building approved by code officials should meet all code requirements (that is, compliance should be 100% for all requirements).

Introduced first in the late 1970s, building energy codes represent a relatively new type of building code. Many jurisdictions have instituted energy codes only recently, and others still have no energy codes. In some states' rigid home-rule laws do not permit the state to establish or enforce building codes, including energy codes, that apply at the local level. Studies have shown code officials consider energy codes less important than regulations addressing fire and other direct, life-threatening issues in buildings.[1] Many stakeholders find typical energy codes complex to understand and difficult to implement and enforce.

Given these unique characteristics, and code enforcement agency resource constraints (especially in times of tight budgets), it is widely acknowledged that, compared to other codes, the building industry places less emphasis on fully meeting energy code requirements, and code officials typically give energy codes a relatively low priority in the enforcement process. Consequently, despite their legal status, not every energy code requirement may be met in all buildings (that is, compliance often does not achieve 100%).

Defining Code Compliance

Very large energy savings can be achieved when buildings are constructed to meet or exceed energy-efficiency codes. To assess energy code effects on energy consumption, the degree of compliance must be determined—assuming full compliance can overestimate code savings significantly. Because code impacts on energy savings can be very large, a certainty level similar to the level required for energy-efficiency program savings should be applied to estimate energy code savings and the effects of code compliance.

[1] There is growing evidence that buildings that are not energy efficient can contribute to morbidity or mortality when extreme weather conditions occur.

How to most meaningfully quantify compliance with the energy code depends on one's objectives. One could apply a strict determination based on the literal code requirements—every process and reporting requirement would have to be met, along with energy-efficiency requirements for every building component. Failure to satisfy all these requirements would result in a failing grade—compliance would be a binary finding so each building would either fully comply or not. By treating all requirements equally in the compliance determination, however, this metric does not account for how different requirements affect energy savings.

To at least partially reflect the importance of different code requirements, one could assign each an importance weight, and then calculate the compliance rate as the percent of the total possible compliance score achieved, using the weighted value for each requirement that was met. To support the ARRA requirement to achieve at least 90% compliance with the energy code, the Pacific Northwest National Laboratory (PNNL) developed checklists for measuring residential and commercial building code compliance that implement such an approach. PNNL assigned an importance weight (from 1 to 3) to each requirement; the compliance rate equals the sum of weights for code requirements met, divided by the sum of possible weights for all applicable requirements. PNNL assigned the weights (from one to three) based on its assessment of the relative importance of each requirement. The method seeks to account to some extent for energy impacts, but it includes several code requirements that do not directly affect energy use (for example, posting of specific labels), and the weighting scale used does not sufficiently capture variations in energy impacts.

From an energy impact perspective, the most meaningful assessment of energy code compliance is to compare energy consumption of a building as-built with the amount of energy it would use if it were built to just meet code requirements (often called the "reference building"). The most common way to apply this method is to use an energy simulation model to estimate the energy used in both cases and perform the analyses for a sample of buildings. The results of the analysis can be used to project compliance and energy savings for the population of new buildings.

Energy code compliance studies over at least two decades have used all of these approaches, but a standardized approach or protocol has not been established. The PNNL method probably comes the closest to a widely used approach, but it does not directly provide information on energy impacts.

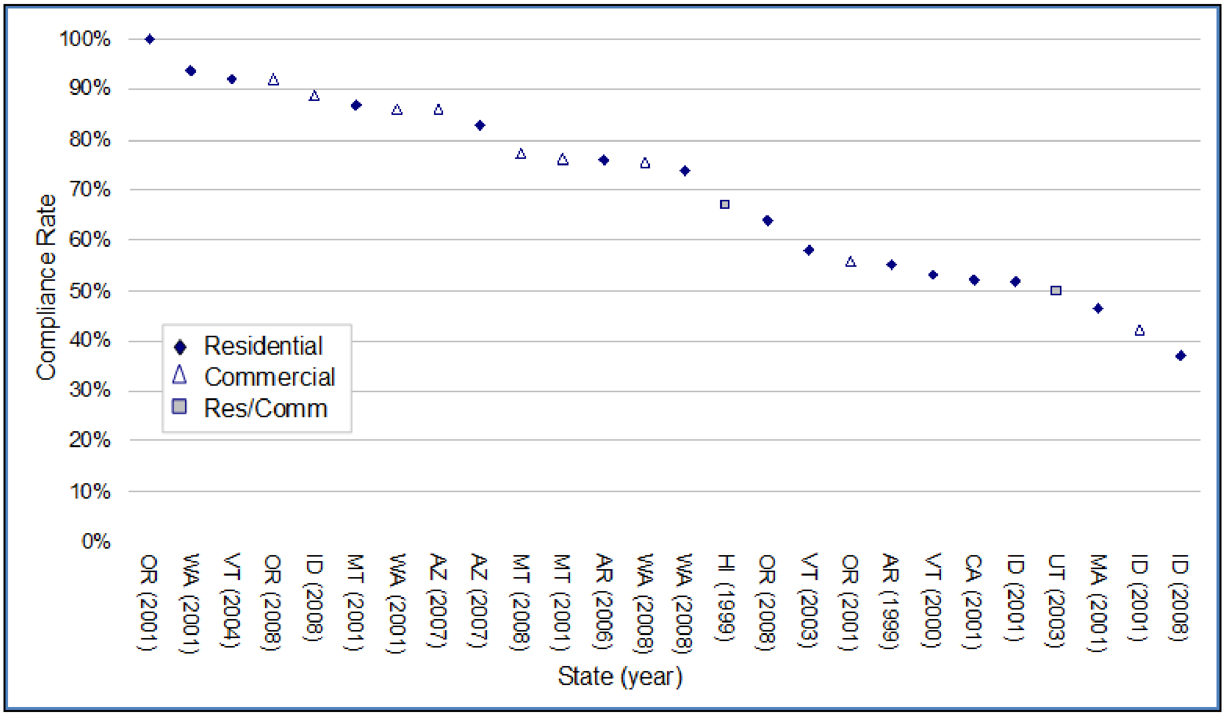
Importance of Determining Compliance

Once an appropriate method and meaningful metric have been established for measuring code compliance, determining compliance offers multiple benefits by:

- Providing a more accurate baseline for estimating efficiency program savings.
- Identifying weak compliance.
- Tracking compliance trends.
- Providing data to assess the effects of programs designed to increase compliance.

Code Compliance Estimates

Code compliance studies have been conducted since at least the early 1990s. To illustrate findings from some code compliance studies conducted since 1999, Figure 1 shows results from a recent report that summarizes 26 studies conducted in several states, for both residential and commercial buildings (Misuriello et al. 2012). The studies indicate compliance rates ranging from 37% to 100%. The report, however, noted these studies used nine different compliance rate metrics; thus, few reliable conclusions can be drawn from these data regarding trends or differences in compliance rates. This report highlights the need to develop a consistent code compliance metric that can be used to compare and assess trends.



Source: Misuriello, Kwatra, Kushler, Nowak (2012)

Figure 1. Findings from Code Compliance Studies

Compliance Study Design Considerations

To design a code compliance study, a researcher must decide among an array of options, and the decisions are driven by study objectives. For this paper, we assumed the objective is to determine, with an acceptable level of rigor, how *ex ante* energy impacts must be adjusted to account for the effect of buildings' energy performance, relative to the expected influence of code requirements on energy use. Thus, code savings may exceed—as well as fall short—of *ex ante* estimates.

The authors note a compliance study design should be guided by the same principles as an M&V study or program impact evaluation (particularly for a new buildings program), with variations to reflect the unique nature of the code compliance and enforcement process. We have identified these key study design and implementation characteristics for consideration:

- **Sample size:** The typical unit of analysis for determining code compliance is the building. Consequently, a study must determine how many buildings are needed to provide results at the desired precision/confidence level. An appropriate sample size can be based on the expected mean compliance rate metric and its variance.
- **Basis for compliance assessment:** Some studies have analyzed compliance based on information filed for permitting. Several studies have shown, however, that characteristics of buildings as-constructed can differ from the information filed for permitting purposes. Therefore, we recommend choosing to collect (1) both permit and site visit data or (2) just data from building site visits.
- **Recruiting participants:** With an energy code in place, all new buildings become "program participants," though not in the conventional energy-efficiency program sense of signing up for a program. Energy-efficiency programs usually require participants, as a condition of participation, to permit site visits, interviews, metering, and other typical evaluation activities. In a code compliance study, these conditions do not apply: builders, building occupants, or code officials are not obligated to participate in the study. This may be an obstacle to recruiting buildings for analysis. Because

participant self-selection can introduce significant bias, it is essential to minimize this bias and randomize the sample as much as possible.

- **Multiple site visits:** Verifying efficiency features for new buildings poses special problems as some building components can be observed only at certain construction stages; thus, multiple site visits may be necessary throughout construction. In a new buildings program, this may be possible because the program requires it. For assessing code compliance, researchers may have the challenge of attaining cooperation of building owners or occupants.
- **Treatment of unobservable features:** If certain efficiency features cannot be observed directly during site visits, it may be necessary to infer their compliance level. This will require implementing a reasonable strategy, introducing the least possible bias, to fill in missing values.
- **Energy analysis:** Engineering analyses and simulation modeling are the most feasible means of estimating the energy use of buildings covered by an energy code. Observed deviations from code requirements would be reflected in the estimated energy consumption. Metering or billing data could be used to calibrate engineering or modeling estimates, thereby improving their accuracy. However, these steps can increase study costs and schedules, rendering them impractical for some studies.

Recent Compliance Studies

Due to ARRA requirements, the number of energy code compliance studies has increased significantly since 2009. Recent studies have been conducted in the following states; states shown with an asterisk were included in US Department of Energy (DOE) funded tests of the PNNL checklist:[2]

- Georgia*
- Utah*
- Iowa*
- Wisconsin*
- New York
- California (2006-2008; 2010-2012)
- Massachusetts*
- Idaho*
- Oregon*
- Montana*
- Washington*
- Connecticut
- Rhode Island
- Illinois

Other states have used the PNNL checklist too, thereby establishing some commonality in their compliance measurement methods; however, overall, the approaches applied varied widely.

One of the earliest of these studies was conducted for the New York State Energy Research and Development Authority (NYSERDA) (VEIC 2011), which examined both residential and commercial buildings. As it covered compliance with a mix of codes, the study was more a test of methodology than a definitive assessment of compliance with the most recent energy code. The study evaluated compliance for 44 residential buildings and 26 commercial buildings using two different methods: an early version of the PNNL checklist and DOE compliance software (RES*check*™ for residential buildings and COM*check*™ for commercial buildings). The study pointed out many research challenges, such as the likely self-selection bias of participating buildings and the difficulty in gaining cooperation of building officials. The study showed the PNNL checklist provided higher compliance rates than the DOE software for both residential and commercial buildings. A large share of buildings did not meet the code despite submitting documentation to building officials indicating code compliance. The lifetime energy savings lost due to noncompliance by buildings constructed during a five-year period exceeded $1.3 billion.

NYSERDA plans to conduct a series of compliance studies over the next few years, with the first of these studies addressing renovations in commercial buildings. As NYSERDA supports a substantial

[2] Participating states submitted a report to DOE about their projects; a DOE report summarizing the results is in progress.

program to improve code compliance, its studies will serve to establish a baseline and determine program impacts over time.

The first California study listed above was conducted as part of investor-owned utilities' (IOUs) 2006–08 Codes and Standards Program (KEMA Team 2010) impact evaluation, and covered compliance in residential and commercial buildings. California adopts and implements its own energy code (referred to as Title 24) so, given the code's uniqueness and the compliance study's purpose, analysis did not use the PNNL checklist.

The California residential compliance study relied on data collected from site visits to 194 new homes and 37 new or renovated commercial buildings. The authors determined savings of residential buildings by comparing modeled energy consumption of each home as-built to a reference home that was built to just meet the prior Title 24 code. The study calculated residential compliance by comparing these savings to expected savings of the same home if it had been built to just meet the current Title 24. Commercial building compliance was determined using a simpler approach, relying on a scoring system that provided an estimate of the proportion of expected savings achieved. The study showed that residential buildings saved on average 20% more than expected from the code change; thus, overall compliance based on energy use was more than 100%. Because the commercial building sample was relatively small, code compliance could not be determined with sufficient accuracy; however, the limited data showed 38% of commercial buildings did not meet the code requirements.

In two Northeast states, recent studies analyzed code compliance of residential and commercial buildings using multiple methods. For homes (NMR Team 2012a, 2012b), the studies applied four different methods (percent of prescriptive criteria met, HERS Index, energy cost compliance, and UA[3]); since all methods were applied regardless of the compliance path elected by the builder, the results were not necessarily an accurate determination of compliance. In both states, compliance rates were low using all methods. Massachusetts homes performed better than Rhode Island homes based on average values for all four compliance metrics. Although the compliance metric magnitudes were not very consistent, the results suggested correlations among the metrics within a state and consistent differences between the two states.

The last three studies—all of residential buildings—were conducted in Northwest states by Cadmus for the Northwest Energy Efficiency Alliance (NEEA). Each study was intended to apply the PNNL checklist method with additional approaches that varied across the states. For all homes, Cadmus' team conducted site visits to document construction characteristics. In some cases, we reviewed building plans and permit data at the building departments (sometimes this information was available at the home).

The PNNL checklist accounts for all measures applicable to each home. The code allows three paths a builder can use to demonstrate compliance: prescriptive, tradeoff, or performance. Table 1 shows how PNNL recommends using the checklist in each case. If a measure (e.g., ceiling insulation) can be observed, its value is recorded, and compliance with the code requirement can be determined. The analysis excludes measures not observable or not applicable to a given home.

As Montana had adopted the 2009 IECC, Cadmus determined compliance based on the PNNL checklist for this code (Lee, Cook & Horton 2012). Montana offered a special challenge in that over one-half of the homes had been built in areas without building departments or code enforcement. To determine statewide compliance, the sample of jurisdictions included those with and without building departments.

Table 1. Builder Compliance Demonstration Path and PNNL Checklist Approach

Path Used by Builder to Demonstrate Compliance	PNNL Checklist Approach
Prescriptive	Compare each field observed measure to prescriptive requirement
Tradeoff	Compare each field-observed measure to the level listed in tradeoff

[3] UA is the overall thermal transmittance.

	documentation
Performance	Conduct simulation based on field-observed measures; compare to reference home
Unknown/Undocumented	Follow prescriptive approach

In a first attempt to adjust for variations in the amount of data observable in each home, Cadmus calculated a "modified PNNL checklist" score by weighting the compliance score for each home, depending on how many measures were observable compared to the average number observable for all homes studied; this method produced a 61% compliance rate (nearly 80% in jurisdictions with building departments and about 50% in jurisdictions without).

Cadmus developed a second method by counting (and equally weighting in the basic checklist) the compliance of only the eight "significant items" that the study team deemed had the largest impacts on energy use. This approach provided a considerably higher compliance rate of 81% (96% in jurisdictions with building departments and 72% in jurisdictions without).

Finally, because the study scope did not permit building energy analysis, Cadmus developed an "energy consumption approach," which used the basic checklist method and weighted checklist items based on their contributions to total home energy use, as estimated in a prior study. This approach more directly accounts for the effect of compliance with each code requirement on energy use and resulted in a compliance rate of 64% (83% in jurisdictions with building departments and 52% in those without), quite close to the estimate from the "modified PNNL checklist" method.

Idaho also adopted the 2009 IECC, so Cadmus applied the PNNL checklist for the Idaho climate, but did not include the modifications implemented in the Montana study to adjust for the amount of data observable for each home (Lee et al. 2013a). This method produced a 90% compliance rate. Cadmus then estimated compliance using the significant items method, deriving a slightly lower compliance rate of 83%. The study scope permitted energy simulations of each home to be conducted, and these analyses indicated, on average, that homes just met the code requirements or were 100% compliant.

Washington posed unique challenges as it did not adopt the IECC code. Consequently, Cadmus developed a modified PNNL checklist to permit analysis of the Washington State Energy Code (WSEC), comparable to the Idaho and Montana studies (Lee et al. 2013b). This required adding WSEC-specific requirements to the original PNNL checklist. With this method, Washington achieved a 96% compliance rate, the highest among the three states. Cadmus also applied the significant items method in Washington, which produced very consistent compliance results, at 97% (also the highest of the three states).

In addition, Cadmus analyzed the energy consumption estimated for each home as-built, comparing it to the estimated usage of the same home built to just meet code (the reference home). Rather than use an energy-based compliance metric to indicate compliance, Cadmus defined the "energy compliance index" as the ratio of estimated usage as-built to usage of the reference home, thus providing a compliance metric. This index is similar to the HERS Index—presented as a percent, the ratio indicates how much less energy (for ratios less than 100%) or more energy (for ratios greater than 100%) the home uses compared to a home just meeting the code (100%). For Washington, the index estimated the average home used about 4% less energy than a home built to just meet the code.

Table 2 summarizes the compliance study results for these three Northwest states. The Cadmus team and NEEA refined the methodologies from one study to the next based on lessons learned from each study. The "significant items" approach provides a common methodology for comparing compliance among the states. However, Cadmus did not find this methodology was sufficiently correlated with energy-based compliance, so it could not be used, as is, to accurately estimate energy effects of compliance. The three studies do recommend that more research be conducted on ways to infer energy impacts of code compliance that might not require building simulations.

Table 2. Compliance Results for Three Northwest States*

Montana		Idaho		Washington	
Method	Result	Method	Result	Method	Result
Modified PNNL Checklist	61%	PNNL Checklist	90%	PNNL Checklist	96%
Significant Items	81%	Significant Items	83%	Significant Items	97%
Energy Consumption	64%	Energy Modeling	100%	Energy Compliance Index	96%**

* Compliance methods across states are not directly comparable in all cases.
**An energy compliance index less than 100% indicates homes perform better than if built to just meet code.

In addition to quantitative measures of code compliance, these recent studies also provided information about which code requirements were not met most often. This information is an important complement to the compliance metric as it identifies where training and other activities to enhance code compliance are most needed.

Programs to Enhance Energy Code Compliance

Over the past two decades, many program administrators have conducted programs to enhance code compliance. The typical scale of the efforts has been relatively modest and the efforts often have focused on training and been conducted in conjunction with other programs. The authors are unaware of any such programs that have claimed energy savings so far, but working to increase industry code compliance and jurisdiction code enforcement will likely provide a cost-effective way to reduce energy consumption. One study estimates a benefit-cost ratio of about 6:1 for activities that increase compliance rates from typical levels to 90%, accounting for all public and private sector costs (IMT 2010). Several recent studies have discussed this opportunity and the challenges associated with attributing the resulting energy savings (Lee et al. 2013c; Misuriello et al. 2012; Misuriello et al. 2010).

Elements of a Compliance Enhancement Program

NYSERDA in New York and utilities in California are implementing substantial, exemplary compliance enhancement programs (CEPs). NYSERDA's CEP is a multifaceted approach provided by nine contractors and comprising training of code officials and the building industry, technical assistance services for selected communities, plan review compliance assessments for code officials, and outreach to diverse professional organizations (Cadmus Team 2012).

The California CEP started with interviews of plans examiners, building inspectors, and energy consultants (CA IOUs 2010). The interviews documented skills, knowledge, and resources that would most help improve compliance and grouped needs into six categories. For each category, the team identified specific CEP activities to address the needs. The CEP has been underway since 2010 and, in addition to a range of trainings, the major activity to date is development of a best practices enforcement guide based on working with a small group of targeted jurisdictions.

Though more extensive than most CEPs, the activities in these programs are typical of the range of CEP support. Other activities and services are circuit riders who travel to different jurisdictions to provide targeted enforcement support, technical assistance hotlines, code books, and funding of third-party enforcement.

Underlying implementation of these CEPs is an assumption that they will lead to enhanced compliance and energy savings. Of 17 states with program administrators involved in building energy codes, the authors identified only Rhode Island as having a defined and accepted mechanism to credit savings to program administrator efforts to increase code compliance. In a utilities commission decision (RI PUC

2012), the regulator reached agreement with National Grid on its proposed Compliance Enhancement Initiative, designed to increase the building industry's ability (and desire) to comply with the building energy code and improve the ability of local building departments to enforce it. The resulting approach for determining and attributing energy savings requires the utility to begin with a deemed estimate of potential savings, based on a prior analysis of baseline compliance, and a deemed attribution factor for specific utility efforts accomplished. The process includes a working group to adjust savings and attribution, based on progress and future compliance studies.

Measuring the Effects of a Compliance Enhancement Program

Although the Rhode Island approach is a good first step toward claiming savings from compliance enhancement efforts, deeming savings and attribution are not likely to be acceptable in the long term if compliance enhancement offers significant energy savings. The California utilities and NYSERDA will want to claim energy savings from their CEPs, but for the claimed savings to be accepted they must be based on a credible and robust analysis method. A credible, robust methodology to estimate compliance enhancement program savings must have at least the four following components:

1. A way to estimate compliance without the program
2. A method to determine a change in compliance
3. An approach for quantifying energy savings from a code compliance change
4. A method for determining how much of a change in compliance is attributable to the program.

The first two components depend on a valid method being developed to measure compliance, given all the issues described earlier. The third component requires a method to calculate energy impacts of constructed buildings, such as energy simulations or simplified methods using correlation models to estimate use based on building characteristics. The fourth component calculates what share of energy savings from enhanced compliance is due to the compliance enhancement program.

Figure 2 illustrates the assessment process. The "initial energy savings" are potential code savings, diminished by the amount of noncompliance. The analyst must compile information on the characteristics of buildings constructed under the current code, prior to program intervention, to determine the average compliance level. Industry experience and code enforcement can influence the compliance level and initial savings. The analyst must then estimate energy consumption of the buildings constructed prior to the program. The "final energy savings" are achieved after the program has been implemented. Compliance must again be measured, based on the characteristics of constructed buildings, and the researcher must estimate energy consumption of the buildings then being constructed. The change in savings between the pre-program level and post-program level is the difference between the pre- and post- program values. The researcher must then determine what share of the savings is attributable to the program. Some of the change in consumption is due to other factors, such as the learning curve effect on compliance levels, and this compliance improvement and associated energy savings should not be credited to the program.

A combination of qualitative and quantitative methods is needed to assess CEP effects. The core analysis, measuring the code compliance change, needs to be based on a research design. Ideally, a randomized experiment would be conducted in which program targets—such as jurisdictions or builders—would be selected randomly to participate in the program and others would be selected as control groups. This is not likely to be very feasible, however, because of issues such as logistics implementing program delivery and self-selection. More feasible designs are basic pre/post and quasi-experimental designs. In the former, compliance would be assessed for participants pre- and post-program intervention. In the quasi-experimental design, compliance would be assessed for both participants and nonparticipants pre and post the program; unlike the experimental design, however, participants would not be selected randomly.

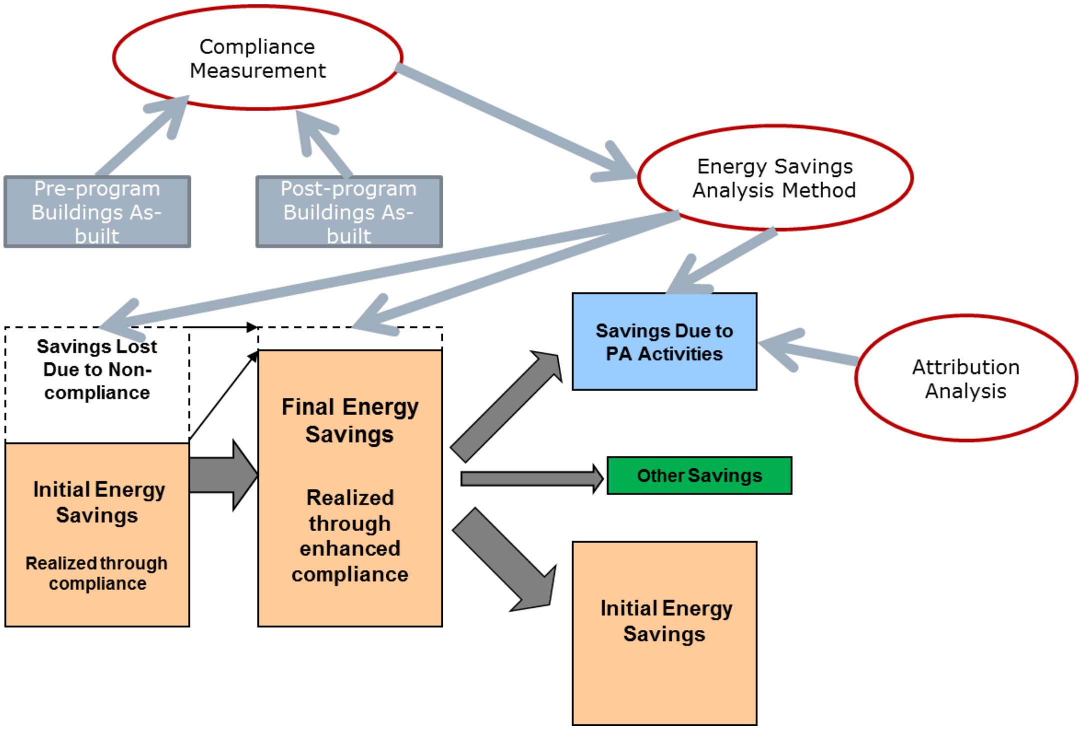


Figure 2. Measuring Compliance Enhancement Program Impacts

One challenge of assessing CEP effects is the difficulty of drawing boundaries that demarcate participants. To illustrate, if the program targets builders in a certain jurisdiction, it is likely those builders also operate outside the jurisdiction, so what behaviors they change due to the program will have an effect beyond the target jurisdiction. One implication of this is that if another jurisdiction where they do business is selected as a control group, the program effects will be measured there as well, thus reducing the apparent impact of the program in the participant jurisdiction. Another consequence results if the builders do not work in the control group jurisdiction, but do work in others—some benefits of the program will not be measured. In program evaluation, these are referred to as spillover effects. In general, we believe it is preferable to have a true control group that is not influenced by the CEP, and to conduct supporting research (for example, interviewing participating builders) to estimate any spillover.

Determining compliance and energy savings changes attributable to the CEP is the other step in evaluating these programs that differs from general code compliance analysis. If a quasi-experimental design is implemented, attribution is essentially 100% of the changes that exceed those in the control group. However, participating jurisdictions may be self-selected so observed program effects may be biased and not representative of what would occur with typical jurisdictions. In the case of a pre/post program analysis, attribution can be determined using a qualitative approach based on activities conducted in the program, interviews with key market actors, and assessment by independent evaluators. The authors have developed and applied this approach to assess attribution for utility code adoption programs (KEMA Team 2010).

Findings and Recommendations

Findings

Key findings from this study regarding code compliance analysis include the following:

- **The potential energy savings from adopting building energy codes can be significant, but projected savings can be achieved only if compliance with the code is high:** Building energy codes set requirements for new residential and commercial buildings. Consequently, energy savings impacts can be extensive and less expensive to produce than upgrading the efficiency of buildings years after they are constructed. However, if a building does not comply with all the code requirements that affect energy use, the expected savings will not materialize.

- **The compliance analysis method matters**: Code compliance studies have used many different methods to assess compliance and, even within the same state, have produced very different results. The current lack of consistency makes it impossible to compare compliance in different jurisdictions or assess changes in compliance accurately.
- **Accurately assessing compliance requires conducting building site visits:** Site visits are critical for determining actual building characteristics that drive energy performance. Either multiple site visits will need to be conducted to document all required characteristics for each building or methods will need to be implemented for inferring characteristics that cannot be observed during a single visit. Getting the cooperation of builders or occupants to permit one or more site visits can be challenging and require innovative approaches, but is vital to the success of the studies.
- **Reviewing compliance documentation is an essential step in compliance studies:** Documentation submitted to building departments for permitting purposes can help inform compliance study building site visits, reducing the amount of data that has to be collected during the site visit. In addition, discrepancies between submitted documentation and actual construction can highlight compliance problem areas.
- **Estimating energy impacts of code compliance is essential, but analysis costs can be high.** To date, researchers have estimated these impacts using building simulation models or engineering analyses. The Cadmus studies in three Northwest states examined approaches to demonstrate sufficiently accurate estimates of energy impacts using simpler approaches than simulation models, but further research will be needed to identify possible methods that are less costly than simulations.
- **Assessing code compliance of commercial buildings poses different challenges and opportunities than residential buildings:** In general, commercial buildings are more complex and have more complex systems than residential buildings, resulting in more complex code requirements and challenges for compliance assessments. It is more difficult to recruit building owners or occupants to participate in site visits than residential builders or owners. On the other hand, the professions involved with commercial building projects are more likely to properly document construction information and code compliance than those involved with residential projects.

Key findings regarding compliance enhancement programs include these:

- **Many program administrators have become involved in building energy codes through programs providing services to enhance code compliance:** These efforts typically involve training and, to date, none have claimed credit for energy savings results from increased code compliance.
- **Estimating the effects of CEPs requires two steps in addition to those required to analyze code compliance impacts:** To assess CEP effects the evaluator must determine compliance and energy consumption prior to the program and compliance and energy consumption after the program is implemented. Compliance measurements and associated energy analyses must be performed twice. If a quasi-experimental design is possible, similar analyses must be conducted with jurisdictions or stakeholders who were not exposed to the program. If a pre/post program evaluation method is used, then a technique for determining attribution to the program must be designed and implemented.

Recommendations

Based on the research conducted for this paper, we have identified several key recommendations to address issues involving energy code compliance:

- **Research should be conducted to determine the level of compliance with energy codes:** Research has shown that it cannot be assumed that all buildings comply with the energy code. For program administrators, energy planners, and regulators, the consequences of noncompliance can be significant when efficiency programs assume full code compliance as the baseline and energy savings projections are based on full compliance with the code. To manage compliance study costs, code compliance can be determined in conjunction with a buildings baseline study.
- **Code compliance data should be gathered through building site visits, supplemented with information submitted for permitting purposes:** Determining noncompliance effects accurately requires gathering information on buildings as constructed. Information submitted for permitting purposes should be collected and reviewed also, but is not an adequate substitute for information characterizing buildings as constructed. Compliance studies comparing permit information and constructed building characteristics can provide useful information about compliance issues.
- **Efforts should be made to develop standardized methods for assessing code compliance:** The checklists developed by PNNL made a significant contribution toward development of standardized code compliance assessments. However, more automated and efficient procedures need to be developed as well as consistent methods to quantify compliance energy impacts. Such efforts may be best undertaken at the national level, perhaps through the auspices of DOE.
- **Simplified, cost-efficient approaches need to be developed to assess energy impacts of code compliance**: Most estimates of energy code impacts are generated using building energy simulation models. This approach is effective and moderately costly for residential buildings. For commercial buildings, the analysis can be both complex and expensive. If builders use such models to demonstrate compliance for permitting, gaining access to the original models can reduce compliance study costs. Opportunities for making this a requirement of the permitting process should be investigated. Another approach that should be investigated is using a large number of building simulation runs to estimate relationships between energy use and building characteristics that can be incorporated in simplified analysis tools for estimating effects of observed characteristics on energy use. DOE funded this type of analysis in the late 1980s to support the development of energy codes.
- **Energy code compliance should be presented using a metric that indicates relative energy use:** We recommend reporting compliance using an "energy compliance index" based on the ratio of a building's estimated as-built energy use to the estimated energy use if built to just meet code. This value can be calculated for individual buildings and reported for a sample or population of buildings.
- **Program administrators should explore opportunities to support code compliance enhancement and receive credit for energy savings:** Many program administrators have provided compliance enhancement services, such as code training. They should investigate developing full-scale compliance enhancement programs, CEP s, and work with their regulators to establish policies and procedures that would allow them to receive credit for resulting energy savings. CEPs should be designed and implemented to facilitate evaluation of the energy savings they generate.
- **Methods should be developed for measuring and crediting CEP energy savings to program administrator efforts:** Initially, a deemed savings approach can be negotiated based on best available information. After the first stage, a method should be developed to measure changes in compliance and energy savings and the amount attributable to the CEP.

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